19th International Workshop on Low Temperature Detectors

Program version 1.24 - Korean Standard Time [1]

Date	Time	Session
Monday 19 July	22:00 - 22:15	Introduction and Welcome
	22:15 - 23:15	Oral O1: Devices 1
	23:15 - 23:25	Break
	23:25 - 00:55	Oral O1: Devices 1 (continued)
	00:55 - 01:05	Break
	01:05 - 02:00	Poster P1: MKIDs and TESs 1
Tuesday 20 July	22:00 - 23:15	Oral O2: Cold Readout
	23:15 - 23:25	Break
	23:25 - 00:55	Oral O2: Cold Readout (continued)
	00:55 - 01:05	Break
	01:05 - 02:30	Poster P2: Readout, Other Devices, Supporting Science 1
	04:00 - 05:00	Virtual Tour of NIST Quantum Sensor Group Labs
Wednesday 21 July	22:00 - 23:15	Oral O3: Instruments
	23:15 - 23:25	Break
	23:25 - 00:55	Oral O3: Instruments (continued)
	00:55 - 01:05	Break
	01:05 - 02:30	Poster P3: Instruments, Astrophysics and Cosmology 1
	02:00 - 03:00	Vendor Exhibitor Hour
Thursday 22 July	22:00 - 23:15	Oral O4A: Rare Events 1
		Oral O4B: Material Analysis, Metrology, Other
	23:15 - 23:25	Break
	23:25 - 00:55	Oral O4A: Rare Events 1 (continued)
		Oral O4B: Material Analysis, Metrology, Other (continued)
	00:55 - 01:05	Break
	01:05 - 02:30	Poster P4: Rare Events, Materials Analysis, Metrology, Other Applications
	04:00 - 05:00	Virtual Tour of NIST Cleanoom
Tuesday 27 July	07:00 - 08:15	Oral O5: Devices 2
	08:15 - 08:25	Break
	08:25 - 09:55	Oral O5: Devices 2 (continued)
	09:55 - 10:05	Break
	10:05 - 11:30	Poster P5: MMCs, SNSPDs, more TESs
Wednesday 28 July	07:00 - 08:15	Oral O6: Warm Readout and Supporting Science
	08:15 - 08:25	Break
	08:25 - 09:55	Oral O6: Warm Readout and Supporting Science (continued)
	09:55 - 10:05	Break
	10:05 - 11:30	Poster P6: Readout, Other Devices, Supporting Science 2
Thursday 29 July	05:00 - 06:00	Vendor Exhibitor Hour
	07:00 - 08:15	Oral O7A: Rare Events 2
		Oral O7B: Astrophysics and Cosmology
	08:15 - 08:25	Break
	08:25 - 09:55	Oral O7A: Rare Events 2 (continued)
		Oral O7B: Astrophysics and Cosmology (continued)
	09:55 - 10:05	Break
	10:05 - 11:30	Poster P7: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs
Friday 30 July	07:00 - 08:30	Oral O8: Devices 3
	08:30 - 08:40	Break
	08:40 - 10:25	Oral O8: Devices 3 (continued)
	10:25 - 10:35	Break
	10:35 - 11:00	Closing and Introduction of LTD20 Hosts

[1] Other time zones available here

Week 1 Day 1 Monday 19 July 22:00 - Tuesday 20 July 02:00 (Korean Standard Time)

Introduction and Welcome: 22:00 - 22:15 (Conference webpage)

Oral O1: Devices 1 22:15 - 00:55 (Conference webpage)
Session chairs: Mark Croce, Los Alamos National Laboratory
Ben Mates, National Institute of Standards and Technology

1. 22:15 "Microwave Kinetic Inductance Detectors – detector physics and recent developments" (Invited)
   Pieter de Visser - SRON
2. 22:45 "Subgap kinetic inductance detector sensitive to 85-GHz radiation"
   Florence Levy-Bertrand - Institut Néel, Grenoble (France)
3. 23:00 "Strong Generation-Recombination Noise Reduction in Hybrid NbTiN-Al MKIDs"
   Steven de Rooij - SRON, Netherlands Institute for Space Research

Break: 23:15 - 23:25 (10 minutes)

4. 23:25 "Bolometer operating at the threshold for circuit quantum electrodynamics [Nature 586, 47 (2020)]"
   Mikko Möttönen - Aalto University
5. 23:40 "Modeling of superconductor-ferromagnet thermoelectric detector for X-ray detection"
   Zhuoran Geng - Nanoscience Center, University of Jyväskylä
6. 23:55 "Transition-Edge Sensors for low-energy electron detection"
   Mauro Rajteri - INRIM
7. 00:10 "Voltage fluctuations in transition edge sensors and other effects from the 70's"
   Luciano Gottardi - NWO-I SRON, Netherlands Institute for Space Research
8. 00:25 "Impact of the absorber coupling design for Transition Edge Sensor X-ray Calorimeters"
   Martin de Wit - Netherlands Institute for Space Research (SRON)
9. 00:40 "Fine optimization of TES microcalorimeter design for the X-IFU instrument on ATHENA"
   Nicholas Wakeham - University of Maryland Baltimore County / NASA Goddard Space Flight Center

Break: 00:55 - 01:05 (10 minutes)

Poster P1: MKIDs and TESs 1 01:05 - 02:00 (Conference webpage)

1. "A Far-Infrared TES Bolometer with a Magnetically-Switchable High-Power Mode"
   Michael Audley - SRON Netherlands Institute for Space Research
2. "A kinetic inductance detectors array design for high background conditions at 150 GHz"
   Shibo Shu - California Institute of Technology
3. "Characterization of the Superconducting Microwave Properties of Aluminum Manganese"
   Marharyta Lisovenko - Argonne National Laboratory
4. "Compton spectroscopy measurements at the APS 1-BM beamline using traditional semiconductor and advanced high-energy TES X-ray detectors"
   Umeshkumar Patel - Argonne National Laboratory
5. "Decoupling of the quasiparticle number and lifetime in titanium nitride resonators"
   Sunil Golwala - California Institute of Technology
6. "Design and preliminary results of the spectroscopic focal plane for the South Pole Telescope Summertime Line Intensity Mapper"
   Pete Barry - Argonne National Laboratory
7. "Design of a multi-chroic kinetic inductance detectors array coupled to a hierarchical phased-array antenna"
   Shibo Shu - California Institute of Technology
8. "Development of a fabrication process for large suspended gold absorbers for TES microcalorimeters"
   Conjeepuram Ambarish - University of Wisconsin-Madison
9. "Development of a prototype detector for Torio-229 experiment"
   Mariia Fedkevych - Department of Physics, University of Genoa, Genoa, Italy
10. "Development of high-resolution, large absorber TES microcalorimeters for the soft X-ray range"
    Felix Jaeckel - University of Wisconsin - Madison
11. "Development of MKIDs for Measurement of the Cosmic Microwave Background with the South Pole Telescope"
    Karia Dibert - The University of Chicago

12. "Energy Calibration of Phonon-Mediated Dark Matter Detectors using MKIDs"
Ritoban Basu Thakur - California Institute of Technology
13. "Influence of Width of Ti/Au Transition Edge Sensors"
Kenichiro Nagayoshi - NWO-I/SRON Netherlands Institute for Space Research
14. "Investigation of Optical Coupling Performance in LEKIDs Using Superconducting Reflective Plates"
Paul Nicaise - GEPI - Observatoire de Paris - CNRS
15. "LiteBIRD Low and Mid-Frequency Detectors: Design and Status"
Greg Jaehnig - University of Colorado Boulder
16. "Low stray power cross-coupling between MKIDs, for future focal plane spectrometer arrays"
Stephen Yates - SRON, Netherlands Institute for Space Research
17. "Model and measurements of an optical stack for broadband absorption in Optical LEKIDs"
Kevin Kouwenhoven - SRON Netherlands Institute for Space Research
18. "Modeling and Optimizing Microwave Kinetic Inductance Detectors for the EXCLAIM Mission"
Trevor Oxholm - University of Wisconsin-Madison
19. "Near Infrared and Visible Kinetic Inductance Detectors for SPIAKID"
Faouzi Boussaha - GEPI-Observatoire de Paris CNRS UMR8111
20. "On-chip Spectrometers operating at 90GHz"
Usasi Chowdhury - Institut Neel, UGA
21. "Optimization of Ti/TiN multilayers for optical to near-IR MKIDs and exploring their commercial foundry potential"
Gerhard Ulbricht - Dublin Institute for Advanced Studies
22. "Overcoming the challenges for reproducible fabrication of 15 mK tungsten-based TESs with tunable and predictable T_c"
Ahmed Abdelhameed - Max-Planck-Institut für Physik
23. "Phonon-trapping enhanced energy resolution in superconducting single photon detectors"
Pieter de Visser - SRON
24. "Progress in the development of Thermal Kinetic Inductance Detectors for X-ray spectroscopy"
Marco Faverzani - University and INFN of Milano-Bicocca
25. "Resolving power of visible/near-infrared hybrid NbTiN/β-Ta LEKIDs"
Kevin Kouwenhoven - SRON Netherlands Institute for Space Research
26. "Simulation of radiative transfer within X-ray microcalorimeter absorbers."
Maximilian Lorenz - Dr. Karl Remeis-Observatory & ECAP
27. "Simulation of the Cosmic Ray impact on the TES detectors of SPICA/SAFARI"
Thijs Stockmans - leiden University
28. "Stability Analysis of SAFARI FDM Readout System"
Micha Heilman - Leiden Univeristy/ SRON
29. "SuperSpec Improvements for Future Far-IR Missions"
Ryan McGeehan - University of Chicago
30. "Susceptibility study of transition-edge sensor micro-calorimeters for X-ray spectroscopy under frequency-domain multiplexing readout"
Davide Vaccaro - SRON
31. "Temperature and current sensitivities of bare Mo/Au Transition-Edge Sensors: size effects"
Lourdes Fàbrega - ICMAB-CSIC
32. "Thermal Conductance of Individual Layers on TES Legs"
Angelina Harke-Hosemann - National Institute of Standards and Technology; University of Colorado Boulder
33. "TiNx MKIDs from a 3.5M euro UHV state-of-the-art sputter system"
Mario De Lucia - Dublin Institute for Advanced Studies
34. "X-ray transition edge sensors as backup option for X-IFU on ATHENA space telescope"
Emanuele Taralli - Netherlands Institute for Space Research

Week 1 Day 2 Tuesday 20 July 22:00 - Wednesday 21 July 05:00 (Korean Standard Time)

Oral O2: Cold Readout 22:00 - 00:55 (Conference webpage)
Session chairs: Randy Doriese, National Institute of Standards and Technology
Kelsey Morgan, University of Colorado, Boulder

1. 22:00 "Advances in time-division SQUID multiplexing for TES X-ray-microcalorimeter arrays" (Invited)
Malcolm Durkin - University of Colorado
2. 22:30 "BICEP Array: 150 GHz detector module development"
Alessandro Schillaci - California Institute of Technology
3. 22:45 "The Simons Observatory microwave SQUID multiplexing detector module design"
Heather McCarrick - Princeton
4. 23:00 "Demonstration of 37-pixel frequency domain multiplexing readout of cryogenic X-ray microcalorimeters"
Hiroki Akamatsu - SRON

Break: 23:15 - 23:25 (10 minutes)

5. 23:25 "Recent Progress on Digital Frequency-Domain Multiplexed Readout of Transition Edge Sensors"
Tucker Elleflot - Lawrence Berkeley National Laboratory
6. 23:40 "Advances in microwave SQUID multiplexers for superconducting calorimeters"
John Mates - National Institute of Standards and Technology
7. 23:55 "Demonstration of simultaneous MMC readout using a tailored microwave SQUID multiplexer based readout system"
Mathias Wegner - Karlsruhe Institute of Technology
8. 00:10 "Hybrid Microwave SQUID Multiplexer"
Sebastian Kempf - Institute of Micro- and Nanoelectronic Systems, Karlsruhe Institute of Technology
9. 00:25 "Design of the TDM-readout chips for Athena X-IFU"
William Doriese - NIST
10. 00:40 "FDM readout of 60 low-NEP transition-edge sensor bolometers"
Qian Wang - SRON

Break: 00:55 - 01:05 (10 minutes)

Poster P2: Readout, Other Devices, Supporting Science 1 01:05 - 02:30 (Conference webpage)

1. "A comparison of two different cryogenic platforms for working at 300mK"
Dale Westbury-Rund - Chase Research Cryogenics Ltd
2. "A kinetic inductance traveling-wave amplifier to read out microwave SQUID multiplexers"
Maxime Malnou - NIST
3. "A New Class of Cryo-Nanopositioners"
Steven Tan - Onnes Technologies BV,
4. "A new readout electronics for Kinetic Inductance Detectors"
Andrea Limonta - Università di Milano - Bicocca
5. "Composition dependence of transport properties in YSi thermometric films."
Le Hong Hoang To - IJCLab
6. "Detector Array Readout with Traveling Wave Amplifiers"
Andrea Giachero - University and INFN of Milano-Bicocca
7. "Developments of Laboratory-Based Transition-Edge Sensor Readout Electronics using Commercial-Off-The-Shelf Modules"
Kazuhiro Sakai - NASA/Goddard Space Flight Center
8. "Estimation of the TiNx critical temperature at room temperature"
Jean-Marc Martin - GEPI - Observatoire de Paris
9. "Finite-element simulations for geometry optimization of an X-ray absorber for the superconductor-ferromagnet thermoelectric detector"
Ari Helenius - University of Jyväskylä
10. "Frequency Domain Multiplexing for MKIDs: Comparing the Xilinx ZCU111 RFSoC with their new 2x2 RFSoC board"
Eoin Baldwin - Dublin Institute for Advanced Studies

11. "High sensitivity and high dynamic range polarimetric detectors arrays for space and ground based cameras."
Louis R. Rodriguez - CEA -Commissariat à l'energie Atomique et energies alternatives
12. "High speed microwave rf-SQUID multiplexing read-out for neutrino mass experiment"
Andrea Giachero - University and INFN of Milano-Bicocca
13. "High-Impedance Surfaces for Above-IC Integration of Cooled Bolometer Arrays at the 350-µm Wavelength"
Laurent Dussopt - CEA
14. "Hydrogenated amorphous silicon carbide: A low-loss deposited dielectric for millimeter-submillimeter astronomy"
Bruno Buijtendorp - TU Delft
15. "Magnetic Field Sensitivity of Microwave SQUID Multiplexers"
Jake Connors - NIST-Boulder QSG
16. "Magnetic Shielding Measurements for the Simons Observatory Universal Multiplexing Module"
Zachary Huber - Cornell University
17. "Microwave-SQUID multiplexer for TES array readout: fabrication process development and noise analysis"
Yuki Nakashima - Physikalisch-Technische Bundesanstalt (PTB), Braunschweig
18. "Millimetre wave kinetic inductance parametric amplification using ridge gap waveguide"
Danielius Banys - University of Manchester
19. "Modeling a Three-Stage SQUID System in Space with the First Micro-X Sounding Rocket Flight"
Joshua Fuhrman - Northwestern University
20. "Monte-Carlo Simulation Framework for optimizing Microwave SQUID Multiplexers"
Constantin Schuster - Karlsruhe Institute of Technology
21. "Multiplexing the room temperature electronics of frequency domain multiplexed (FDM) TES readout"
Jan van der Kuur - SRON Netherlands Institute for Space Research
22. "Online Demodulation and Trigger for Fluxramp Modulated MMC Signals"
Nick Karcher - KIT - IPE
23. "Optimization of Flux and Magnetic Field Sensitive Kinetic Inductance Magnetometer (KIM)"
Sasha Sypkens - Arizona State University
24. "Optimization of the CUPID detector structure via bolometric measurements in the CROSS cryogenic facility at the Canfranc underground laboratory"
Madhujith Madhukuttan - IJC Lab
25. "Parametric amplification via superconducting contacts in a Ka band niobium pillbox cavity"
Valerio Gilles - The University of Manchester
26. "Polarization Modulator Unit Harness design for the mid- and high- frequency telescopes of the LiteBIRD space mission"
Fabio Columbro - Sapienza, University of Rome
27. "Polarization sensitive silicon bolometers cooled at 50 mK for millimetre wave absorption"
Abdelkader Aliane - CEA-LETI
28. "Progress of the ECHo SDR readout hardware for multiplexed MMCs"
Robert Gartmann - KIT - IPE
29. "Readout of thermally multiplexed transition-edge sensors with a microwave SQUID multiplexer"
Kelsey Morgan - University of Colorado Boulder
30. "Signal processing and data analysis for the HOLMES experiment"
Matteo Borghesi - INFN, sezione di Milano Bicocca
31. "Simulating travelling wave kinetic inductance parametric amplifiers using a commercial circuit simulator"
Thomas Sweetnam - University of Manchester
32. "Simulation and measurement of out-of-band resonances for the FDM readout of a TES bolometer"
Amin Aminaei - SRON
33. "The MUSCAT readout electronics backend: design and pre-deployment performance."
Sam Rowe - Cardiff University
34. "Thermodynamic Properties of Silver Erbium Alloys for Use in Metallic Magnetic Calorimeters"
Matthew Herbst - Kirchhoff-Institute for Physics, Heidelberg University
35. "Warm ASIC for the SQUID/TES Readout of ATHENA's X-IFU Instrument"
Si Chen - Astroparticle and Cosmology laboratory

Virtual Tour of NIST Quantum Sensor Group Labs: 04:00 - 05:00 (Conference webpage)

Week 1 Day 3 Wednesday 21 July 22:00 - Thursday 22 July 03:00 (Korean Standard Time)

Oral O3: Instruments 22:00 - 00:55 (Conference webpage)
Session chairs: Johannes Hubmayr, National Institute of Standards and Technology
Katrina Koehler, Los Alamos National Laboratory

1. 22:00 "Single optical photon detection using low temperature detectors" (Invited)
   Sae Woo Nam - NIST
2. 22:30 "TOMographic Circuit Analysis Tool (TOMCAT) – An instrument for 3D x-ray imaging of nanoscale integrated circuits using a TES spectrometer"
   Nathan Nakamura - National Institute of Standards and Technology
3. 22:45 "An update on the TES-based x-ray microcalorimeter project at the NIST EBIT"
   Paul Szypryt - National Institute of Standards and Technology
4. 23:00 "A gamma-ray TES spectrometer for the analytical laboratory of a working nuclear facility based on a new, scalable detector architecture"
   Abigail Wessels - University of Colorado Boulder

Break: 23:15 - 23:25 (10 minutes)

5. 23:25 "The QUBIC experiment : Readout Detection Chain"
   Guillaume Stankowiak - CNRS
6. 23:40 "Flat low loss silicon optics for millimeter and submillimeter wavelengths"
   Fabien Defrance - Caltech
7. 23:55 "MISTRAL and its KIDs"
   Alessandro Paiella - Dipartimento di Fisica, Università di Roma Sapienza
8. 00:10 "SuperSpec: On-Chip Spectrometer Design, Characterization, and Performance"
   Joseph Redford - California Institute of Technology
9. 00:25 "Superconducting on-chip spectrometer for mesoscopic quantum systems"
   Ramiro Hernan Rodriguez - Flux Quantum Lab, Collège de France
10. 00:40 "The Simons Observatory Ultra-High Frequency Focal-Plane Module: Design and Initial Characterization"
    Erin Healy - Princeton University

Break: 00:55 - 01:05 (10 minutes)

Poster P3: Instruments, Astrophysics and Cosmology 1 01:05 - 02:30 (Conference webpage)

1. "A high resolution fiber-fed spectrometer based on a MKID integrated with a photonic circuit"
   Miguel Daal - UC Santa Barbara
2. "A High-Capacity Microwave SQUID Multiplexer Chip Screening System"
   Zachary Whipps - Simons Collaboration
3. "A Reproduceable Setup to Evaluate Wideband Sub-mm Detectors"
   Matthijs Gouwerok - TU Delft
4. "Absorber design and optimization of Kinetic Inductance Detectors for the Terahertz Intensity Mapper"
   Rong Nie - University of Illinois at Urbana-Champaign
5. "An Interesting Problem"
   Dan McCammon - U of Wisconsin-Madison
6. "Beamline TES characterization with monochromatic X-rays up to 80 keV at the Advanced Photon Source"
   Tejas Guruswamy - Argonne National Laboratory
7. "Building an optical test facility for very low flux : testing the B-BOP detectors"
   Camille Gennet - CEA Saclay
8. "Commissioning of the ion implanter for the HOLMES experiment"
   Matteo De Gerone - INFN Genova
9. "COSMO: Measuring CMB spectral distortions from Antarctica"
   Lorenzo Mele - Sapienza University of Rome
10. "Cryomechanical Design and Validation of the Simons Observatory's Ultra-High Frequency Small Aperture Telescope"
    Kevin D. Crowley - Princeton University

11. "Design of a mm-Wave Kinetic Inductance (Kineticon) Qubit"
Farzad Faramarzi - Arizona State University
12. "Design of Kinetic Inductance Detector Packaging for The Terahertz Intensity Mapper"
Lunjun Liu - California Institute of Technology
13. "Development of a Ka band superconducting on-chip Fourier transform spectrometer"
Nikita Klimovich - Caltech
14. "Development of an end-to-end demonstration readout chain for Athena/X-IFU"
Sophie Beaumont - IRAP / UMBC - NASA GSFC
15. "EXCLAIM Mission Review"
Maryam Rahmani - NASA Goddard Space Flight Center
16. "Gamma ray spectrometers based on modular arrays of superconducting transition-edge sensors"
Sophie Weidenbenner - LANL
17. "Hyperspectral X-ray Imaging: Next-Generation TES Microcalorimeters on the SEM"
Matthew Carpenter - Los Alamos National Laboratory
18. "In-flight gain monitoring of SPIDER transition-edge sensor arrays"
Jeffrey Filippini - University of Illinois, Urbana-Champaign
19. "Micro-X Sounding Rocket Payload Re-flight Progress"
Renee Manzagol-Harwood - Northwestern University
20. "MKID spectroscopic surveys of physical conditions in extreme galaxies"
Matus Rybak - TU Delft / Leiden Observatory
21. "mm-Wave Superconducting Circuits and Components for Observational Astrophysics"
Farzad Faramarzi - Arizona State University
22. "MMOST – The MKID Multi-Object Spectrograph Testbed"
John Bailey - University of California at Santa Barbara
23. "Modeling and characterization of quasi-optical elements in the optical system of LSPE/SWIPE"
Luca Lamagna - Physics Dept. Sapienza University of Rome
24. "Operation of an archaeological lead PbWO crystal to search for neutrinos from astrophysical sources with a Transition Edge Sensor"
Nahuel Ferreiro - Max-Planck Institut für Physik
25. "Optical characterisation of ultra-sensitive far-infrared TES bolometer arrays with frequency-domain multiplexed readout"
Angiola Orlando - SRON Netherlands Institute for Space Research
26. "Optical leakage mitigation in ortho-mode transducer detectors formicrowave applications"
Riccardo Gualtieri - Argonne National Laboratory
27. "Optomechanical design for optical performance characterization of kinetic inductance detectors in the W-Band"
David Arrazola - University of Alcalá
28. "Preliminary Characterization of the first 2000-pixel array for SPIAKID"
Jie Hu - GEPI, Paris Observatory; APC, Universite de Paris
29. "Progress toward absolute calibration of x-ray transition edge sensors (TESs)"
Daniel McNeel - Los Alamos National Laboratory
30. "Pulse tube cooler with >100 m flexible lines optimized for operation of cryogenic detector arrays at large radiotelescopes"
Alessandro Coppolecchia - University of Rome SAPIENZA
31. "QUBIC experiment towards the first light"
Giuseppe D'Alessandro - University Sapienza of Rome, Physics department
32. "Scalable Lens Array Assembly for Millimeter/Submillimeter Astronomical Instrument"
Kenichi Karatsu - SRON - Netherlands Institute for Space Research
33. "Simons Observatory Focal-Plane Modules: In-lab Testing and Characterization Program"
Kaiwen Zheng - Princeton University
34. "Simulating the effect of Time-Division Multiplexing readout on the energy scale calibration of TES microcalorimeters"
Christian Kirsch - Remeis-Observatory & ECAP, FAU Erlangen-Nuernberg

35. "Status of the HOLMES experiment"
    Matteo De Gerone - INFN Genova
36. "The Athena X-IFU instrument simulator xifusim"
    Christian Kirsch - Remeis-Observatory & ECAP, FAU Erlangen-Nuernberg
37. "The PICTURE-C MKID Camera: Using MKIDs for High Contrast Direct Imaging on a Balloon-Based Observatory at Optical Wavelengths"
    Noah Swimmer - University of California, Santa Barbara
38. "The Simulation and Design of an On-Chip Superconducting Millimetre Filter-Bank Spectrometer"
    Gethin Robson - Cardiff University
39. "The SuperSpec Instrument: status and deployment plans"
    Erik Shirokoff - University of Chicago

Vendor Exhibitor Hour: 02:00 - 03:00

Week 1 Day 4 Thursday 22 July 22:00 - Friday 23 July 05:00 (Korean Standard Time)

Oral O4A: Rare Events 1 22:00 - 00:55 (Conference webpage)
Session chairs: Gene Hilton, National Institute of Standards and Technology
Maurice Chapellier, Irène-Joliot Curie Physics of Two Infinities Lab

1. 22:00 "Massive Low Temperature Calorimeters: Developments, Challenges, and Future Prospects" (Invited)
Matt Pyle - University of California Berkeley
2. 22:30 "Direct dark matter search with CRESST-III experiment"
Abhijit Garai - Max-Planck Institut für Physik 80805 Munich, Germany
3. 22:45 "Low-mass Dark Matter searches with EDELWEISS"
Jules Gascon - IP2I (Universite Lyon 1 / CNRS-IN2P3)
4. 23:00 "The CROSS experiment: bolometers with metallic film coating capable of rejecting surface α and β events"
Hawraa Khalife - IRFU (CEA Paris-Saclay)

Break: 23:15 - 23:25 (10 minutes)

5. 23:25 "CUPID-Mo: a new world limit on neutrinoless double beta decay of ^{100}Mo"
Claudia Nones - CEA-IRFU
6. 23:40 "Characterising a single photon detector for ALPS II"
Rikhav Shah - JGU Mainz
7. 23:55 "Latest results from the CUORE experiment"
Irene Nutini - Milano Bicocca INFN and University
8. 00:10 "Final results of CALDER: Kinetic inductance light detectors for double beta decay."
Marco Vignati - Sapienza University and INFN
9. 00:25 "Development of phonon-mediated dark-matter detectors using kinetic inductance phonon sensors"
Sunil Golwala - California Institute of Technology
10. 00:40 "Ricochet Progress and Status"
Scott Hertel - University of Massachusetts - Amherst

Oral O4B: Material Analysis, Metrology, Other 22:00 - 00:55 (Conference webpage)
Session chairs: Douglas Bennett, National Institute of Standards and Technology
Ilari Maasilta, University of Jyvaskyla

1. 22:00 "A Review of Decay Energy Spectroscopy" (Invited)
Katrina Koehler - Los Alamos National Laboratory
2. 22:30 "X-ray spectroscopic studies of biological catalysts - new opportunities with XES spectrometers and LTDs?" (Invited)
Serena DeBeer - Max Planck Institute for Chemical Energy Conversion
3. 23:00 "Experience from the analytical labs: first results from deployed microcalorimeter gamma spectrometers"
Mark Croce - Los Alamos National Laboratory

Break: 23:15 - 23:25 (10 minutes)

4. 23:25 "NIST TES soft x-ray spectrometers at synchrotron beamlines"
Galen O'Neil - NIST
5. 23:40 "High Resolution Decay Energy Spectroscopy Using Transition Edge Sensor Microcalorimetry"
Katherine Schreiber - Los Alamos National Laboratory
6. 23:55 "Absolute energies and emission line shapes of the L x-ray transitions of lanthanide metals"
Joseph Fowler - NIST
7. 00:10 "Determining decay data from multi-branch electron capture decays using Metallic Magnetic Calorimeters"
Philipp Chung-On Ranitzsch - Physikalisch-Technische Bundesanstalt
8. 00:25 "X-ray Spectroscopy of Highly Charged Uranium Ions with Metallic Magnetic Calorimeters"
Daniel Hengstler - KIP, Heidelberg University
9. 00:40 "Characterization of the SARS-CoV-2 S1 Spike Protein Using Superconducting Tunnel Junction Cryodetection Mass Spectrometry"
Lixue Jiang - Carnegie Mellon University

Break: 00:55 - 01:05 (10 minutes)

Poster P4: Rare Events, Materials Analysis, Metrology, Other Applications 01:05 - 02:30 (Conference webpage)

1. "A Delayed-Choice Quantum Eraser Experiment with Photon-Counting MKIDs"
   Colm Bracken - Manynooth University
2. "A Quantitative Comparison Of Transition-Edge Sensor Microcalorimeters And High-Purity Germanium Detectors For Plutonium Isotopic Analysis"
   Dan Becker - University of Colorado
3. "A thermal model for low-temperature TeO_2 calorimeters read out by NTD thermistors"
   Simone Quitadamo - GSSI - Gran Sasso Science Institute
4. "Accurate Calibration of Nuclear Recoils at the 100 eV Scale Using Neutron Capture"
   Victoria Wagner - Technische Universität München
5. "Active Inner Veto for Improved Dark Matter Search and Neutrino Detection Sensitivity"
   Andrew Jastram - Texas A&M University
6. "Anisotropy of quantized electronic excitations in semiconductors for directional dark matter searches"
   Nader Mirabolfathi - Texas A&M University
7. "BASKET innovative bolometers with MMCs for the CEνNS detection"
   Beatrice Mauri - CEA/IRFU/DPhP
8. "BINGO: Bi-Isotope $0\nu2\beta$ Next Generation Observatory"
   Hawraa Khalife - IRFU (CEA Paris-Saclay)
9. "Constraints on Dark Photon Dark Matter from LAMPOST using superconducting nanowire detectors"
   Sae Woo Nam - NIST
10. "Contact-free readout concept and recent progress toward single-electron resolution large-mass semiconductor detectors"
    Matthew Lee - Texas A&M University
11. "COSINUS – the first NaI-based low-temperature detector for direct dark matter detection"
    Karoline Schaeffner - Max-Planck Institut für Physik
12. "CUPID: the next generation neutrinoless double beta decay experiment"
    Antoine Armatol - CNRS-IJCLAB
13. "Determination of fractional electron capture probabilities by means of Metallic Magnetic Calorimeters"
    Arshjot Kaur - CEA Saclay
14. "Determining the Sm-146 half-life using Metallic Magnetic Calorimeters for Early Solar System Chronology"
    Geon-Bo Kim - Lawrence Livermore National Laboratory
15. "Development of a contactless feedline KID detector on massive crystal for direct rare event searches"
    Jules Colas - CNRS Grenoble
16. "Development of a data processing pipeline for RICOCHET"
    Jules Colas - IP2I Lyon
17. "Development of an Organic Plastic Scintillator based Muon Veto Operating at Sub-Kelvin Temperatures for the NUCLEUS Experiment"
    Andreas Erhart - Technical University of Munich
18. "Development of cryogenic calorimeters to measure the spectral shape of Indium-115 beta decay"
    Lorenzo Pagnanini - INFN-LNGS & GSSI
19. "Effect of Crystal Defects on The Expected Dark Matter Signal in Phonon Mediated Detectors"
    Kai Nordlund - University of Helsinki
20. "First dark matter searches with the CUPID-Mo detectors"
    Dounia Helis - CEA/IRFU/DPhP
21. "Ge bolometers with high impedance TES for the EDELWEISS dark matter experiment"
    Stefanos Marnieros - IJCLab - CNRS
22. "High Impedance, low dissipation, and ultra-low noise HEMT-based 1K front-end electronics and readout for the CryoCube detector array of the future RICOCHET experiment"
    Jean-Baptiste Filippini - IP2I/IN2P3/CNRS
23. "High-resolution beta spectrometry of Tc-99 employing Metallic Magnetic Calorimeters"
    Michael Paulsen - PTB Berlin, KIP Heidelberg

24. "Machine learning techniques for pile-up rejection in cryogenic calorimeters"
Guido Fantini - Sapienza Università di Roma
25. "Neutrinoless double beta decay search of 128-Te with the CUORE TeO2 cryogenic bolometers"
Valentina Dompè - GSSI / La Sapienza Università di Roma
26. "NUCLEUS – searching for coherent neutrino nucleus scattering at lowest energies"
Holger Kluck - Institute of High Energy Physics (HEPHY) of the Austrian Academy of Sciences
27. "Optimization and performance of the CryoCube detector for the future Ricochet low-energy neutrino experiment"
Thomas Salagnac - IP2I Lyon
28. "Performance of cryogenic diamond detectors for low-mass dark matter searches"
Lucia Canonica - Max-Planck Institut für Physik
29. "Perspectives of scintillating bolometer with ZnO crystal as a detector for rare processes searches"
Serge Nagorny - Queen's University
30. "Phonon wind effects on charge collection in cryogenic Ge detectors for rare event searches at low energies"
Alexandre Broniatowski - IJCLab, Université Paris-Saclay and CNRS/IN2P3, 91405 Orsay, France
31. "Phonons and charge signal from IR and X excitation in the SELENDIS Ge cryogenic detector"
Hugues Lattaud - Institut de Physique des 2 Infinis de Lyon
32. "Polarized Bolometers, a future tool for neutrino physics?"
Maurice Chapellier - IJCLab/IN2P3/CNRS
33. "Radiopure CaWO4 Crystals for Direct Dark Matter Search with CRESST-III"
Angelina Kinast - Technical University of Munich
34. "Status of BULLKID, an array of kinetic inductance detectors to search for Dark Matter."
Sergio Manthey Corchado - INFN Roma
35. "$Tm_3Al_5O_{12}$ crystal as a perspective cryogenic detector for a solar axion search"
Evgeniy Unzhakov - Petersburg Nuclear Physics Institute - NRC Kurchatov Institute
36. "Towards absolute massic activity (Bq/g) using transition edge sensors"
Ryan Fitzgerald - NIST
37. "Transition Edge Sensor Chip Design of Modular CEvNS Detector for the Ricochet Experiment"
Ran Chen - Northwestern University

Virtual Tour of NIST Cleanoom: 04:00 - 05:00 (Conference webpage)

Week 2 Day 1 Tuesday 27 July 07:00 - Tuesday 27 July 11:30 (Korean Standard Time)

Oral O5: Devices 2 07:00 - 09:55 (Conference webpage)
Session chairs: Joel Ullom, National Institute of Standards and Technology
Yong-Hamb Kim, Institute for Basic Science

1. 07:00 "Developments in Magnetic Microcalorimeters" (Invited)
Simon Bandler - NASA Goddard Space Flight Center
2. 07:30 "A high-efficiency superconducting upconverter at microwave frequencies"
Nikita Klimovich - Caltech
3. 07:45 "Single Charge and eV-Scale Resolution Detectors for SuperCDMS Dark Matter Searches"
Noah Kurinsky - Fermilab
4. 08:00 "Novel Active Noise Cancellation Algorithms for CUORE"
Kenneth Vetter - UC Berkeley

Break: 08:15 - 08:25 (10 minutes)

5. 08:25 "Improved speed and sensitivity in low-G far-IR TES bolometers"
Matt Bradford - JPL / Caltech
6. 08:40 "Transition-Edge Sensor Microcalorimeter Optimized for Hard X-ray Applications"
Daikang Yan - NIST, University of Colorado Boulder
7. 08:55 "Light detector development for zero-neutrino double beta decay experiments"
Sang Goon Kim - Institute for Basic Science
8. 09:10 "Development of precise light delivery setup for calibration of transition-edge sensors"
Avirup Roy - University of Wisconsin-Madison
9. 09:25 "Development of transition-edge sensor with high counting rate"
Yoshitaka Miura - National Institute of Advanced Industrial Science and Technology
10. 09:40 "Performance of TES X-Ray Microcalorimeters Designed for 14.4 keV Solar Axion Search"
Yuta Yagi - The Univ. of Tokyo, ISAS/JAXA

Break: 09:55 - 10:05 (10 minutes)

Poster P5: MMCs, SNSPDs, more TESs 10:05 - 11:30 (Conference webpage)

1. "Challenge to improve the ^{229}Th isomer energy measurement with TES calorimeters"
Keita Tanaka - ISAS
2. "Characterization of bilayer-TES based light detectors for CUPID"
Vivek Singh - University of California Berkeley
3. "Correcting energy estimation errors due to finite sampling of transition edge sensor data"
Michael Witthoeft - NASA/GSFC
4. "Data acquisition and analysis for a TES-based spectrometer"
Jingkai Xia - ShanghaiTech University
5. "Data Reduction Algorithms for the ECHo Experiment"
Arnulf Barth - Kirchhoff Institute for Physics, Heidelberg University
6. "Development of a robust, efficient process to produce scalable, superconducting kilopixel Far-IR Detector Arrays"
Johannes Staguhn - Johns Hopkins University
7. "Development of an Optical Ti/Au Transition-Edge Sensor for Single Photon Detection"
Xiaolong Xu - National Institute of Metrology, China
8. "Development of self-aligned Ti optical transition-edge sensors at 1550 nm"
Wen Zhang - Purple Mountain Observatory, CAS
9. "Development of the characterization methods for TES bolometers for CMB measurements"
Yume Nishinomiya - University of Tokyo
10. "Development of Transition Edge Sensor Microcalorimeter for Several-MeV Gamma Rays"
Tetsuya Tsuruta - Kyushu University
11. "Electroplated Bi RRR measurements for X-ray TES"
Cindy Xue - Argonne National Laboratory

12. "Fabrication of Transition edge sensor for X ray spectrometer"
Yanru Song - ShanghaiTech University
13. "Fabrication of transition edge sensors using selective-area ion-implantation technique"
Bo Gao - Shanghai institute of microsystem and information technology, Chinese Academy of Sciences
14. "Finite-Element Simulation of Transition-Edge Sensor Microcalorimeters for Gamma rays"
Naoko Iyomoto - Kyushu University
15. "Gamma-ray Transition Edge Sensor with SiO2/SixNy/SiO2 Membrane for Uniform Property"
Takahiro Kikuchi - National Institute of Advanced Industrial Science and Technology
16. "High response rate in low kinetic inductance MgB_2 nanowire photon detectors"
Sergey Cherednichenko - Chalmers University of Technology
17. "Improvement of the photon number resolving detector with superconducting transition edge sensor"
Jodoi Takeshi - The University of Tokyo
18. "Influence of environmental parameters on the performance of transition-edge sensor microcalorimeters"
Stephen Smith - NASA GSFC
19. "Iridium/gold bilayer optical transition edge sensor and optical cavity structure for single-photon detection at telecommunication wavelengths"
Yuki Mitsuya - The University of Tokyo
20. "Large-scale metallic magnetic calorimeter arrays for the Lynx X-ray Microcalorimeter"
Archana Devasia - NASA Goddard Space Flight Center
21. "MMC-based X-ray Detectors for IAXO"
Daniel Unger - Heidelberg University
22. "MOCCA, a 4k-pixel molecule camera for the position and energy resolving detection of neutral molecule fragments: First light"
Ansgar Lowack - Kirchhoff Institute for Physics, Heidelberg University
23. "Optimized detector design of transition edge sensors for the calorimetry of carbon ion beam"
Ryan Smith - University of Tokyo
24. "Photon Detection by Optical Transition Edge Sensor Array"
Toshio Konno - National Institute of Advanced Industrial Science and Technology
25. "RF Mode Structure and Damping in Magnetic Microcalorimeter Sensors for Direct-Coupled Readout"
Stephen Boyd - University of New Mexico
26. "Simulation of TES X-Ray Microcalorimeters designed for 14.4 keV Solar Axion Search"
Shohei Mori - Kyushu University
27. "Systematic Study of Pile-up Effects in Cryogenic Decay Energy Spectroscopy"
Alexander Kavner - University of Michigan (Ann Arbor)
28. "The ATHENA X-IFU detector: Fabrication and Integration of Full-Scale Arrays"
Edward Wassell - NASA Goddard Space Flight Center
29. "The Simons Observatory: Device Characterization for Detectors in Synchrotron Channels"
Kevin T. Crowley - University of California, Berkeley
30. "The study for improvement on the fabrication processes of MMC (metallic magnetic calorimeter)"
Jiwan Song - KRISS
31. "Thermodynamic noise in optical transition-edge sensors"
Kaori Hattori - AIST
32. "Towards very fast high granular TES with parallel biasing and single readout scheme"
Hiroyuki Takahashi - The University of Tokyo

Week 2 Day 2 Wednesday 28 July 07:00 - Wednesday 28 July 11:30 (Korean Standard Time)

Oral O6: Warm Readout and Supporting Science 07:00 - 09:55 (Conference webpage)
Session chairs: Adriana Lita, National Institute of Standards and Technology
Sae Woo Nam, National Institute of Standards and Technology

1. 07:00 "Superconducting opto-electronic hardware for neuromorphic computing" (Invited)
Sonia Buckley - NIST
2. 07:30 "Fully differential broadband LNA with active impedance matching for SQUID readout"
Manuel Gonzalez - Astroparticle and Cosmology laboratory
3. 07:45 "End-to-end Deep Learning Pipeline for Microwave Kinetic Inductance Detector (MKID) Resonator Identification and Tuning"
Neelay Fruitwala - UC Santa Barbara
4. 08:00 "Comparing hydrogenated amorphous silicon fabrication techniques for low loss, low noise dielectrics in superconducting detectors"
Andrew Beyer - Jet Propulsion Laboratory

Break: 08:15 - 08:25 (10 minutes)

5. 08:25 "Designing the Next Generation UVOIR MKID Readout on RFSoC Devices"
Jennifer Smith - University of California, Santa Barbara
6. 08:40 "Thermal Filtering in BICEP Array"
David Goldfinger - Harvard University
7. 08:55 "Flexibility in Array Design with Hybrid Additive-Subtractive TES Process"
Joel Weber - NIST Boulder
8. 09:10 "Low Loss Thin Film Al-on-Si Microwave Resonators for Astronomy Applications"
Carolyn Volpert - University of Maryland & NASA Goddard
9. 09:25 "Hafnium, Zirconium and Vanadium Superconducting Resonators"
Miguel Daal - UC Santa Barbara
10. 09:40 "Measuring the Effects of Background Radiation on Superconducting Devices"
Jason Stevens - University of Colorado Boulder

Break: 09:55 - 10:05 (10 minutes)

Poster P6: Readout, Other Devices, Supporting Science 2 10:05 - 11:30 (Conference webpage)

1. "A Cryogenic Quality Assurance Test Platform For SQUID-Based Readout Electronics"
Carl Reintsema - NIST
2. "A novel superconducting RF low-pass filter based on low-T_c Ti/TiN artificial transmission line for detector and qubit readout"
Yingni Chen - Southwest Jiaotong University
3. "A quantitative study in STEM-EDS with a broadband TES X-ray microcalorimeter toward astromaterials analysis"
Tasuku Hayashi - ISAS/JAXA
4. "A μK-level Temperature Stability Control Method for TES Energy Resolution Test"
Jiao Ding - Department of Astronomy, Tsinghua University
5. "Assessment of the RFI by the X-band antenna in LiteBIRD using a 3D electromagnetic field simulator"
Masatoshi Tsuji - National Institute of Technology, Kagawa College
6. "Bandwidth and Aliasing in the Microwave SQUID Multiplexer"
Cyndia Yu - Stanford University
7. "Broadband multi-layer Anti-reflection coatings with mullite and duroid used for half wave plate and alumina filter for CMB polarimetry"
Kana Sakaguri - University of Tokyo
8. "Cryogenic Readout Electronics for SIS Photon Detectors"
Hiroshi Matsuo - National Astronomical Observatory of Japan
9. "Design of the On-board Data Compression of the Bolometer Data for LiteBIRD"
Mayu Tominaga - the University of Tokyo, JAXA
10. "Development of Hybridization Processes for Superconducting Sensors and Readout Circuitry"
Tammy Lucas - National Institute of Standards and Technology

11. "Development of inductively coupled position and temperature sensors for cryogenic rotating half wave plate"
Kyohei Yamada - The university of Tokyo
12. "Development of low-cost readout electronics for resonator-based multiplexing detector arrays"
Junya Suzuki - Kyoto University
13. "Direct RF Readout of SQUID Multiplexed Transition-Edge Sensors Using Xilinx RFSoC"
Jozsef Imrek - NIST
14. "Epoxy IR Filters for Superconducting Resonators"
Gabriel Spahn - University of Minnesota Twin Cities
15. "Gamma-Ray Position-Sensitive Transition-Edge-Sensor Microcalorimeters With a Bismuth Absorber"
Naoko Iyomoto - Kyushu University
16. "Large-Area TKIDs for a New Generation of Neutron Beta Decay Experiments"
Elizabeth Mae Scott - National Institute of Standards and Technology
17. "Low loss microstrip materials with MKIDs for microwave applications"
John Hood - Vanderbilt University
18. "Low noise hydrogenated amorphous silicon for superconducting resonators"
Fabien Defrance - Caltech
19. "Low-temperature scintillation characteristics of Li2MoO4 and CaMoO4 crystals measured in AMoRE-I"
Kyung-Rae Woo - Institute for Basic Science, KOREA
20. "Material properties of a low contraction and resistivity silicon-aluminum alloy for cryogenic detectors"
Tatsuya Takekoshi - Kitami Institute of Technology
21. "Measurement of thermal crosstalk from charged particles absorbed in the Si substrate of a microcalorimeter array"
Hideyuki Tatsuno - Tokyo Metropolitan University
22. "Metal film deposition on molybdate crystals"
Sora Kim - Institute for Basic Science
23. "Modelling signal oscillations arising from electrothermal coupling and stray capacitance in semiconducting bolometer impulse response"
Samantha Stever - Okayama University
24. "Monte-Carlo Simulations of Superconducting Tunnel Junction Quantum Sensors for the BeEST Experiment"
Connor Bray - Colorado School of Mines
25. "Noise analysis in electromagnetically induced transparency in nitrogen-vacancy diamond"
Cole Brookhouse - University of Illinois Urbana-Champaign
26. "Properties of SIS Devices for Terahertz Photon Detection"
Hajime Ezawa - National Astronomical Observatory of Japan
27. "Recent developments of commercially fabricated horn antenna-coupled Transition Edge Sensor bolometer detectors for next generation Cosmic Microwave Background polarimetry experiments"
Aritoki Suzuki - Lawrence Berkley National Laboratory
28. "Scalable FPGA Design for Frequency Division Multiplexed Microwave Readout"
Jozsef Imrek - NIST
29. "Spatial map of X-ray emission spectra using a 240-pixel X-ray TES array at the SPring-8 synchrotron X-ray light source"
Hirotaka Suda - Tokyo Metropolitan University
30. "The Thermal Conductivity of Sapphire Ball Based Detector Clamps"
Harold Pinckney - University of Massachusetts Amherst
31. "Thermal Conductance of a Titanium Hot-Electron Bolometer with Different Microbridge Thicknesses"
Feiming Li - Purple Mountain Observatory, Chinese Academy of Sciences
32. "Two stage temperature control system using an MMC readout for a long-term data taking"
Kyung-Rae Woo - Institute for Basic Science, KOREA
33. "Uniformity of Superconducting Tunnel Junction Detector Arrays"
Stephan Friedrich - Lawrence Livermore National Laboratory

Week 2 Day 3 Thursday 29 July 05:00 - Thursday 29 July 11:30 (Korean Standard Time)

Vendor Exhibitor Hour: 05:00 - 06:00

Oral O7A: Rare Events 2 07:00 - 09:55 (Conference webpage)
Session chairs: Michael Rabin, Los Alamos National Laboratory
Sunil Golwala, California Institute of Technology

1. 07:00 "Neutrino mass measurements using cryogenic detectors" (Invited)
Loredana Gastaldo - Kirchhoff Institute for Physics, Heidelberg University
2. 07:30 "From ECHo-1k to ECHo-100k: Optimisation of high-resolution metallic magnetic calorimeters with embedded Ho-163 for the determination of the electron neutrino mass"
Markus Griedel - Kirchhoff Institute for Physics, Heidelberg University
3. 07:45 "The BeEST Experiment: Searching for Sterile Neutrinos in 7Be Decay with STJs"
Kyle Leach - Colorado School of Mines
4. 08:00 "HeRALD - a superfluid He-4 detector with transition edge sensor readout for light dark matter"
Junsong Lin - Univeristy of California Berkeley

Break: 08:15 - 08:25 (10 minutes)

5. 08:25 "MINER Reactor Neutrino Experiment for CENNS and ALP Searches"
Rupak Mahapatra - Texas A&M University
6. 08:40 "Design and First Results of a Gram-Scale Low-Surface-Coverage Athermal-Phonon Detector for Polar Crystal Dark Matter Searches"
Caleb Fink - University of California Berkeley
7. 08:55 "Status and performance of the AMoRE-I experiment for neutrinoless double beta decay"
Han beom Kim - Institute for Basic Science
8. 09:10 "Test measurements of an MMC-based 510-g lithium molybdate crystal detector for AMoRE-II experiment"
SeungCheon Kim - Institute for Basic Science
9. 09:25 "Dark-photon Observation System for Unexplored Radio Range - DOSUE-RR"
Shumpei Kotaka - Kyoto University
10. 09:40 "A new method of neutrino studies from tritium beta decay spectrum in LiF crystals"
YongChang Lee - IBS(Institute of Basic Science), Korea

Oral O7B: Astrophysics and Cosmology 07:00 - 09:55 (Conference webpage)
Session chairs: Nils Halverson, University of Colorado, Boulder
Jordan Wheeler, National Institute of Standards and Technology

1. 07:00 "Cosmology with Low-Temperature Detectors" (Invited)
Masashi Hazumi - Institute of Particle and Nuclear Studies (IPNS), High Energy Accelerator Research Organization (KEK)
2. 07:30 "Characterization of the first light 280 GHz kinetic inductance detector array for the CCAT-prime project"
Cody Duell - Cornell University
3. 07:45 "ATHENA X-IFU Demonstration Model: First joint test between the main TES array and the Cryogenic Anti-Coincidence (CryoAC) detector system"
Matteo D'Andrea - INAF/IAPS Roma
4. 08:00 "ASCENT - A Superconducting Energetic X-ray Telescope Using A Gamma-ray Transition Edge Sensor Array For Astrophysics On A Suborbital Platform"
Fabian Kislat - University of New Hampshire

Break: 08:15 - 08:25 (10 minutes)

5. 08:25 "Super DIOS mission for exploring dark baryon"
Kosuke Sato - Saitama University
6. 08:40 "Discovery of a Low Mass Stellar Companion to HIP 109427 Using Stochastic Speckle Discrimination with The MKID Exoplanet Camera"
Sarah Steiger - University of California, Santa Barbara
7. 08:55 "Design and performance of kinetic inductance detector arrays for the Terahertz Intensity Mapper balloon mission"
Reinier Janssen - Jet Propulsion Laboratory

8. 09:10 “In Flight-Performance of the BLAST-TNG Kinetic Inductance Detector Arrays and Readout Electronics”
Adrian Sinclair - Arizona State University
9. 09:25 “DESHIMA 2.0: Development of a science-grade integrated superconducting spectrometer for astronomical observations”
Akio Taniguchi - Nagoya University
10. 09:40 “SPT-SLIM: The South Pole Telescope Summertime Line Intensity Mapper”
Kirit Karkare - University of Chicago/Fermilab

Break: 09:55 - 10:05 (10 minutes)

Poster P7: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs 10:05 - 11:30 (Conference webpage)

1. “A broadband search for hidden photon dark matter using a cryogenic reflecting dish and kinetic inductance parametric amplifiers”
Karthik Ramanathan - Caltech
2. “A study for $PbMoO_4$ phonon-scintillation detection with MMC read outs for neutrinoless double beta decay”
Hyelim Kim - Institute for Basic Science
3. “A study of timing jitter of superconducting tunnel junction x-ray detector”
Shigetomo Shiki - National Institute of Advanced Industrial Science and Technology
4. “An Improved Sinuous Antenna Design for Next-Generation Cosmic Microwave Background Surveys”
Aashrita Mangu - University of California, Berkeley
5. “Application of deep learning to the waveform processing of transition-edge sensor calorimeters”
Yuto Ichinohe - Rikkyo University
6. “Athermal phonon mediated large-mass Sapphire detectors for Dark Matter and CEvNS searches.”
Shubham Verma - Texas A&M University
7. “Characterization of two-level-system noise for microwave kinetic inductance detector made with niobium film on silicone substrate”
Yoshinori Sueno - Kyoto University
8. “Configuration of Probe Tones for MKID Readout with Frequency Sweeping Scheme”
Makoto Nagai - National Astronomical Observatory of Japan
9. “Development of Al/Nb hybrid Lumped-Element Kinetic Inductance Detectors for infrared photon detection”
Tomoki Terasaki - the University of Tokyo
10. “Development of an electron neutrino detector system using superconducting detectors and the surface microstructure forming technique”
Hirokazu Ishino - Okayama University
11. “Evaluation of instrumental polarization of a 200 mm diameter achromatic HWP with anti-reflective structures and impact on TES non-linearity”
Ryota Takaku - The University of Tokyo
12. “Light dark matter detection with hydrogen-rich crystals and low-T_c TES detectors”
Gensheng Wang - Argonne National Lab
13. “LiteBIRD High Frequency Detectors: Design and Status”
Johannes Hubmayr - NIST
14. “Mechanical cryocooler noise observed in the ground testing of the Resolve X-ray microcalorimeter instrument onboard XRISM”
Ryuta Imamura - Ehime University
15. “Millimeter-wave absorber using 3-D printed mold for cryogenic application”
Shunsuke Adachi - Kavli Institute for the Physics and Mathematics of the Universe (WPI), The University of Tokyo
16. “MMC-based low-threshold silicon detector using Neganov-Luke (NL) phonon amplification”
Jin-A Jeon - Institute for Basic Science/Center for Underground Physics
17. “Modeling of Sensitivity of LiteBIRD”
Takashi Hasebe - Kavli Institute for the Physics and Mathematics of the Universe
18. “Modelling TES non-linearity induced by a rotating HWP in a CMB polarimeter”
Tommaso Ghigna - Kavli IPMU - The University of Tokyo

19. "Observation of Long-Lived UV Induced Fluorescence from Environmental Materials Using the HVeV detector as developed for SuperCDMS"
Francisco Ponce - PNNL
20. "Parallel-Plate Capacitor TiN Kinetic Inductance Detectors for Infrared Astronomy"
Joanna Perido - University of Colorado Boulder
21. "Performance of a multi-KID phonon-mediated particle detector"
Karthik Ramanathan - Caltech
22. "Performance of a phonon-mediated detector using KIDs optimized for sub-GeV dark matter"
Osmond Wen - California Institute of Technology
23. "Plans for the Test of a NIST Microcalorimeter Array for Hard X-ray and γ-ray Astronomy on a Stratospheric Balloon Flight"
Md Arman Hossen - Washington University in St. Louis
24. "Plastic Laminate Antireflective Coatings for Millimeter-wave Optics in BICEP Array"
Marion Dierickx - Harvard University
25. "Potential extra noise from a continuously rotating HWP using superconducting magnetic bearing for CMB polarimetry"
Shinya Sugiyama - Saitama University
26. "Simulated performance of laser-diced metamaterial anti-reflection coatings"
Nicole Farias - UC Berkeley
27. "Study of $PbWO_4$ Crystal for a Coherent Elastic Neutrino-Nucleus Scattering Experiment at Taishan Nuclear Power Plant"
Mingxuan Xue - University of Science and Technology of China
28. "Study of quasi-particle dynamics using the optical pulse response of a superconducting resonator"
Jingjing Hu - Southwest Jiaotong University
29. "SuperCDMS IMPACT: Measuring the sub-keV Ionization Yield in Cryogenic Solid-State Detectors"
Tyler Reynolds - SuperCDMS
30. "Superconducting resonators with niobium airbridge inductors for high-energy particle detection"
Masato Naruse - Saitama University

Week 2 Day 4 Friday 30 July 07:00 - Friday 30 July 11:00 (Korean Standard Time)

Oral O8: Devices 3 07:00 - 10:25 (Conference webpage)
Session chairs: Barry Zink, University of Denver
Shinji Okada, Chubu University

1. 07:00 "Superconducting nanowire single photon detectors for quantum information" (Invited)
Lixing You - Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences (SIMIT, CAS)
2. 07:30 "Investigation of fluctuations in superconducting molybdenum silicide nanostrips for single photon detectors"
Loredana Parlato - Università di Napoli Federico II
3. 07:45 "Single-photon detection in superconducting MgB_2 micro-wires operating up to 20 K"
Ilya Charaev - Massachusetts Institute of Technology
4. 08:00 "The CONCERTO wide field-of-view millimeter-wave spectrometer at APEX"
Alessandro Monfardini - CNRS Grenoble
5. 08:15 "Ultrawide MoSi SNSPD detectors"
Tony Zhou - RLE, MIT

Break: 08:30 - 08:40 (10 minutes)

6. 08:40 "Single Photon Detection in a Large array of Quantum Capacitance Detectors"
Pierre Echternach - Jet Propulsion Laboratory
7. 08:55 "Development of far-infrared to mm-wave feedhorn-coupled kinetic inductance detector arrays."
Jordan Wheeler - National Institute of Standards of Technology
8. 09:10 "Optical performance of the microstrip-coupled lumped-element kinetic inductance detector"
Pete Barry - Argonne National Laboratory
9. 09:25 "Development of Superconducting On-chip Fourier Transform Spectrometer devices"
Ritoban Basu Thakur - California Institute of Technology
10. 09:40 "Progress on improving the energy resolution of optical to near-IR MKIDs"
Nicholas Zobrist - University of California, Santa Barbara
11. 09:55 "Contribution of residual quasiparticles to the resonance properties of MKID resonators"
Takashi Noguchi - National Astronomical Observatory of Japan / RIKEN
12. 10:10 "Strategies for reducing frequency scatter in large arrays of superconducting resonators"
Juliang Li - Argonne national lab

Break: 10:25 - 10:35 (10 minutes)

Closing and Introduction of LTD20 Hosts: 10:35 - 11:00

Session: Oral O1-1: Devices 1

Schedule: Monday 19 July 22:15 - Monday 19 July 22:45

Submitted by: Pieter de Visser - SRON

Microwave Kinetic Inductance Detectors – detector physics and recent developments

Pieter de Visser

SRON Netherlands Institute for Space Research

Microwave Kinetic Inductance Detectors (MKIDs) promise high sensitivity and relative ease of fabrication and multiplexing into large arrays. MKIDs are operated nowadays in various instruments on telescopes and in labs, which range from detecting sub-millimeter radiation to near-infrared, visible and x-ray and in high-energy particle detectors. MKIDs can be operated as sensitive power integrating detectors for long wavelengths, photon counting and energy resolving detectors for shorter wavelengths, and are used for particle detection as phonon detectors. While they are successfully applied, at array sizes of >20 kpixels, our understanding of the detector physics and of engineering problems is still rapidly increasing.

In this talk I will introduce the operation principle of MKIDs for different applications. I will review the understanding of the detector physics and the various ways MKIDs can be operated and optimized for different applications, with focus on recent developments.

Session: Oral O1-2: Devices 1

Schedule: Monday 19 July 22:45 - Monday 19 July 23:00

Submitted by: Florence Levy-Bertrand - Institut Néel, Grenoble (France)

Subgap kinetic inductance detector sensitive to 85-GHz radiation

F. Levy-Bertrand [1], A. Benoît [1], O. Bourrion [2], M. Calvo [1], A. Catalano [2], J. Goupy [1], F. Valenti [3,4], N. Maleeva [4,5], L. Grünhaupt [4], I. M. Pop [6,4], A. Monfardini [1]

[1] Univ. Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, 38000 Grenoble, France
[2] Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble Alpes, CNRS, 53 rue des Martyrs, 38026 Grenoble Cedex, France
[3] IPE, Karlsruhe Institute of Technology, 76344 Eggenstein-Leopoldshafen, Germany
[4] PHI, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany
[5] National University of Science and Technology MISIS, 119049 Moscow, Russia
[6] IQMT, Karlsruhe Institute of Technology, 76344 Eggenstein-Leopoldshafen, Germany

We have fabricated an array of subgap kinetic inductance detectors (SKIDs) made of granular aluminum ($T_c \sim 2$ K) sensitive in the 80-90 GHz frequency band and operating at 300 mK [1]. We measure a noise equivalent power of 1.3×10^{-16} W/Hz$^{0.5}$ on average and 2.6×10^{-17} W/Hz$^{0.5}$ at best, for an illuminating power of 50 fW per pixel. Even though the circuit design of SKIDs is identical to that of the kinetic inductance detectors (KIDs) [2], the SKIDs operating principle is based on their sensitivity to subgap excitations. This detection scheme is advantageous because it avoids having to lower the operating temperature proportionally to the lowest detectable frequency. The SKIDs presented here are intrinsically selecting the 80-90 GHz frequency band, well below the superconducting spectral gap of the film, at approximately 180 GHz. These SKIDs may provide a scalable technology for imaging at 85 GHz.

[1] F. Levy-Bertrand et al, Subgap kinetic inductance detector sensitive to 85-GHz radiation, Physical Review Applied 15, 044002 (2021).
[2] P. K. Day et al, A broadband superconducting detector suitable for use in large arrays, Nature, 425, 817 (2003).

Session: Oral O1-3: Devices 1

Schedule: Monday 19 July 23:00 - Monday 19 July 23:15

Submitted by: Steven de Rooij - SRON, Netherlands Institute for Space Research

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Strong Generation-Recombination Noise Reduction in Hybrid NbTiN-Al MKIDs

Steven A. H. de Rooij [1,2], Jochem J. A. Baselmans [1,2], Vignesh Murugesan [2], David J. Thoen [1,3], Pieter J. de Visser [2]

[1] SRON - Netherlands Institute for Space Research, Sorbonnelaan 2, 3584 CA Utrecht, The Netherlands
[2] Faculty of Electrical Engineering, Mathematics and Computer Science, Delft University of Technology, Mekelweg 4, 2628 CD Delft, the Netherlands
[3] Delft University of Technology, Kavli Institute of NanoScience, Faculty of Applied Sciences, Delft, The Netherlands

An MKID is a superconducting, pair-breaking detector: an incoming photon is detected by the breaking Cooper-pairs, which generates quasiparticles. Therefore, random Generation and Recombination (GR) of quasiparticles form a fundamental noise source. At the same time, a measurement of GR noise can give valuable information on the detector physics, such as the quasiparticle lifetime and quasiparticle number.

We present measurements of GR noise for different temperatures in hybrid NbTiN-Al MKIDs, both on substrate and on membrane, which enhances phonon trapping. The MKID design, with small Al volume, gives a high responsivity, which allows for read out at low microwave powers, minimizing the creation of excess quasiparticles.

We observe that the quasiparticle lifetime saturates at about 1 ms for low temperatures (250 mK). Surprisingly, the GR noise level reduces a factor 100 going from 350 to 200 mK for the membrane device, where the level is expected to stay constant as a function of temperature. We show that this noise reduction at constant lifetime implies a thermal number of quasiparticles. Trapping of quasiparticles is consistent with this observation.

This effect leads to a mch higher signal-to-noise for photon counting MKIDs than expected, which we verify by measuring the resolving power at 1545 nm. Moreover, this opens up paths for engineering quasiparticle traps in MKIDs to reduce GR noise and adjust the low temperature quasiparticle lifetime.

Session: Oral O1-4: Devices 1

Schedule: Monday 19 July 23:25 - Monday 19 July 23:40

Submitted by: Mikko Möttönen - Aalto University

Bolometer operating at the threshold for circuit quantum electrodynamics [Nature 586, 47 (2020)]

Mikko Möttönen, R. Kokkoniemi, J.-P. Girard, D. Hazra, A. Laitinen, J. Govenius, R. E. Lake, I. Sallinen, V. Vesterinen, M. Partanen, J. Y. Tan, K. W. Chan, K. Y. Tan, P. Hakonen, K. Kohvakka, W. Liu, G. Catto

Aalto University

Several important applications for thermal radiation sensors are currently emerging from quantum technology and especially from electrical circuits that behave quantum mechanically, that is, circuit quantum electrodynamics. This field has given rise to single-photon microwave detectors and a quantum computer that is superior to classical supercomputers for certain tasks. Thermal sensors hold potential for enhancing such devices because they do not add quantum noise and they are smaller, simpler and consume about six orders of magnitude less power than the frequently used travelling-wave parametric amplifiers. However, no bolometer has previously met the threshold for circuit quantum electrodynamics, which lies at a time constant of some 100 ns and energy resolution of some 10×h×GHz. Here, we experimentally demonstrate a bolometer that operates at this threshold, with a noise-equivalent power of 30 zW/$\sqrt{\mathrm{Hz}}$ at a thermal time constant of 500 ns. Both of these values are measured directly on the same device, giving an accurate estimation of 30×h×GHz for the calorimetric energy resolution. These improvements stem from the use of a graphene monolayer with extremely low specific heat as the active material. The minimum observed time constant of 200 ns is well below the dephasing times of roughly 100 µs reported for superconducting qubits and matches the timescales of currently used readout schemes, thus enabling circuit quantum electrodynamics applications for bolometers.

Session: Oral O1-5: Devices 1

Schedule: Monday 19 July 23:40 - Monday 19 July 23:55

Submitted by: Zhuoran Geng - Nanoscience Center, University of Jyväskylä

Modeling of superconductor-ferromagnet thermoelectric detector for X-ray detection

Zhuoran Geng, Ari Helenius, Tatu Korkiamäki, I.J. Maasilta

Nanoscience Center, University of Jyväskylä

Superconductor-ferromagnet thermoelectric detector (SFTED) is a novel low-temperature radiation detector concept based on the giant thermoelectric effect in superconducting ferromagnet hybrids. This type of detector can be operated without the need of additional bias lines and has been considered as promising low temperature bolometer and calorimeter. The performance of such SFTED with SQUID readout has also been analyzed theoretically under the small signal assumption.

Here we report our progress in more advanced modeling on SFTED as a microcalorimeter in both linear and non-linear regimes, targeting for keV X-ray detection. With simulations of the time evolution of the expected detector pulses and noise, we are investigating different configurations and options, such as the coupling to a superconducting absorber, and the detector performance beyond the small signal assumption. Such analysis helps us with the practical detector and absorber designs, implementation, and optimization, as well as with future pulse analysis.

Early results seem promising, with an indication that an SFTED detector can have a wide dynamic range with a good linearity, and a competitive energy resolution and speed.

Session: Oral O1-6: Devices 1

Schedule: Monday 19 July 23:55 - Tuesday 20 July 00:10

Submitted by: Mauro Rajteri - INRIM

Transition-Edge Sensors for low-energy electron detection

M. Rajteri [1,2], M. Faverzani [3,4], E. Ferri [3,4[, R. Filippo [1], F. Gatti [5,6], A. Giachero [3,4], E. Monticone [1,2], A. Nucciotti [3,4], C. Pepe [1,7]

[1] Istituto Nazionale di Ricerca Metrologica (INRiM) - Torino Italy
[2] Istituto Nazionale di Fisica Nucleare (INFN) Sezione di Torino, Italy
[3] Università di Milano - Bicocca, Milano Italy
[4] Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano Italy
[5] Università di Genova – Genova Italy
[6] Istituto Nazionale di Fisica Nucleare (INFN) Sezione di Genova, Italy
[7] Politecnico di Torino - Torino Italy

Transition-edge sensors (TESs) are microcalorimeters with intrinsic energy resolution. For optical and near-infrared single photon detectors an energy resolution of about 0.2 eV is often enough to guarantee a good photon number resolving capability; however, there are some applications where a much higher resolution is required, like the PTOLEMY project, devoted to directly detect the Cosmic Neutrino Background, exploiting the neutrino capture processes on unstable nuclei like tritium. The relic neutrino capture evidence should be a peak in the electron spectrum above the beta decay endpoint and to be detected an energy resolution of 0.05 eV at around 10 eV is needed. To fulfill this objective, we started to reduce the transition temperature of our TiAu TES, while maintaining a suitable saturation energy. Thanks to the high electron stopping power of metals, the penetration depth of incident electrons is limited to few nanometers and allows to reduce the overall thickness of the TES without affecting the detection efficiency. We report results based on the optical characterization of a TiAu TES with an overall thickness of 43 nm and active area of 50 μm x μ50 m with a transition temperature of 52 mK. With photons at 1540 nm we obtained and energy resolution close to 0.1 eV and with the ability to detect photons up to an equivalent energy of 10 eV. The response time is around 20 μs. The results state we are heading towards reaching TES requirements for PTOLEMY 's target.

Session: Oral O1-7: Devices 1

Schedule: Tuesday 20 July 00:10 - Tuesday 20 July 00:25

Submitted by: Luciano Gottardi - NWO-I SRON, Netherlands Institute for Space Research

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Voltage fluctuations in transition edge sensors and other effects from the 70's

L. Gottardi, M. de Wit, E. Taralli, K. Nagayoshi, A. Kozorezov, H. Akamatsu, D. Vaccaro, J. van der Kuur, M. L. Ridder, K. Ravensberg, S. Visser , M. P. Bruijn, J-W. den Helder, and J. R. Gao

NWO-I SRON, Netherlands Institute for Space Research

We present the results of an extensive characterization at MHz bias of the noise of TES microcalorimeters with different geometry and normal resistance. We show that the fluctuation-dissipation theorem, generalized for a non-linear system in thermal equilibrium, explains well the observed noise in the Johnson-Nyquist frequency range. The 'excess' noise, typically observed in the TES electrical bandwidth, can be explained by the equilibrium Johnson noise of the quasi-particles generated within a superconducting weak-link. The fluctuations at the Josephson frequency and higher harmonics contribute significantly to the measured voltage noise at the detector bandwidth through the non-linear response of the weak-link.

We have studied the noise over a large range of parameters like the detector normal resistance, the bias voltage, the bias frequency, and the bath temperature. Our MHz readout provides a straightforward method to characterize the TES noise in the Johnson-Nyquist bandwidth. All the parameters used in the noise models can be experimentally estimated. The results can be generalized for the dc bias case as well.

Our noise analysis could help to improve even further the excellent performance of the novel TES microcalorimeters fabricated at SRON, with achieved X-ray energy resolution of 1.5 eV at 6 keV under MHz bias.

Finally, we will discuss the physics of unconventional TES geometries, in line with the pioneering work of physicists from the 70's.

Session: Oral O1-8: Devices 1

Schedule: Tuesday 20 July 00:25 - Tuesday 20 July 00:40

Submitted by: Martin de Wit - Netherlands Institute for Space Research (SRON)

Impact of the absorber coupling design for Transition Edge Sensor X-ray Calorimeters

M. de Wit, L. Gottardi, K. Nagayoshi, E. Taralli, H. Akamatsu, M.L. Ridder, K. Ravensberg, D. Vaccaro, M. P. Bruijn, J.-R. Gao, J. W. A. den Herder

Netherlands Institute for Space Research (SRON)

Transition Edge Sensors (TESs) are the selected technology future spaceborne X-ray observatories, such as Athena, Lynx, and HUBS. These missions demand thousands of pixels to be operated simultaneously with high energy resolving power. To reach these demanding requirements, every aspect of the TES design has to be optimized. In this contribution, we present measurements on rectangular TESs used to study the impact of the absorber coupling design. In particular, we look at the effects of the diameter of the coupling stems and the distance between the stems and the bilayer. We present results of AC complex impedance measurements revealing the shape of the resistive transition R(I,T), as well as measurements of the excess noise. We report a small but consistent reduction in the excess noise as the spacing between the absorber stem and the bilayer is decreased. Additionally, we see a clear effect on the position of measured bumps in the excess noise. These peaks in the noise are so far unexplained by any conventional noise model, and complicate the operation of the TES in most multiplexing schemes. Our observations show that these unwanted structures in the transition shape might be prevented with careful design of the coupling geometry. Furthermore, initial indications are seen that the stem diameter has a significant impact on the amplitude of the weak-link effect-induced oscillations in α and β, an observation that is of great importance for both AC and DC biased TESs.

Session: Oral O1-9: Devices 1

Schedule: Tuesday 20 July 00:40 - Tuesday 20 July 00:55

Submitted by: Nicholas Wakeham - University of Maryland Baltimore County / NASA Goddard Space Flight Center

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Fine optimization of TES microcalorimeter design for the X-IFU instrument on ATHENA

N. A Wakeham [1,2], J. S. Adams [1,2], S. R. Bandler [1], S. Beaumont [1,2,6], J. A. Chervenak [1], F. M Finkbeiner [1,4], J. Y. Ha [1,5], R. Hummatov [1,2], R. L. Kelley [1], C. A. Kilbourne [1], A. M. Miniussi [1,2], F. S. Porter [1], K. Sakai [1,2], S. J. Smith [1], E. J. Wassell [1], S. Yoon [1,3]

[1] NASA Goddard Space Flight Center (GSFC), Greenbelt, MD 20771, USA
[2] CRESST II – University of Maryland, Baltimore County, MD 21250, USA
[3] Science Systems and Applications, Inc. (SSAI) 10210 Greenbelt Rd, Lanham, MD 20706
[4] Sigma Space Corp. / Hexagon US Federal, 4600 Forbes Blvd., Lanham, MD 20706, USA
[5] SB Microsystems, 806 Cromwell Park Dr, Glen Burnie, MD 21061, USA
[6] IRAP, 9 Avenue du Colonel Roche, 31400 Toulouse, France

The X-ray Integral Field Unit (X-IFU) instrument on the Advanced Telescope for High ENergy Astrophysics (ATHENA) is baselined to have 3168 transition-edge sensor (TES) microcalorimeter pixels. These pixels will be DC biased and readout using time division multiplexing. We recently reported a demonstration of the required pixel and readout performance in 252 pixels from a 1 kilo-pixel array (e.g. 2.16 eV resolution for 6.9 keV X-rays). Having achieved the required performance, the 50um square TES design in this demonstration array is considered the baseline pixel design for X-IFU. However, by making small adjustments to the TES design, we may be able to make small but consequential improvements to the instrument performance, while staying within the many constraints of the X-IFU requirements.

In this presentation, we will show results from newly fabricated devices with subtle changes from the baseline TES design to further optimize the performance for X-IFU. We will discuss optimizing the TES sheet resistance, normal metal features, X-ray absorber attachment points, TES aspect ratio, and heat capacity. These minor design changes can have significant effects on thermo-electric time constants, thermal fluctuation noise, resistive transition shape and uniformity, and non-linearity of X-ray event pulses. In addition, full characterization of these new TES designs allows greater understanding of the relevant physics within the TES and gives routes for further optimization.

Session: Poster P1-1: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Michael Audley - SRON Netherlands Institute for Space Research

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A Far-Infrared TES Bolometer with a Magnetically-Switchable High-Power Mode

M. D. Audley, G. de Lange, A. Orlando, M. L. Ridder

SRON Netherlands Institute for Space Research

We describe a far-infrared TES bolometer with magnetically-switchable power handling, used as a reference detector in our optical test facility. The reference detector is an early prototype SAFARI bolometer, with $NEP \sim 2$ aW/$\sqrt{\text{Hz}}$, $T_{\text{c}} \sim 100$ mK, and $P_{\text{sat}} \sim 100$ fW, suspended in an overmoded absorbing cavity so that it has a flat spectral response. Its function is to monitor the incident spectrum so that the intrinsic spectral response of detectors under test can be derived from FTS measurements. By design there is a small overlap between the TES bilayer and the 7 nm thick Ta absorber, giving a double transition and a modest increase in power handling. We also wired the TES and absorber in series, intending to operate the Ta film as a TES at higher temperatures during commissioning of the optical test facility. However, we found that applying a magnetic field to the device switched it into a high-power mode, with a saturation power in the pW range, using the same bias-voltage range and bath temperature as in the low-power state. The device remained in this high-power state when the magnetic field was removed, and could be returned to the low-power mode by driving it normal with no applied field. We are investigating the hypothesis that the high-power state is due to magnetic flux trapped in the thin Ta film. In principle, it should be possible to fabricate such a device with a lower NEP. We present measurements of the characteristics of this device and discuss possible applications.

Session: Poster P1-2: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Shibo Shu - California Institute of Technology

A kinetic inductance detectors array design for high background conditions at 150 GHz

Shibo Shu [1], Jack Sayers [1], Peter Day [2]

[1] California Institute of Technology, Pasadena, CA 91125, USA
[2] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA

We present a design for an array of kinetic inductance detectors (KIDs) integrated with phased array antennas for imaging at 150 GHz under high background conditions. The microstrip geometry KID detectors are projected to achieve photon noise limited sensitivity with larger than 100 pW absorbed optical power. Both the microstrip KIDs and the antenna feed network make use of a low-loss amorphous silicon dielectric. A new aspect of the antenna implementation is the use of a NbTiN microstrip feed network to facilitate impedance matching to the 50 ohm antenna. The array has 256 pixels on a 6-inch wafer and each pixel has two polarizations with two Al KIDs. The KIDs are designed with a half wavelength microstrip transmission line with parallel plate capacitors at the two ends. The resonance frequency range is 400 to 800 MHz. The readout feedline is also implemented in microstrip and has a impedance transformer from 50 Ohm to 9 Ohm at its input and output. Details of the design will be discussed in this presentation.

Session: Poster P1-3: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Marharyta Lisovenko - Argonne National Laboratory

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Characterization of the Superconducting Microwave Properties of Aluminum Manganese

M. Lisovenko, P. Barry, T. Cecil, C. Chang, J. Hood, J. Li, V. Novosad, Z. Pan, G. Wang, V. Yefremenko

Argonne National Laboratory

A Microwave Kinetic Inductance Detector (MKID) is a superconducting pair breaking detector that offers a number of unique advantages for realizing large-format arrays of ultra-sensitive detectors. With the detection threshold being set by the Cooper pair binding energy, and correspondingly, the superconducting critical temperature (T_c), typical well-understood MKID materials such as aluminum (Al), present a lower limit on the operating frequency. Mn-doped aluminum (AlMn) is a promising candidate material for MKIDs because it can be fabricated with nearly identical processing as pure Al, but allows for control of the T_c with varying levels of Mn doping. We present results from early characterization of superconducting resonators made from AlMn, including measurements of internal quality factor, kinetic inductance, and noise performance over a range of Mn doping.

Session: Poster P1-4: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Umeshkumar Patel - Argonne National Laboratory

Compton spectroscopy measurements at the APS 1-BM beamline using traditional semiconductor and advanced high-energy TES X-ray detectors

U. Patel [1], T. Guruswamy [1], O. Quaranta [1], L. Gades [1], J. Baldwin [1], R. Divan [2], and A. Miceli [1], H. Charalambous [3], A. J. Krzysko [3], Y. Ren [3], U. Ruett [3]

[1] Detectors Group, X-ray Science Division, Advanced Photon Source, Argonne National Laboratory
[2] Center for Nanoscale Materials, Argonne National Laboratory
[3] Structural Science Group, X-ray Science Division, Advanced Photon Source, Argonne National Laboratory

The momentum resolution of synchrotron Compton scattering experiments is typically limited by the energy resolution of the solid-state detector (SSD), energy broadening of the source and geometrical broadening due to the width of the detected scattering angle. We report inelastic X-ray scattering experiments with high momentum and energy transfer performed at the Advanced Photon Source (APS) 1-BM beamline. Compton profiles were measured for reference silicon wafers (Si, SiO_2), and for lithium and cobalt oxide powders (Li_2O, $LiCoO_2$, Co_3O_4, CoO) relevant to lithium ion battery research. Spectroscopic analysis of the measured Compton profiles of the scattering system show a high-sensitivity to the low-Z elements. The line shape analysis of the measured Compton profiles in comparison with simulated Hartree-Fock profiles is limited by the semiconductor detector resolution. High-energy X-ray Transition Edge Sensors (TESs) offer an order of magnitude improvement in detector resolution compared to SSDs for the entire hard X-ray energy range from 20-100 keV. First generation X-ray TES detectors were characterized for hard X-ray energy applications. A second-generation composite X-ray detector chip, incorporating both electroplated Au and Bi absorbers was designed and fabricated for the deep hard X-ray regime. We report detector development challenges, present performance and future prospects of these advanced high-energy TES detectors.

Session: Poster P1-5: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Sunil Golwala - California Institute of Technology

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Decoupling of the quasiparticle number and lifetime in titanium nitride resonators

S. Golwala, S. Shu, F. Defrance, A. Beyer, J. Sayers

California Institute of Technology

We report on an apparent discrepancy between the quasiparticle density in titanium nitride kinetic inductance detectors (KIDs) inferred from kinetic inductance frequency shifts and from generation-recombination (g-r) noise measurements from 240 to 360 mK. We are able to measure both the magnitude and the roll-off frequency of the g-r noise, providing measurements of the quasiparticle lifetime and density. We find the quasiparticle density inferred via this technique is significantly lower than that inferred from frequency shift data over the entire temperature range probed.

Session: Poster P1-6: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Pete Barry - Argonne National Laboratory

Design and preliminary results of the spectroscopic focal plane for the South Pole Telescope Summertime Line Intensity Mapper

P. Barry [1], A. Anderson [2], B. Benson [2], T. Cecil [1], C. Chang [1], M. Dobbs [3], K. Karkare [4], D. Marrone [5], J. Montgomery [3], Z. Pan [1], G. Robson [6], M. Rouble [3], E. Shirokoff [4], G. Smecher [7]

[1] Argonne National Laboratory
[2] Fermilab
[3] McGill University
[4] University of Chicago
[5] University of Arizona
[6] Cardiff University
[7] Three-Speed Logic, Inc.

The Summertime Line Intensity Mapper (SLIM) is a new mm-wave line-intensity mapping (mm-LIM) experiment for the South Pole Telescope (SPT). With an on-sky demonstration scheduled for the austral summer of 2022-23, the goal of SPT-SLIM is to serve as a pathfinder capable of demonstrating the in-field performance and suitability of on-chip, multi-pixel mm-wave spectrometers for future mm-LIM experiments. Even as a pathfinder, the combination of the spectrometer design, the spatial resolution of the SPT, and the atmospheric conditions at the South Pole will deliver a competitive detection of the CO power spectrum and constrain the molecular gas fraction in the full population of $z{\sim}2$ galaxies. The SPT-SLIM focal plane will include 18 dual-polarization pixels, each coupled to an $R = 300$ superconducting filter-bank spectrometer covering the 2-mm atmospheric window (120-180 GHz). Each spectral channel terminates on a microstrip-coupled lumped-element kinetic inductance detector (KID), which provides the highly multiplexed readout for the $\sim$10k detectors needed for SPT-SLIM. Here we present key aspects of the focal plane design, detailed simulations of the filter-bank, optimization of KID performance, along with preliminary laboratory characterization of a series of prototype spectrometers that will be used to inform the final design of the SPT-SLIM spectrometer array.

Session: Poster P1-7: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Shibo Shu - California Institute of Technology

Design of a multi-chroic kinetic inductance detectors array coupled to a hierarchical phased-array antenna

Shibo Shu [1], Andrew Beyer [2], Peter Day [2], Fabien Defrance [1], Jack Sayers [1], Sunil Golwala [1]

[1] California Institute of Technology, Pasadena, CA 91125, USA
[2] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA

We present a multi-chroic kinetic inductance detector (KID) pixel design integrated with a broadband hierarchical phased-array antenna. Each low-frequency pixel consists of four high-frequency pixels. Four passbands are designed from 125 to 365 GHz according to the atmospheric windows. The lumped element KIDs are designed with 100 nm Al as the inductor and with Nb parallel plate capacitors using hydrogenated amorphous Si as a dielectric. Due to the broadband coverage, two different types of structures are needed to couple light from microstripline to the KIDs. The KIDs designs are optimized for a 10-m-class telescope at a high, dry site. We will discuss the design detail and the optimization of the KIDs in this presentation.

Session: Poster P1-8: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Conjeepuram Ambarish - University of Wisconsin-Madison

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Development of a fabrication process for large suspended gold absorbers for TES microcalorimeters

C. V. Ambarish, H. Dai, C.Howe, F. T. Jaeckel, E. John, S. Liu, D. McCammon, A. Roy, H. Stueber, Z. Wang, T. Yan
University of Wisconsin - Madison

Astrophysical plasmas at a million Kelvin are ubiquitous in our universe. The forest of lines from such plasmas in the 150-300 eV range requires energy resolution better than 2eV FWHM, to identify individual lines and allow the study of the various astrophysical components along a line of sight.

For a sounding rocket mission to study the diffuse X-ray background, we need a relatively large collecting area ($> 2\ \ cm^2$) with a limited number of readout channels. This requirement coupled with our strict energy resolution needs drives our goal of fabricating large (1mm $\times$ 1mm) thin (200nm) gold absorbers.

Our previous attempts at fabricating these absorbers showed that we needed a large number of support posts as far out as possible to keep the thin absorber from sagging and thermally shorting to the substrate. The need for the support posts increases membrane sizes which increases the thermal conductance to the bath. It is also detrimental to detector energy resolution due to athermal phonon loss from the increased absorber-membrane thermal conductance.

Here, we explore the idea of adding corrugations to the absorber to mechanically stiffen it and decrease the number of support stems needed. This process builds on the "mushroom" absorber process developed at NASA's GSFC. We explore different corrugation designs and show first results from our fabrication attempts.

Session: Poster P1-9: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Mariia Fedkevych - Department of Physics, University of Genoa, Genoa, Italy

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Development of a prototype detector for Torio-229 experiment

M. Fedkevych [1,2], M. Biasotti [1,2], M. De Gerone [2], L. Ferrari Barusso [1,2], G. Gallucci [2], F. Gatti [1,2], M. Giovannini [2,3], M. Osipenko [2], M. Ripani [2], B. Siri [1,2]

[1] Department of Physics, University of Genoa, Genoa, Italy
[2] INFN (Istituto Nazionale di Fisica Nucleare) Genoa, Genoa, Italy
[3] Department of Chemistry, University of Genoa, Genoa, Italy

At present, ^{229m}Th isomeric nuclear state is a unique known realistic candidate for development of nuclear clock. Such a clock would extend a precision by up to two orders of magnitude comparing to the the best existing up-to-date atomic clock. To achieve this, accurate knowledge of energy and lifetime of the state is necessary.

Torio-229 experiment aims for a direct model-independent determination of the transition energy of ^{229m}Th produced in ^{233}U alpha decay. As a detector for the isomeric transition, it is planned to use an array of fast ($\sim\mu$s signal-rise time and $< 7\ \mu$s signal-decay time) Transition Edge Sensors (TESs) of ~ 1 eV resolution. Such a microcalorimeter will allow to register the transition from every possible channel in the energy range from 3 to 50 eV and a lifetime of $> 5\ \mu$s.

In this contribution we will report on a development and test measurements of a low-temperature single-photon iridium-based TES as a prototype for the Torio-229 detector.

Session: Poster P1-10: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Felix Jaeckel - University of Wisconsin - Madison

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Development of high-resolution, large absorber TES microcalorimeters for the soft X-ray range

F. T. Jaeckel, C. V. Ambarish, H. Dai, S. Liu, D. McCammon, K. Nelms, A. Roy,
H. Stueber, Z. Wang, and T. Yan

University of Wisconsin - Madison

Disentangling the various astrophysical sources of the soft X-ray background (1 keV) requires development of 1-2 eV resolution microcalorimeters. To obtain sufficient count rates on a sounding rocket mission, we aim to develop large absorber area ($\sim$ 1 mm^2) TES microcalorimeters that need to simultaneously provide high thermal sensitivity (α) and low current sensitivity (β), along with minimal excess noise (M).

We are exploring two different fabrication approaches to achieve this goal with Mo/Cu bilayer transition edge sensors: a) in-situ bilayer deposition with subsequent wet-chemical and dry etching to pattern the device, and b) a Cu lift-off process on pre-patterned Mo films, where the Mo surface is cleaned using an ion-beam prior to Cu evaporation to ensure good interface transparency. The lift-off approach is similar to the Mo/Au "hybrid additive-subtractive" process developed at NIST [1]. We test different device designs (sizes, membrane perforations, with and without normal metal "noise mitigating" fingers) and present first results in this poster.

[1] Joel C Weber et al., "Development of a transition-edge sensor bilayer process providing new modalities for critical temperature control," Supercond. Sci. Technol. 33, 115002 (2020)

Session: Poster P1-11: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Karia Dibert - The University of Chicago

Development of MKIDs for Measurement of the Cosmic Microwave Background with the South Pole Telescope

Karia Dibert and Peter Barry on behalf of the SPT Collaboration

We present details of the design, simulation, and initial test results of prototype detectors for the fourth-generation receiver of the South Pole Telescope (SPT4). Optimized for the detection of key secondary anisotropies of the cosmic microwave background (CMB), SPT4 will enable extraordinarily sensitive measurements of the temperature and polarization of the mm/sub-mm sky at observing frequencies at 225, 285, and 345 GHz, beyond the peak of the CMB blackbody spectrum. In combination with data from the currently operational SPT-3G, SPT4 will target cosmological observables such as the kinematic Sunyaev-Zel'dovich effect and the Rayleigh scattering of the CMB. The SPT4 focal plane will be populated with monochroic microwave kinetic inductance detectors (MKIDs), a highly-sensitive, highly-multiplexable, and cost-effective detector technology, allowing for significantly increased detector density with reduced cryogenic complexity. We present simulation-backed designs for dual-polarization MKID pixels at each SPT4 observation frequency. We further address design choices made to promote resonator quality and uniformity, enabling us to maximize the channel capacity of our 1 GHz readout bandwidth. We also discuss the simplified fabrication process that enables rapid production of these devices and present initial dark and optically-loaded test results for a series of prototype devices.

Session: Poster P1-12: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Ritoban Basu Thakur - California Institute of Technology

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Energy Calibration of Phonon-Mediated Dark Matter Detectors using MKIDs

R. Basu Thakur, T. Aralis, B. Bumble, Y.-Y. Chang, K. Ramanathan, O. Wen, S. R. Golwala

California Institute of Technology

Microwave Kinetic Inductance Detectors (MKIDs) lithographed on silicon wafers can be engineered to sense energies at a few eV level as deposited by particle interactions in the substrate. Such detectors enable efficient searches for low mass dark matter (MeV-GeV scale masses) candidates. The inherent multiplexing advantage allows multiple MKIDs to provide positional information on the energy deposited in the substrate. This is critical in discriminating standard radioactive (background) processes from dark matter like rare interactions. The absolute and relative energy calibration of such an MKID array, factoring in the position dependence of the events, will be discussed. Absolute energy calibration is performed using optical photons illuminating a small spot on the detector surface, while relative energy calibration is performed by pulsing individual resonators with a large RF power to create quasiparticles.

Session: Poster P1-13: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Kenichiro Nagayoshi - NWO-I/SRON Netherlands Institute for Space Research

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Influence of Width of Ti/Au Transition Edge Sensors

K. Nagayoshi [1], M. de Wit [1], M.L. Ridder [1], E. Taralli [1], L. Gottardi [1], S. Visser [1], H. Akamatsu [1], D. Vaccaro [1], M. P. Bruijn [1], J.-R. Gao [1,2], J. W. A. den Herder [1]

[1] NWO-I/SRON Netherlands Institute for Space Research
[2] Kavli Institute of Nanoscience, Delft University of Technology

We are developing transition edge sensor (TES) microcalorimeters based on superconducting Ti/Au bilayer thin films for future X-ray astronomical observatories. It has been shown that transition temperature T_c and the width of a transition curve are scaled with $1/L^2$, where L is the spacing between superconducting leads attached to a TES bilayer. These observations are to be explained by the longitudinal proximity effect induced by the superconducting leads of which transition temperature is higher than that of the TES bilayer. Recently, we experimentally found that T_c was also scaled with $1/W^2$, where W is the TES width ranging from 20 µm to 40 µm. We observed that the T_c dropped as the width decreased, suggesting the lateral inverse proximity effect induced by the presence of normal metal on the edge of the bilayer.

In this contribution, we present latest research developments regarding superconducting characteristics affected by the width of Ti/Au bilayers. Various TES widths including below 10 µm were investigated and the results are to be discussed by revealing the bilayer edge microstructures in details.

Session: Poster P1-14: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Paul Nicaise - GEPI - Observatoire de Paris - CNRS

Investigation of Optical Coupling Performance in LEKIDs Using Superconducting Reflective Plates

Paul Nicaise, Jie Hu, Christine Chaumont, Josiane Firminy, Thibaut Vacelet, Florent Reix, Samir Beldi, David Horville, Jean-Marc Martin, José Palomo, Michael Rosticher, Michel Piat, Piercarlo Bonifacio, Faouzi Boussaha

GEPI - Observatoire de Paris - CNRS

To improve the optical coupling in Lumped Element Kinetic Inductance Detectors (LEKIDs), we investigate the use of a reflective plate beneath the meandered absorber. We designed, fabricated and characterized high-Q factors TiN-based LEKIDs on sapphire operating at optical wavelengths with an Au/Nb or Al/Nb reflective thin bilayer below the meander. The reflector is set at a quarter-wavelength distance from the meander using a transparent Al_2O_3 dielectric layer to reach the peak photon energy. We expect the plate to recover undetected photons by reflecting them back onto the absorber. Here, we will present the detailed design and preliminary experimental results.

Session: Poster P1-15: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Greg Jaehnig - University of Colorado Boulder

LiteBIRD Low and Mid-Frequency Detectors: Design and Status

G. C. Jaehnig, J.E. Austermann, J.A. Beall, J. Connors, S.M. Duff, N.W. Halverson, G.C. Hilton, J. Hubmayr, C.L. Kuo, J. Van Lanen, A.T. Lee, C. Raum, K. Thompson, M.R. Vissers, B. Westbrook

LiteBIRD is a satellite experiment that will precisely measure the polarization of the cosmic microwave background. Its mission is to survey the full sky with three telescopes covering 15 frequency bands centered on 40 to 402 GHz. The pixel design for the low- and mid-frequency telescopes features a hemispherical lenslet coupled to a broadband sinuous antenna. The radiation detected by the sinuous antenna propagates through a superconducting microstrip and on-chip bandpass filters before being detected by the TES bolometers. The TES design balances requirements for low saturation power of the space environment while maintaining a fast time response for use with a continuously-rotating half-wave plate. We present measurements of a dual-polarization trichroic pixel at 40, 60, and 78 GHz suitable for the low-frequency telescope, designs for a mid-frequency detector array at 100, 140, and 195 GHz, as well as measurements of the electrical and thermal properties of the TES.

Session: Poster P1-16: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Stephen Yates - SRON, Netherlands Institute for Space Research

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Low stray power cross-coupling between MKIDs, for future focal plane spectrometer arrays

S. J. C. Yates [1] , K. Karatsu [3,2], S. Dabironezare [2], A. Endo [2,4], N. Llombart [2], V. Murugesan [3], D. J. Thoen [2,4], J. J. A. Baselmans [3,2]

[1] SRON, Netherlands Institute for Space Research, Landleven 12, Groningen, The Netherlands.
[2] Terahertz Sensing Group, Delft University of Technology, Mekelweg 1, 2628 CD Delft, The Netherlands
[3] SRON, Netherlands Institute for Space Research, Sorbonnelaan 2, Utrecht, The Netherlands
[4] Kavli Institute of NanoScience, Faculty of Applied Sciences, Delft University of Technology, Delft, The Netherlands

We present measurements on a device to test the lens-antenna system and stray light rejection proposed for the DESHIMA 2.0 spectrometer. We compare a direct antenna coupled hybrid Al-NbTiN MKID to nominally identical but blind MKIDs, some behind the lens and some not. Measurements of the optical coupling efficiency and phase and amplitude beam patterns are presented, pointing towards different coupling mechanisms: electromagnetic coupling to stray in-band radiation scattered in the lens for MKIDs behind the lens, the beam patterns are uncorrelated to the lens-antenna coupled MKID; readout crosstalk or low-level phonon coupling for MKIDs not under the lens, the beam patterns are correlated to the lens-antenna coupled MKID. With a stray light absorber of low T_c β-phase Ta placed only on a spacer wafer for the lens but not on the detector substrate itself, we see a low optical efficiency relative to the antenna coupled MKID of $\sim 1{\times}10^{-4}$ for MKIDs behind the lens to $\sim 0.2{\times}10^{-4}$ for those not under the lens. This is in-line with the expectation of low surface wave excitation in the detector substrate by the "leaky-wave" antenna: spillover radiation losses in the lens should not enter the detector substrate due to the NbTiN ground plane and thin membrane used for the antenna. Either rejection is sufficient for current generation of on chip spectrometers like DESHIMA 2.0, and could even enable the placement of the spectrometers behind the lens for future focal plane spectrometer arrays.

Session: Poster P1-17: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Kevin Kouwenhoven - SRON Netherlands Institute for Space Research

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Model and measurements of an optical stack for broadband absorption in Optical LEKIDs

Kevin Kouwenhoven [1,2], Ibrahim Elwakil [3], Johannes van Wingerden [4] Vignesh Murugesan [1], David J. Thoen [2], Jochem J. A. Baselmans [1,2], Pieter J. de Visser [1,2]

[1] SRON, Netherlands Institute for Space Research, Utrecht, Netherlands
[2] Department of Microelectronics, Delft University of Technology, Delft, Netherlands
[3] De Haagse Hogeschool, Den Haag, Netherlands
[4] Else Kooi Laboratory, Delft University of Technology, Delft, Netherlands

Using Microwave Kinetic Inductance Detectors (MKIDs) we aim to realise a camera for the visible and near-IR spectrum with energy resolving pixels. Even for high resistivity superconductors, such as TiN and β-Ta the quantum efficiency (QE) is limited to around 40%. To reach a QE of 90% the detector must be embedded in an optical stack. In this work we focus on broadband absorption for 400-1550 nm with a high-resistivity superconductor.

We present the modelling, optimisation and measurement of a stack of anti-reflection layers based on the optical constants of high resistivity TiN films, measured with an ellipsometer. The entire stack is modelled using a transmission line model, where the optical constants of each film set the properties of the different transmission line segments. Using this approach, we design a stack for a 60 nm layer of TiN which, for this thickness, is semi-transparent at 400-1550 nm. The stack consists of two SiO_2 layers and a 100 nm aluminum backing reflector which yields 80% absorption in the 400-1550 nm band with near unity absorption for 600-800 nm.

Using a spectrophotometer, we measure the absorption of the optical stack. The measured absorption is 100% from 600-800 nm and 80% absorption from 500-1550 nm. We attribute the deviation to uncertainties in the optical properties and thicknesses of the layers.

Session: Poster P1-18: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Trevor Oxholm - University of Wisconsin-Madison

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Modeling and Optimizing Microwave Kinetic Inductance Detectors for the EXCLAIM Mission

Trevor Oxholm, Emily M. Barrentine, James P. Hays-Wehle, Maryam Rahmani, Thomas R. Stevenson, Eric R. Switzer, Peter T. Timbie, Carolyn G. Volpert, on behalf of the EXCLAIM Collaboration

University of Wisconsin-Madison

Microwave Kinetic Inductance Detectors (MKIDs) are highly scalable detectors that have demonstrated background-limited sensitivity in space-like infrared environments. The detectors have a rich design space with many optimizable parameters, allowing highly sensitive measurements over a wide dynamic range. While MKIDs show great promise, a number of uncertainties remain in predicting their performance under very low or high loads; namely, it is difficult to model all of the phenomena that may lead to increased noise or decreased responsivity. Microwave-induced pair-breaking and parasitic two-level systems significantly impact the design and optimization of MKIDs for use in astronomical instruments, warranting the need for robust modeling efforts. We present on the status of an MKID model being developed for the spectrometer for the Experiment for Cryogenic Large-Aperture Intensity Mapping (EXCLAIM), a balloon-based telescope targeting nearly background-limited performance from 420-540 GHz. We highlight how sources of loss within the detectors may affect the noise and responsivity of the MKID array, and how the resonator volume, incident readout power, and coupling capacitance may be optimized to minimize these effects. Understanding these dynamics will help to maximize the scientific output of the EXCLAIM mission, while also providing a crucial testbed for MKIDs being developed for future missions.

Session: Poster P1-19: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Faouzi Boussaha - GEPI-Observatoire de Paris CNRS UMR8111

Near Infrared and Visible Kinetic Inductance Detectors for SPIAKID

Faouzi Boussaha [1], Jie Hu [1,6], Jean-Marc Martin [1], Samir Beldi [2], Paul Nicaise [1], Christine Chaumont [1], Piercarlo Bonifacio [1], Elisabetta Caffau [1], Martino Calvo [3], Moustapha Dekkali [4], Josiane Firminy [1], Stéphane Gauffre [5], David Horville [1], Pascal Jagourel [1], Shan Mignot [1], Alessandro Monfardini [3], Michel Piat [6], Florent Reix [1], Michael Rosticher [7], Thibaut Vacelet [8]

[1] GEPI,Observatorie de Paris, Univesité PSL, 77 avenue Denfert-Rochereau 75014 Paris - France
[2] ESME - 67 Boulevard de Brandebourg, 94200 Ivry-sur-Seine - France
[3] Université de Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, 38000 Grenoble - France
[4] LESIA - Observatorie de Paris, Univesité PSL, 5 , place Jules Janssen 92195 Meudon Cedex - France
[5] LAB, Allée Geoffroy Saint-Hilaire, 33600 Pessac - France
[6] Laboratoire AstroParticule et Cosmologie, Université de Paris, 75013 Paris - France
[7] Ecole Normale Supérieure, 45 Rue d'Ulm, 75005 Paris - France
[8] LERMA, Observatorie de Paris, Univesité PSL, 77 avenue Denfert-Rochereau 75014 Paris - France

We are developing lumped element kinetic inductance detectors (LEKIDs) for the Spectro-Photometric Imaging for Astronomy with Kinetic Inductance Detectors (SPIAKID) project. SPIAKID is a novel near-IR and visible MKIDs-based instrument to be deployed on the ESO 3.58 m NTT telescope. It will be dedicated to primarily observe and study ultra-faint dwarf (UFD) galaxies in the Local Group. We aim to build several 130x130 pixel arrays. Two LEKID geometries are being investigated: parallel plate capacitor-based LEKIDs [1] and interdigitated capacitor-based LEKIDs. In order to choose the most suitable geometry for the SPIAKID instrument, we carried out intensive experimental investigations of temperature and feedline power dependence, frequency and phase noises, as well as optical photon detection performance. In this talk, we will present the two LEKID array designs operating in 400-1600 nm wavelength range and the corresponding experimental results.

Session: Poster P1-20: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Usasi Chowdhury - Institut Neel, UGA

On-chip Spectrometers operating at 90GHz

Usasi Chowdhury [1], Alessandro Monfardini [1], Martino Calvo [1], Florence Levy- Bertrand [1], Johannes Goupy [1], Andrea Catalano [2], Julien Bounmy [2], Gregory Garde [1]

[1] Univ. Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, 38000 Grenoble, France
[2] Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble Alpes, CNRS, 53 rue des Martyrs, 38026 Grenoble Cedex, France

In the framework of ground-based millimeter-wave astronomy, the atmospheric windows centered on 90 GHz, 150 GHz and 240 GHz are most relevant for a number of applications ranging from galactic to cosmology.

Our group has, in the past years, developed very sensitive large arrays of Lumped Element Kinetic Inductance Detectors (LEKIDs), and deployed them in a number of instruments and telescopes, i.e. NIKA2 at Pico Veleta, KISS at Teide Observatory, CONCERTO at APEX. We have in this way achieved the mapping of large areas of the Sky in intensity and polarization. We obtain low-spectral-resolution information by coupling Martin-Puplett interferometers to large field-of-view cameras.

In this work, we propose to complement this experience by developing on-chip spectrometer using KIDs. The aim is to improve, at least for small patches of the field-of-view and without affecting the overall optics, the sensitivity and spectral resolution of our future instruments. A simple slot microstrip antenna with low loss dielectric will be used to obtain a relatively wide bandwidth. We focused, for the first prototype, on the range 80 GHz to 110 GHz, i.e. the so-called “3-mm atmospheric window”. The pixels consist of superconducting Al (filters) and Ti-Al (absorber) resonators. They will couple with a single microwave transmission line feedline and readout respectively. In this poster, we outline the design, simulation, and fabrication of the first prototypes.

Session: Poster P1-21: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Gerhard Ulbricht - Dublin Institute for Advanced Studies

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Optimization of Ti/TiN multilayers for optical to near-IR MKIDs and exploring their commercial foundry potential

Gerhard Ulbricht, Mario De Lucia, Eoin Baldwin, Jack Piercy, Oisin Creaner, Colm Bracken, Tom Ray

Dublin Institute for Advanced Studies

A big challenge in the development of MKIDs is that their fabrication requires high quality cleanroom environments and specialized and expensive deposition tools. The possibility to outsource the fabrication to commercial foundries is therefore very attractive but many places only offer a strictly limited range of materials to work with. As Ti and TiN are routinely used in semiconductor manufacturing, Ti/TiN multilayers are among the few superconductor options for MKIDs that can be fabricated at commercial sites. Ti/TiN multilayers have already been shown to perform great in far-IR MKIDs and are less reflective then Al, making them an intriguing candidate for the further development of energy resolving MKIDs in the optical to near-IR range.

Energy resolving MKIDs rely on a small T_c, and Ti/TiN becomes challenging when its T_c gets too low. At DIAS we intend to characterize multilayer optical MKIDs over varying T_c and plan to optimize our detectors for a T_c of 800 mK. We will investigate if sub-stoichiometric TiNx can replace TiN in multilayers to further reduce T_c and how that affects Q_i, QP-lifetimes and energy resolution. We have access to both a state-of-the-art UHV sputtering system as well as an older HV chamber. We will compare these systems with samples prepared for us by Tyndall National Institute who provide CMOS prototyping services from Cork, Ireland. First experiments are underway and we will present initial results and elaborate further on future experiments.

Session: Poster P1-22: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Ahmed Abdelhameed - Max-Planck-Institut für Physik

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Overcoming the challenges for reproducible fabrication of 15 mK tungsten-based TESs with tunable and predictable T_c

A. H. Abdelhameed, G. Angloher, A. Bento, E. Bertoldo, L. Canonica, N. Ferreiro, D. Fuchs, A. Garai, D. Hauff, M. Mancuso, F. Petricca, F. Pröbst, J. Rothe

Max-Planck-Institut für Physik

Cryogenic detectors employing TESs are a mature technology that has access to the parameter space of low-mass dark matter thanks to their cutting-edge sensitivity. The TES technology is progressively adapting to cope with the increased demands, e.g., reaching exceedingly low thresholds, and finding a route to deploy large detector arrays. The foreseen upgrade of the CRESST experiment aims to deploy $\mathcal{O}(100)$ detectors with TES read-out. This work presents the latest results on tungsten-based TES research activities in CRESST. In contrast to the evaporation system used to date, the investigated sputtering process allows for a more reliable and much quicker TES fabrication. Two independent sputter systems were utilized for this purpose and succeeded in producing superconducting tungsten films with the required properties. This work will give some insights into the effect of the process parameters on the T_c as well as some design aspects required to precisely tune the T_c. Thanks to a new approach, it is now possible to produce TESs with unprecedented reproducibility. This approach includes the use of xenon gas for sputtering instead of the standard argon gas and the use of a seed layer, of the order of one nanometer, deposited underneath the tungsten film. Through multiple modifications applied to the sputter system, automated recipes for tungsten deposition on different substrate materials are defined. Lastly, a testing approach will be presented that can predict the T_c with high confidence excluding the need to cool down the films to the mK range.

Session: Poster P1-23: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Pieter de Visser - SRON

Phonon-trapping enhanced energy resolution in superconducting single photon detectors

Pieter J. de Visser [1], Steven A. H. de Rooij [1,2], Vignesh Murugesan [1], David J. Thoen [2,3], Jochem J. A. Baselmans [1,2]

[1] SRON Netherlands Institute for Space Research, Sorbonnelaan 2, 3584CA Utrecht, The Netherlands
[2] Faculty of Electrical Engineering, Mathematics and Computer Science, Delft University of Technology, Mekelweg 4, 2628 CD Delft, The Netherlands
[3] Delft University of Technology, Kavli Institute of NanoScience, Faculty of Applied Sciences, Delft, The Netherlands

A noiseless, photon counting detector, which resolves the energy of each photon, is a wish for low light applications in astronomy, biophysics and quantum optics. Novel space telescopes to characterise exoplanets require very low noise detectors (at wavelengths of 300 nm to 2 micron), ideally with a resolving power R=E/dE140. The energy resolution practically eliminates the dark counts and read noise that limit semiconductor detectors. We study superconducting energy-resolving Microwave Kinetic Inductance Detectors (MKIDs). Each absorbed photon breaks Cooper pairs, the number of which can be determined from the response of a superconducting microwave resonator.

A visible/near-IR photon creates a few thousand quasiparticles through various stages of electron-phonon interaction. We have measured that high-energy phonons lost in this process strongly compromise the resolving power to R = 20 (10) for aluminium MKIDs on a solid substrate, measured with 402 (1545) nm lasers. When fabricated on a 110 nm SiN membrane, R increases to 52 (19), which is consistent with a factor 8 better phonon trapping than on substrate. It also demonstrates that the theoretical promises on resolving power for MKIDs are becoming realistic. We plan to make the last step in phonon trapping, needed to reach the fundamental limit in resolving power, by patterning the membrane into a phononic crystal.

Our manuscript on this work can be found at arXiv:2103.06723

Session: Poster P1-24: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Marco Faverzani - University and INFN of Milano-Bicocca

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Progress in the development of Thermal Kinetic Inductance Detectors for X-ray spectroscopy

Marco Faverzani [1,2], M. Borghesi [1,2], A. Cruciani [3], E. Ferri [1,2], A. Giachero [1,2], B. Margesin [4,5], R. Mezzena [6,5], E. Monticone [7,5], A. Nucciotti [1,2], M. Rajteri [7,8]

[1] Università di Milano-Bicocca, Milano, Italy
[2] INFN - Sezione di Milano-Bicocca, Milano, Italy,
[3] INFN - Sezione di Roma1, Roma, Italy
[4] Fondazione Bruno Kessler (FBK), Trento, Italy
[5] INFN - Trento Institute for Fundamental Physics and Applications (TIFPA), Trento, Italy
[6] Dipartimento di Fisica, Univeristà di Trento, Povo, Trento, Italy
[7] INRIM - Istituto Nazionale di Ricerca Metrologica, Torino, Italy
[7] INFN - Sezine di Torino, Torino, Italy

Thermal Kinetic Inductance Detectors (TKIDs) are a variation of Microwave Kinetic Inductance Detectors (MKIDs) that exploit the dependence of the kinetic inductance of a superconductor on its temperature. They operate the resonators in quasi-thermal equilibrium mode: the resonator acts as a thermometer sensing the temperature variation caused by a release of energy in an absorbing material. Our project plans to develop absorber-coupled superconducting resonators to detect soft X-ray photons in a thermal quasi-equilibrium manner (pure calorimeter) exploiting resonators films made of Ti/TiN multilayer, Ti/Al bilayerand Al/Ti/Al trilayer.

A deep detector characterization is currently in progress and will continue for the entire 2021 with the goal to compare the different designs and materials. At end of this R&D phase the best performing configuration will be selected and implemented in a larger array. In this contribution, the status of the development is reported, with detailed reference to the microresonators design, to the fabrication process and to the obtained characterization results.

Session: Poster P1-25: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Kevin Kouwenhoven - SRON Netherlands Institute for Space Research

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Resolving power of visible/near-infrared hybrid NbTiN/β-Ta LEKIDs

Kevin Kouwenhoven [1,2], Enrico Biancalani [3], Daniel Fan [4], Tawab Karim [4], Carlas S. Smith [4] Vignesh Murugesan [1], David J. Thoen [2], Jochem J. A. Baselmans [1,2], Pieter J. de Visser [1,2]

[1] SRON, Netherlands Institute for Space Research, Utrecht, Netherlands
[2] Department of Microelectronics, Delft University of Technology, Delft, Netherlands
[3] Leiden Observatory, Leiden, Netherlands
[4] Delft Center for Systems and Control, Delft University of Technology, Delft, Netherlands

When an optical photon is absorbed in a Microwave Kinetic Inductance Detector (MKID), it creates thousands of quasiparticle excitations. Because the number of excitations depends on the photon energy, MKIDs have intrinsic energy resolution at visible and near-IR wavelengths. Energy-resolving MKID arrays can be used as chromatic wavefront sensors, order sorting detectors in a spectrometer, or as an imaging spectrometer to measure the atmospheric spectrum of exoplanets.

We present a hybrid Lumped Element (LEKID) design with a resolving power (R = E/dE) ranging from 6.3 at 1545 nm to 14.9 at 402 nm. The design is based on a high resistivity beta phase tantalum (β-Ta) inductor, and a NbTiN capacitor, with a 150 µm pixel pitch. The β-Ta inductor has a thickness of 60 nm and a T_c of 1 K. Both the interdigitated capacitor and the CPW readout line are made from a 150 nm layer of NbTiN. The KIDs are connected to the readout line with a capacitively coupled NbTiN strip, which galvanically connects to the readout line with an Aluminum/Polyimide bridge. This hybrid design yields a $Q_i > 10^5$ at 8-8.5 GHz.

The photon-sensitive part of a LEKID is the inductor, which makes up just 2% of the footprint of each pixel. To increase the number of detected photons a microlens array is 3D-printed on the substrate. A comparison between KIDs shows an increase in the number of absorbed photons of a factor 20-45 for the lens coupled MKIDs, which is consistent with the expected increase in fill fraction.

Session: Poster P1-26: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Maximilian Lorenz - Dr. Karl Remeis-Observatory & ECAP

Simulation of radiative transfer within X-ray microcalorimeter absorbers.

Maximilian Lorenz, Christian Kirsch, Thomas Dauser, Philippe Peille, Valentina Fioretti, Simone Lotti, Joern Wilms

Dr. Karl Remeis-Observatory & ECAP

We present Monte-Carlo simulations of radiative transfer within the absorbers of X-ray microcalorimeters, utilizing a numerical model for the photon propagation and photon absorption process within the absorber structure. In our model we include effects of Compton scattering off bound electrons and fluorescence. Scattered or fluorescence photons escaping the absorber can result in partial energy depositions. To study the consequences of these energy loss effects on the spectral response of a microcalorimeter, we apply our model to the sensors of the cryogenic X-ray spectrometer X-IFU on board the future Athena X-ray observatory.

Session: Poster P1-27: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Thijs Stockmans - leiden University

Simulation of the Cosmic Ray impact on the TES detectors of SPICA/SAFARI

T.A.Stockmans [1], A. Almasi [2], S.L. Stever [3], P. Khosropanah [2]

[1] Leiden Observatory, Leiden University, Niels Bohrweg 2, 2333 CA Leiden, The Netherlands
[2] Netherlands Institute for Space Research (SRON), Sorbonnelaan 2, 3584 CA Utrecht, The Netherlands
[3] Kavli IPMU (WPI), UTIAS, The University of Tokyo, Kashiwa, Chiba 277-8583, Japan

The data from the Planck and Herschel space observatories [1, 2] revealed that the cosmic rays at L2 orbit can have a significant impact on the performance of different scientific instruments. In this paper, we present our simulation results of such impacts on SAFARI/SPICA, a far-infrared spectrometer equipped with transition-edge sensors (TESs). These TESs are fabricated on SiN membranes and suspended by long and thin SiN legs that thermally isolate them from the surrounding Silicon structure (wafer). Cosmic rays that pass through this surrounding structure deposit a portion of their energy, leading to temperature fluctuations in the wafer. These temperature fluctuations are sensed by the TESdetectors as an effective bath temperature and result in additional noise. To simulate the impact, we generate a 2D model of the wafer and the suspended TESs in COMSOL. This 2D model is bombarded with 27 randomly generated Cosmic Rays according to the observed energy distributions at L2 and the temperature fluctuations at different points on the wafer are estimated. Our results show that these thermal fluctuations and the calculated additional TES noise caused by them very much depend on the heat sink design of the wafer. We simulate multiple heat sink scenarios to determine the resulting noise impact relative to the noise requirements of the SAFARI instrument.

Session: Poster P1-28: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Micha Heilman - Leiden Univeristy/ SRON

Stability Analysis of SAFARI FDM Readout System

M. Heilman[1,2], Q. Wang [1,3], P. Khosropanah [1], M.D. Audley [1], A. Orlando [1], G. de Lange [1], B. Brandl [2]

[1] SRON Netherlands Institute for Space Research, Groningen/Utrecht, The Netherlands
[2] Leiden Observatory, Leiden University, Leiden, The Netherlands
[3] Kapteyn Astronomical Institute, University of Groningen, Groningen, The Netherlands

Transition Edge Sensor (TES) detectors are promising technology that allows ultra-sensitive measurements at infrared wavelengths. Here we conduct a stability analysis of the prototype SAFARI detector system, featuring an 88 TES bolometer array, a two-stage SQUID amplifier, and a baseband feedback frequency division multiplexed (FDM) readout. We measure the single-pixel stability, both with the TES in different states, and with separate components of the FDM system. The measurements are in time series, 300 s long, with 156.250 kS/s sampling frequency, and at 4 K and/or 90 mK base temperature.

To measure the stability of our system, several modes of analysis are used. A noise model is generated combining white noise, Brownian noise, and 1/f noise [1]. Various levels of each noise are added to match the features seen in the FDM readout noise. Allan Variance analysis [2] of the time series data shows stability of the measurement over time. Finally, a Fourier transform of the measured time series data allows analysis of 1/f noise and the f_{knee} in the frequency series.

Using model comparisons, Allan Variance, and 1/f and f_{knee} analysis, we find the stability of the FDM system components. From here we can improve the overall system stability and determine the best integration time for observing with TES arrays. The paper will discuss our latest results for the limits of stability of the SAFARI FDM, and compare them with similar XIFU data using an FDM in the x-ray regime.

Session: Poster P1-29: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Ryan McGeehan - University of Chicago

SuperSpec Improvements for Future Far-IR Missions

Ryan McGeehan

University of Chicago

SuperSpec is an ultra-sensitive, moderate resolution (R $\sim$ 300), on-chip spectrometer for mm and sub-mm wave observations of high redshift dusty galaxies. The device employs a filter-bank architecture in which kinetic inductance detectors (KIDs) are coupled to mm-wave resonant filters along a single microwave feedline. The detector's small size and multiplexability will enable future multi-object spectrographic measurements as well as high-redshift line intensity mapping observations.

We report the progress on improvements to the SuperSpec filter bank technology that will enable future far-IR missions. In particular, we present the characterization of a filter-bank design utilizing thin film aluminum (Al) KIDs for higher sensitivity compared to previous titanium nitride (TiN) films, as well as a newly designed mm-wave filter-bank structure with tunable couplings.

Session: Poster P1-30: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Davide Vaccaro - SRON

Susceptibility study of transition-edge sensor micro-calorimeters for X-ray spectroscopy under frequency-domain multiplexing readout

D. Vaccaro [1], H. Akamatsu [1], L. Gottardi [1], J. van der Kuur [1], M. P. Bruijn [1], R. H. den Hartog [1], M. Kiviranta [2], K. Nagayoshi [1], A. J. van Linden [1], K. Ravensberg [1], M. L. Ridder [1], E. Taralli [1], S. Visser [1], M. de Wit [1], B. D. Jackson [1], J-R. Gao [1], R. W. M. Hoogeveen [1], J-W. A. den Herder [1]

[1] SRON
[2] VTT Finland

Transition-edge sensors (TES) are the baseline detecting technology in future X-ray spaceborne telescopes, such as Athena X-IFU. To meet the scientific goals, thousands of TESs will be hosted on the instrument focal plane, with high requirements on energy and spatial resolution, and count-rate capability. Employing large arrays of detectors at sub-K temperatures with limited cooling power imposes the use of a multiplexing scheme. The requirement on the detector spectral performance dictates a stringent energy resolution budget on the various contributors to the total instrumental energy resolution, such as the detector, readout noise, the sensitivity to environmental conditions and instrumental drifts.

We present a characterization of the sensitivity of TES X-ray micro-calorimeters to environmental conditions under frequency-domain multiplexing (FDM) readout, where each TES in a readout chain is in series with a LC band-pass filter and AC biased with an independent carrier at MHz range. Using TES arrays, cold readout circuitry and warm electronics fabricated at SRON and SQUIDs produced at VTT Finland, we characterize the sensitivity of the detectors to magnetic field, bath temperature, bias voltage and the level of thermal crosstalk, and evaluate the impact on the detectors' response and energy resolution. We compare our results with the ERB of X-IFU, showing that the thermal crosstalk and TES sensitivities for our FDM-based system are suitable for spaceborne applications.

Session: Poster P1-31: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Lourdes Fàbrega - ICMAB-CSIC

Temperature and current sensitivities of bare Mo/Au Transition-Edge Sensors: size effects

Lourdes Fàbrega [1], Agustín Camón [2], Pavel Strichovanec [2], Carlos Pobes [2], Juan Bolea [3], Manel Mas [1]

[1] Institut de Ciència de Materials de Barcelona, ICMAB-CSIC, Campus de la UAB, E-08193 Bellaterra (SPAIN)
[2] Instituto de Nanociencia y Materiales de Aragón, CSIC-Universidad de Zaragoza, E-50009 Zaragoza (SPAIN)
[3] Centro Universitario de la Defensa, E-50090 Zaragoza (SPAIN)

Performances of transition-edge sensors (TESs) are intimately linked to the temperature and current sensitivities of their electrical resistance within the superconducting transition; these sensitivities are characterized by α and β, the logarithmic derivatives of the device resistance to temperature and current, respectively. Stability and noise of a TES depend on α and β.

Knowing α and β not only helps to optimize empirically the TES performances but also provides information on the mechanisms responsible for dissipation in the device.

The relevance of knowing α and β has been evidenced in several studies. Most of them analyse data of devices with absorber, normal metal structures or banks; all these features may alter the current distribution inside the TES, thus modifying the response intended to explore.

In this communication we study α and β of bare Mo/Au TES sensors without any normal metal structure, with and without relevant weak link effects. Both parameters display a smooth dependence with bias. We analyze them as a function of bath temperature, current and aspect ratio, with the aim of studying the intrinsic shape of the transition and getting insights into the ultimate limitations of TES sensitivity, through their correlation to the excess noise parameter M.

Session: Poster P1-32: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Angelina Harke-Hosemann - National Institute of Standards and Technology; University of Colorado Boulder

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Thermal Conductance of Individual Layers on TES Legs

Angelina Harke-Hosemann, Joel Ullom, Peter Lowell, Kelsey Morgan, Johannes Hubmayr, Gene Hilton, Shannon M. Duff

National Institute of Standards and Technology; University of Colorado Boulder

Transition Edge Sensor (TES) bolometers are a low-noise detector technology used widely in microwave polarimetry. The TES detection mechanism is a change in sensor resistance due to a temperature increase from incident photons, requiring the sensor be thermally isolated from the substrate. To achieve thermal isolation, TES sensors are often suspended on an micromachined island via long, thin legs. Sensor wiring and insulating layers run along these legs. Understanding the contribution of individual thin film layers to total TES leg thermal conductivity will enable more precise engineering of the thermal conductivity, which is critical for optimizing sensitivity in detectors with saturation power on the order of a picowatt.

We present a study of the thermal conductivity of the wiring, insulating, and substrate leg layers on a TES designed for mm-wavelength observations. We measure thermal conductances of bolometers with varying complementary film stack geometries at the TES critical temperature of 170 mK. We then extract individual layer contributions assuming a model where thermal conductivity depends on film thickness. We find that the thermal conductivity of the wiring layers, a few hundred nanometers of niobium, and corresponding insulating SiN layers contribute more thermal conductance than the underlying SiN substrate. The results of this study will inform future TES bolometer design, where thermal conductivity affects saturation power and detector time constant.

Session: Poster P1-33: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Mario De Lucia - Dublin Institute for Advanced Studies

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TiNx MKIDs from a 3.5M euro UHV state-of-the-art sputter system

Mario De Lucia, Eoin Baldwin, Gerhard Ulbricht, Colm Bracken, Jack Piercy, Oisin Creaner, Tom Ray

Dublin Institute for Advanced Studies

We fabricate our MKIDs in the CRANN cleanroom in Trinity College Dublin using a 3.5M euro five-chamber UHV sputter system name “Trifolium Dublinium”. The tool has two magnetron sputtering chambers, a Pulsed Laser Deposition chamber, a Molecular Beam Epitaxy chamber and one for XPS. The two magnetron sputtering chambers are equipped with multiple gas inlets allowing to inject the gases mixture in proximity of the Silicon wafer, or the injection of gases at the chamber’s wall. The system also allows residual gas analysis in order to investigate the elemental composition of the low-pressure atmosphere inside the system which can affect the purity of the superconducting layer. The Trifolium Dublinium also features a magnetron facing target sputtering setup which is designed to produce films with excellent large-area deposition uniformity.

Substoichiometric Titanium Nitride is still one of the most promising and challenging superconductors of choice for Microwave Kinetic Inductance Detectors. One of the main challenges for TiNx is to do with film homogeneity. It is well known that TiNx is prone to exhibiting microscopic areas of different critical temperatures which eventually contribute to a reduced fabrication yield and moderate energy resolution. We intend to present supporting data for deposition recipes produced in the Trifolium system and preliminary results on MKIDs characterisation as well as preliminary results on further work which involves TiNx multilayer stacks

Session: Poster P1-34: MKIDs and TESs 1

Schedule: Tuesday 20 July 01:05 - Tuesday 20 July 02:00

Submitted by: Emanuele Taralli - Netherlands Institute for Space Research

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X-ray transition edge sensors as backup option for X-IFU on ATHENA space telescope

E. Taralli, M. de Wit, L. Gottardi, K. Nagayoshi, S. Visser, M. L. Ridder, H. Akamatsu, D. Vaccaro, M. P. Bruijn, J. R. Gao, J-W den Helder

Netherlands Institute for Space Research

Large arrays of transition edge sensors (TESs) are the baseline for a number of future space observatories. For instance the X-ray integral field unit (X-IFU) instrument on board of ATHENA space telescope will consist of ~3000 TESs with high energy resolution (below 2 eV up to 7 keV). In this contribution we report on the development of X-ray TES array as a backup technology for X-IFU. The baseline readout technology for this mission is time domain multiplexing (TDM) where the detectors are dc biased. Specifically we report on the characterization of four different Ti/Au TESs with the following dimensions (LxW): 30x15, 30x30, 50x25 and 50x50 µm2, respectively, all of which are coupled with a 2.3 µm thick Au absorber. We have performed our characterization using our standard frequency domain multiplexing readout using only pixels connected to low frequencies where nonlinear effects due to the ac biasing are negligible. Promising energy resolution has been obtained, for instance 1.8 eV and 2.0 eV at 6 keV for the 50x25 and 50x50 µm2 respectively. Uniformity among a uniform kilo-pixel array has been also studied confirming the high quality of our fabrication process. These specific devices are also suitable for newly-started microwave readout development at Netherland Institute for Space Research (SRON) in collaboration with Physikalisch-Technische Bundesanstalt (PTB).

This work is funded by the European Space Agency (ESA) under ESA CTP Contract No. 4000130346/20/NL/BW/os.

Session: Oral O2-1: Cold Readout

Schedule: Tuesday 20 July 22:00 - Tuesday 20 July 22:30

Submitted by: Malcolm Durkin - University of Colorado

Advances in time-division SQUID multiplexing for TES X-ray-microcalorimeter arrays

Malcolm Durkin

National Institute for Standards and Technology

The development of effective multiplexed SQUID readout technologies is motivated by demand for large arrays of transition-edge sensors (TESs). Our time-division multiplexing (TDM) architecture has been used to read out TES bolometer arrays on the several kilopixel scale and numerous 250-pixel scale TES X-ray microcalorimeter arrays, which have been deployed in applications ranging from materials science to nuclear physics.

We continue to develop TDM for the 3,168-pixel X-ray Integral Field Unit (X-IFU) imaging spectrometer on the Athena satellite mission. Recent improvements to TDM bandwidth, crosstalk, and noise performance have allowed a spectrometer employing 8-column by 32-row TDM to achieve a best-fit energy resolution of (2.00 ± 0.01) eV for Mn Kα (5.9 keV) X-rays and (2.16 ± 0.006) eV for Co Kα (6.9 keV) X-rays using TESs developed for X-IFU by NASA GSFC. These results meet X-IFU's energy-resolution requirements. Since this demonstration, we have made significant design improvements. Our latest designs for the SQUID multiplexer use 65% percent of the chip area and dissipate 40% of the power of our previous designs without sacrificing noise performance or bandwidth. We have also demonstrated row addressing using two levels of switches at the X-IFU-specified row activation durations of 160 ns. This two-level scheme will allow 34-row TDM to be operated with only 13 row-address lines. We will present our latest TDM designs and results.

Session: Oral O2-2: Cold Readout

Schedule: Tuesday 20 July 22:30 - Tuesday 20 July 22:45

Submitted by: Alessandro Schillaci - California Institute of Technology

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BICEP Array: 150 GHz detector module development

A. Schillaci, P. A. R. Ade, Z, Ahmed, M. Amiri, D. Barkats, R. Basu Thakur, C. A. Bischoff, J. J. Bock, V. Buza, J. R. Cheshire, J. Connors, J. Cornelison, M. Crumrine, A. J. Cukierman, E. V. Denison, M. Dierickx, L. Duband, M. Eiben, S. Fatigoni, J. P. Filippini, N. Goeckner-Wald, D. Goldfinger, J. A. Grayson, P. Grimes, G. Hall, M. Halpern, S. A. Harrison, S. Henderson, S. R. Hildebrandt, G. C. Hilton, J. Hubmayr, H. Hui, K. D. Irwin, J. H. Kang, K. S. Karkare, S. Kefeli, J. M. Kovac, C. L. Kuo, K. Lau, E. M. Leitch, K. G. Megerian, L. Minutolo, L. Moncelsi, Y. Nakato, T. Namikawa, H. T. Nguyen, R. O'brient, S. Palladino, N. Precup, T. Prouve, C. Pryke, B. Racine, C. D. Reintsema, B. L. Schmitt, A. Soliman, T. St. Germaine, B. Steinbach, R. V. Sudiwala, K. L. Thompson, C. Tucker, A. D. Turner, C. Umiltà, A. G. Vieregg, A. Wandui, A. C. Weber, D. V. Wiebe, J. Willmert, W. L. K. Wu, E. Yang, K. W. Yoon, E. Young, C. Yu, L. Zeng, C. Zhang, S. Zhang

Time Domain Multiplexing (TDM) has been chosen as the detector readout technology for the Cosmic Microwave Background Stage-4 (CMB-S4) experiment based on its proven low-noise performance, predictable costs and overall maturity of the architecture. The heritage for TDM is rooted in mm- and submm-wave experiments dating back 20 years and has since evolved to support a multiplexing factor of 64x in Stage-3 experiments.

The BICEP/Keck Collaboration is currently leading the quest to the highest sensitivity measurements of the polarized CMB with a series of cryogenic telescopes, of which BICEP Array is the latest Stage-3 upgrade with a total of 30k+ detectors. The instrument comprises 4 receivers spanning 30 to 270GHz, with the low-frequency 30/40 GHz one already deployed to the South Pole Station in late 2019. The full complement of receivers is forecast to set the most stringent constraints on the cosmological inflationary model and the overarching "small-aperture telescope" concept is already being used as the reference for further Stage-4 experiment design.

In this talk I will present the development of the BICEP Array 150 GHz detector module and its stringent fabrication requirements, with highlights on the high-density TDM design of the cryogenic circuit boards. The low-impedance wiring required between the detectors and the first-stage SQUID amplifiers is crucial for the proper functioning of these devices. A novel multi-layer FR4 PCB with superconducting traces, capable of reading out up to 648 detectors, is presented along with its validation tests.

I will also describe a ultra-high density TDM detector module we developed for a CMB-S4-like experiment that allows up to 1,920 detectors to be read out.

Session: Oral O2-3: Cold Readout

Schedule: Tuesday 20 July 22:45 - Tuesday 20 July 23:00

Submitted by: Heather McCarrick - Princeton

The Simons Observatory microwave SQUID multiplexing detector module design

Heather McCarrick on behalf of The Simons Observatory Collaboration

Princeton University

I will discuss the design and validation of the Simons Observatory (SO) focal-plane modules, focusing on the development of the cold readout component. Each universal focal-plane module (UFM) contains two 910x multiplexers, which is a multiplexing factor 10x that of other SQUID multiplexers used with deployed transition-edge sensor (TES) bolometer arrays. This allows the densely-packed dichroic TES bolometer arrays to be read out with two pairs of coaxial cables and enables close-packing over large focal planes. The overall architecture of the mid-frequency (90 and 150 GHz) and ultra-high frequency (220 and 270 GHz) modules have been finalized; the low-frequency modules will use a simplified version of the cold multiplexer. To validate the design, we have shown the full operation of the multiplexer with and without a mid-frequency detector array. We present performance metrics including noise and yield. These are discussed in the context of SO science requirements, which are exceeded.

Session: Oral O2-4: Cold Readout

Schedule: Tuesday 20 July 23:00 - Tuesday 20 July 23:15

Submitted by: Hiroki Akamatsu - SRON

Demonstration of 37-pixel frequency domain multiplexing readout of cryogenic X-ray microcalorimeters

H. Akamatsu, D. Vaccaro, L. Gottardi, J. van der Kuur, M. Kiviranta, C.P. de Vries, M.P. Bruijn, R.H. den Hartog, K. Nagayoshi, A.J. van Linden, K. Ravensberg, M.L. Ridder , E. Taralli, S. Visser, M. de Wit, B.D. Jackson, J-R. Gao, R.W.M. Hoogeveen, J-W.A. den Herder

SRON

The multiplexed readout technology of a large number of cryogenic sensors is critical for a space application with limited cooling power available. Frequency domain multiplexing is one of the promising readout technologies. In the FDM scheme, about 40 sensor pixels are simultaneously biased with alternating current (AC bias) at MHz frequencies. For the X-ray Integral Field Unit (X-IFU) instrument on board of the future European X-ray observatory Athena, a multiplexing factor of 34 pixels/channel in a frequency range from 1 to 5 MHz is required.

Using high-quality factor LC filters, low-noise two-stage SQUID amps developed by VTT, and room temperature electronics, we have demonstrated good performance with the FDM readout of Ti/Au TESs calorimeters developed at SRON. By tuning the electrical circuit and TESs impedance, we have successfully demonstrated a 37-pixel simultaneous readout with a summed energy resolution of 2.23 eV at 5.9 keV, which meets the specification of X-IFU. The performance degradation due to multiplexing was estimated to be 0.8-1.0 eV in quadrature, thus adding only little to the basic TES sensor noise. Further performance optimizing of the system is in progress, as well as the demonstration of simultaneous 2 times 40-pixel FDM. In this contribution, we report these progresses, prospect for further scaling up of the FDM readout technology.

This work is partly funded by the European Space Agency (ESA) under ESA CTP Contract No. 4000130346/20/NL/BW/os.

Session: Oral O2-5: Cold Readout

Schedule: Tuesday 20 July 23:25 - Tuesday 20 July 23:40

Submitted by: Tucker Elleflot - Lawrence Berkeley National Laboratory

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Recent Progress on Digital Frequency-Domain Multiplexed Readout of Transition Edge Sensors

Tucker Elleflot, Aritoki Suzuki, Kam Arnold, Stephen Boyd, Chris Bebek, Robin Cantor, Kevin T. Crowley, John Groh, Tijmen de Haan, John Joseph, Adrian T. Lee, Tiffany Liu, Joshua Montgomery, Megan Russell, Qingyang Yu

Digital Frequency-Domain Multiplexing (DfMux) is a technique that uses MHz superconducting resonators and Superconducting Quantum Interference Device (SQUID) arrays to read out sets of Transition Edge Sensors (TES). DfMux has been used by several Cosmic Microwave Background (CMB) experiments, including most recently POLARBEAR-2 and SPT-3G with multiplexing factors of 40 and 68, respectively, and is the baseline readout technology for the planned satellite CMB mission LiteBIRD.

Here we present recent work focused on improving DfMux readout noise, reducing parasitic impedance, and improving TES operation. Readout noise in current DfMux systems is limited by two constraints: parasitic resistance limits the achievable TES responsivity by requiring a TES resistance of $\mathcal{O}(1)$ Ω, and interactions between the SQUID array and other readout elements boost the noise of the ambient temperature amplifiers. We have achieved a substantial reduction in stray impedance by integrating the sensors, resonators, and SQUID array onto a single carrier board. This also drastically simplifies the packaging of the cryogenic components and leads to better control over crosstalk. We have also made significant progress toward the development of an optimized SQUID array, achieving a reduction in dynamic resistance and an increase in transimpedance. We will comment on the impact of this work on current and future CMB and particle detection experiments using DfMux.

Session: Oral O2-6: Cold Readout

Schedule: Tuesday 20 July 23:40 - Tuesday 20 July 23:55

Submitted by: John Mates - National Institute of Standards and Technology

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Advances in microwave SQUID multiplexers for superconducting calorimeters

J. A. B. Mates, D. T. Becker, D. A. Bennett, J. W. Fowler, J. D. Gard, G. C. Hilton, J. Imrek, K. M. Morgan, G. C. O'Neil, N. J. Ortiz, D. S. Swetz, L. R. Vale, A. L. Wessels, D. Yan, J. N. Ullom

National Institute of Standards and Technology

Microwave SQUID multiplexing provides potentially large benefits for superconducting microcalorimeters since most applications are high count rate, demanding short calorimeter pulses and correspondingly fast sampling by the readout system. The speed requirements of many applications are such that non-microwave techniques are only capable of readout at single-digit multiplexing factors (1-10), while the bandwidth available for microwave SQUID multiplexing enables readout of hundreds (100-1000) of fast detectors on a single coax pair.

We present the progress at NIST toward improved microwave SQUID multiplexing for various calorimetric applications, including x-ray and gamma-ray TESs and MMCs. We have developed multiple designs, with input sampling rates ranging from roughly 75 kHz to 2 MHz. These designs have been improved in a number of ways, from optimized and tunable capacitive and inductive couplers to the parasitic-nulling input filters. They have also been ported to microsnout variants and successfully demonstrated in the modular micro-snout format. Finally, we discuss a new double-SQUID design that eliminates the need for an input filter at all.

Session: Oral O2-7: Cold Readout

Schedule: Tuesday 20 July 23:55 - Wednesday 21 July 00:10

Submitted by: Mathias Wegner - Karlsruhe Institute of Technology

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Demonstration of simultaneous MMC readout using a tailored microwave SQUID multiplexer based readout system

Mathias Wegner [1,3], Daniel Richter [1], Constantin Schuster [1,3], Nick Karcher [2], Thomas Wolber [2], Felix Ahrens [1], Christian Enss [1], Oliver Sander [2], Marc Weber [2], Sebastian Kempf [1,3]

[1] Kirchhoff-Institute for Physics, Heidelberg University Im Neuenheimer Feld 227, 69120 Heidelberg, Germany
[2] Institute for Data Processing and Electronics, Karlsruhe Institute of Technology Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany
[3] Institute of Micro- and Nanoelectronic Systems, Karlsruhe Institute of Technology Hertzstraße 16, 76187 Karlsruhe, Germany

Metallic magnetic calorimeters (MMCs) are energy dispersive, low-temperature particle detectors that combine an intrinsically fast signal rise time, an excellent energy resolution, a huge dynamic range, a quantum efficiency close to 100% as well as an almost ideal linear response. For these reasons, metallic magnetic calorimeters are nowadays actively used in a wide field of applications. But although microfabrication technologies are technically mature and meanwhile allow producing large-scale detector arrays with virtually identical detectors, the readout of such arrays remains ambitious using established readout technologies that had been developed for single-channel readout in most cases. As a consequence, multiplexing techniques are currently under active development, whereas microwave-SQUID-multiplexing appears to be most promising.

In this contribution we present our latest achievements in microwave SQUID multiplexing of MMC based detector arrays. More precisely, we discuss the design and the performance of a 400 channel microwave SQUID multiplexer based readout system. This particularly includes the cryogenic multiplexer chip combining the detector signals into a single readout line and the custom-made heterogeneous readout electronics. As a first demonstration, we simultaneously read out 8 detectors with 16 pixels which were irradiated with X-ray photons emitted by an Fe-55 calibration source. We achieved an energy resolution as good as $\Delta E_{\mathrm{FWHM}} < 10$ eV.

Session: Oral O2-8: Cold Readout

Schedule: Wednesday 21 July 00:10 - Wednesday 21 July 00:25

Submitted by: Sebastian Kempf - Institute of Micro- and Nanoelectronic Systems, Karlsruhe Institute of Technology

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Hybrid Microwave SQUID Multiplexer

C. Schuster [1], M. Wegner [1], D. Richter [2], C. Enss [2], S. Kempf [1]

[1] Institute of Micro- and Nanoelectronic Systems, Karlsruhe Institute of Technology, Hertzstraße 16, Geb. 06.41, D-76187 Karlsruhe
[2] Kirchhoff-Institute for Physics, Heidelberg University, Im Neuenheimer Feld 227, D-69120 Heidelberg

Presented by Sebastian Kempf

For the readout of large-scale bolometric and calorimetric cryogenic detector arrays, microwave SQUID multiplexers are actively being developed worldwide. Here, non-hysteretic rf-SQUIDs transduce the detector signals into a change of amplitude or phase of a microwave signals probing the resonance frequency of superconducting resonators. In this way, numerous detectors can be simultaneously read out by capacitively coupling multiple resonators to a common transmission line.

The resonator bandwidth is usually adjusted to the signal bandwidth and sets in combination with the allowed crosstalk level a lower limit to the frequency spacing of resonators. This limit, however, can in practice only be reached if the fabrication accuracy is high and is hence often not reached. Within this context, we present a hybrid microwave SQUID multiplexer combining two frequency-division readout techniques to allow multiplexing a given number of detectors with only a fraction of readout resonators. For this reason, the limitations due to fabrication tolerances become less demanding. We present theoretical insights of our approach based on information theory and discuss benefits and drawbacks using Monte-Carlo simulations. We further discuss the performance of a proof-of-concept prototype device indicating that our technique is very well suited for reading out ultra-large cryogenic arrays based on low-bandwidth detectors.

Session: Oral O2-9: Cold Readout

Schedule: Wednesday 21 July 00:25 - Wednesday 21 July 00:40

Submitted by: William Doriese - NIST

Design of the TDM-readout chips for Athena X-IFU

William Doriese on behalf of the international Athena X-IFU Detection-Chain Working Group

The X-ray Integral Field Unit (X-IFU) is an imaging spectrometer of x-ray (200 eV to 12 keV) transition-edge sensors (TESs) under development for ESA's Athena satellite mission. As presently conceived, X-IFU's 3,168 TES pixels will be read out by a 96-column time-division multiplexer (TDM), with 33 TES pixels and one dark-SQUID row in each logical TDM column. In TDM, each dc-biased TES is coupled to its own first-stage SQUID (SQ1). The SQ1s are turned on and off sequentially such that one TES at a time is read out per column.

In this poster, we discuss the architecture, design layout, and segmentation strategy of the readout components on the 50 mK stage of X-IFU's focal-plane assembly (FPA). The 50 mK FPA will have six silicon side panels, each of which will contain an independent 16-column by 34-row TDM system. The TDM components will be manufactured on smaller silicon chips of linear size 20.60 mm x 15.45 mm. These chips will have a logical arrangement of 4 TDM columns by 34 TDM rows and a physical layout of 1.1 mm x 1.7 mm unit cells in a close-packed 8 x 17 rectangular grid. Each unit cell will include the first-stage-SQUID series array plus a symmetry dummy, a flux-actuated switch plus a symmetry dummy, a parallel pair of TES-shunt resistors, and extra inductance for the TES-bias loop (multi-lobed wire coils that we refer to as Nyquist inductors). Four TDM chips will be cold-indium bump bonded to each side panel.

Session: Oral O2-10: Cold Readout

Schedule: Wednesday 21 July 00:40 - Wednesday 21 July 00:55

Submitted by: Qian Wang - SRON

FDM readout of 60 low-NEP transition-edge sensor bolometers

Q. Wang [1,2], P. Khosropanah [1], J. van der Kuur [1], G. de Lange [1], M. D. Audley [1], A. Aminaei [1], M. L. Ridder [1], S. Ilyas [1], A. J. van der Linden [1], M. P. Bruijn [1], F. van der Tak [1,2], J.R. Gao [1,3]

[1] SRON Netherlands Institute for Space Research, Groningen/Utrecht, The Netherlands
[2] Kapteyn Astronomical Institute, University of Groningen, Groningen, The Netherlands
[3] Optics Group, Department of Imaging Physics, Delft University of Technology, Delft, The Netherlands

FDM readout is one of the most promising techniques to read out TES detectors. In order to raise the TRL, it is essential to have an FDM readout system that is capable of reading out a large TES array with an ultra-low noise equivalent power (NEP) and low saturation power.

Over the past few years, we have continuously improved our FDM system using a demonstrator setup. A thorough study of electrical cross talk was reported.

In this contribution, we use TES bolometers with a NEP as low as 0.3 aW/$\sqrt{\text{Hz}}$ to demonstrate simultaneous readout of 60 TES bolometers using our FDM readout system with a bias frequency range between 1 and 3.5 MHz and with a typical frequency spacing of 32 kHz. The readout chain starts with two-stage SQUID amplifiers and has a noise level of 9.5 pA/$\sqrt{\text{Hz}}$. We compare the measured IV curves and noise spectra of the pixels, which are read out in a single mode and a multiplexing mode. We also map the saturation powers and NEPs in both modes, these are extremely useful for characterizing the uniformity of the detector performance within the array. We have for the first time succeeded in reading out a TES with an NEP of 0.3 aW/$\sqrt{\text{Hz}}$ in a multiplexing mode with our FDM system, which illustrates its capability to read out ultra-sensitive TES bolometer arrays. With further improvement of the harness, the bias frequency of our system can be extended to the range of 1-5 MHz which will allow us to read out more than 100 detectors.

Session: Poster P2-1: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Dale Westbury-Rund - Chase Research Cryogenics Ltd

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A comparison of two different cryogenic platforms for working at 300mK

Dale Westbury-Rund, Paul McInnes, Simon Chase

Chase Research Cryogenics Ltd, Cool Works, Parkwood Rd, Sheffield S3 8AG, UK

There are a growing number of sensors and detectors that operate at temperatures in the region of 300mK. In this paper we compare and contrast two different low-power cryogenics platforms for working in this temperature region.

Low temperature detector applications have widely diverse requirements in terms of operating temperature, temperature stability, cooling power, power consumption, operating time, weight, form factor, ease of use and cost. Optimising the cryogenic platform to the end-user requirements often requires compromises to be made between competing requirements.

Extended (or continuous) operating times impose a particular challenge. We compare and contrast two different systems for working at 300mK in terms of performance and other relevant factors influencing technology selection. We discuss the advantages and the limitations of both systems.

Session: Poster P2-2: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Maxime Malnou - NIST

A kinetic inductance traveling-wave amplifier to read out microwave SQUID multiplexers

M. Malnou, M. R. Vissers, J. D. Wheeler, J. Aumentado, J. Hubmayr, J. N. Ullom and J. Gao

National Institute of Standards and Technology

Kinetic inductance traveling wave amplifiers (KITs) have the potential to lower the input-referred flux noise of microwave SQUID multiplexers. Improving this property is important when the microwave SQUID multiplexer is employed to read out arrays of transition edge sensor microcalorimeters, where a reduction in system noise can enable more efficient use of finite and expensive readout bandwidth. In this talk, we will present a KIT [1], whose use as a pre-amplifier placed before the HEMT reduces the input-referred flux noise of a microwave SQUID multiplexer. Furthermore, the measured 4K performance of the KIT shows it can be a potential replacement to the HEMT amplifier: it dissipates 1000 less power, while retaining a large bandwidth, gain, and high power handling. Furthermore, in principle, even at 4K it can also retain its quantum limited nature. Lower power dissipation at 4K is particularly attractive for future space missions based on large numbers of cryogenic sensors where HEMT dissipation has been an important design driver.

[1] Malnou et al. PRX Quantum 2, 010302 (2021)

Session: Poster P2-3: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Steven Tan - Onnes Technologies BV,

A New Class of Cryo-Nanopositioners

Steven Tan[a, Hans Brouwer[a], Max Kouwenhoven[a], Gert-Jan van Baarle[b], Dian van der Zalm[b], Marc de Voogd[c], Prof. T.H. Oosterkamp[d]

[a] Onnes Technologies BV, The Netherlands
[b] Leiden Spin Imaging BV, The Netherlands
[c] De Voogd Scientific BV, The Netherlands
[d] Leiden Institute of Physics, Leiden University, The Netherlands

A new class of nanopositioner is a game changer in cryo-mechanics.

Cryo-researchers are all too familiar with the unreliability and high heat dissipation of conventional piezo motors in cryogenic environments. These problems are inherent to the stick-slip driving mechanism that is used by conventional piezo motors. At cryogenic temperatures, the performance of the piezo-actuators drops dramatically, and the stick-slip mechanism is not able to generate sufficient force to drive the nanopositioner. This results in unpredictable behavior or malfunction leading to loss of valuable experimentation time. Furthermore, the stick-slip mechanism intrinsically generates a lot of heat.

Onnes Technologies BV, a young startup from Leiden University in The Netherlands, has overcome these problems by developing a novel walking-based drive mechanism from the ground up with a specific focus on high reliability and low heat dissipation at cryogenic conditions. This novel design has some other advantages, such as high driving force, high stiffness, and an integrated scanning function. The cryo-walker mechanism is powered by standard cryo-compatible wiring, eliminating the wiring complexities associated with conventional stick-slip piezo motors. Our linear cryo-walker is equipped with an integrated capacitive position sensor and can be powered by standard cryo-compatible wiring.

Session: Poster P2-4: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Andrea Limonta - Università di Milano - Bicocca

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A new readout electronics for Kinetic Inductance Detectors

A. Limonta [1,2], M. Zannoni [1,2], P. de Bernardis [3,4], M. Bersanelli [5,6], F. Boussaha [7], G. Coppi [1,2], A. Coppolecchia [3,4], C. Franceschet [5,6], M. Gervasi [1,2], E. Manzan [5], S. Masi [3,4], A. Mennella [5,6], F. Nati [1,2] , A. Paiella [3,4], A. Passerini1 [2] and A.Tartari [8,9]

[1] Università di Milano-Bicocca, Milano, Italy
[2] INFN sezione di Milano – Bicocca, 20126 Milano, Italy
[3] Università di Roma – La Sapienza, Roma, Italy
[4] INFN Sezione di Roma, 00185 Roma, Italy
[5] Università degli studi di Milano, Milano, Italy
[6] INFN Sezione di Milano, 20133 Milano, Italy
[7] Observatoire de Paris, 92195 Meudon, France
[8] Università di Pisa, Pisa, Italy
[9] INFN Sezione di Pisa, 56127 Pisa, Italy

We have developed a readout electronics for Kinetic Inductance Detectors (KIDs) based on a commercial IQ transceivers from National Instruments, which uses a Virtex 5 class FPGA. It will be used as a part of the COSMO (COSmic Monopole Observer) project, a ground based cryogenic Martin-Puplett Interferometer. The experiment requires a sampling rate in the range of tens of kHz. In this contribution we show the capabilities of our readout electronics using niobium KIDs developed by Paris observatory and compatible with our 4K cryogenic system. We have demonstrated the capability to detect 25 detectors with a sampling rate of 20 KHz. The readout is based on a finite-state machine where the first two states look for the resonances and generate the comb of tones and the third one performs in free running the acquisition of phase and amplitude of each detector. The advantages of using commercial modules are the ease of procurement and the relative simplicity of writing and modifying the firmware within the LabView environment to meet the needs of the experiment for which the readout is designed.

Session: Poster P2-5: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Le Hong Hoang To - IJCLab

Composition dependence of transport properties in YSi thermometric films.

L. H. H. To, S. Sengupta, F. Pallier, L. Bergé, L. Dumoulin, S. Marnieros, C. Marrache-Kikuchi

Université Paris-Saclay, CNRS, IJCLab, 91405, Orsay, France

We report on the low-temperature study of thick YSi films that are of potential interest for applications for low temperature thermometry.

Thick amorphous Y_xSi_{1-x} films (300 to 400 Å) were synthetized the by e-beam co-deposition from two separate sources under ultrahigh vacuum ($\sim 10^{-8}$ mbar). As shown by AFM, SEM and EDX measurements, these films are very homogeneous both in composition and thickness with a film roughness of about 3 – 4 Å. Furthermore, we have studied the temperature behavior of the resistance as a function of the stoichiometry of the alloy. It shows that Y_xSi_{1-x} can exist under various states: insulating, metallic and superconducting. It exhibits a Metal-Insulator Transition (MIT) which is found to occur for a composition of about x = 12%, and a Superconductor-Metal Transition (SMT) at about x = 25%. We have determined a preliminary phase diagram for the 3D Y_xSi_{1-x} alloy.

On the superconducting side, the $Y_{30}Si_{70}$ film shows a sharp transition at about 1K. This superconducting compound therefore is a promising candidate for Transition-Edge Sensors (TES), with a superconducting critical temperature that can be tuned via the composition. On the insulating side, there are theoretical as well as experimental indications of a low electron-phonon coupling in this alloy, which could be of interest for applications as low temperature thermoresistive sensors.

Session: Poster P2-6: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Andrea Giachero - University and INFN of Milano-Bicocca

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Detector Array Readout with Traveling Wave Amplifiers

A. Giachero [1,2], C. Barone [3,4], M. Borghesi [1,2], G. Carapella [3,4], A.P. Caricato [5,6], I. Carusotto [7,8,9], A. Cian [10,9], D. Di Gioacchino [11], E. Enrico [12,9], P. Falferi [10,13,9], L. Fasolo [14,12], M. Faverzani [1,2], E. Ferri [1,2], G. Filatrella [15,4], C. Gatti [11], D. Giubertoni [10,9], A. Greco [14,12], A. Leo [5,6], C. Ligi [11], G. Maccarrone [11], B. Margesin [10,9], G. Maruccio [5,6], R. Mezzena [16,9], A.G. Monteduro [5,6], A. Nucciotti [1,2], L. Oberto [12,9], S. Pagano [3,4], V. Pierro [17,4], L. Piersanti [11], M. Rajteri [12,18], S. Rizzato [5,6], A. Vinante [13,10,9]

[1] University of Milano Bicocca, Department of Physics, I-20126 Milan, Italy
[2] INFN - Milano Bicocca, I-20126 Milan, Italy
[3] University of Salerno, Department of Physics, I-84084 Fisciano, Salerno, Italy
[4] INFN - Napoli, Salerno group, I-84084 Fisciano, Salerno, Italy
[5] University of Salento, Department of Physics, I-73100 Lecce, Italy
[6] INFN Sezione di Lecce, I-73100 Lecce, Italy
[7] INO-CNR BEC Center, I-38123 Povo, Trento, Italy
[8] University of Trento, Department of Physics, I-38123, Povo, Trento, Italy
[9] INFN - Trento Institute for Fundamental Physics and Applications, I-38123, Povo, Trento, Italy
[10] Fondazione Bruno Kessler, I-38123, Povo, Trento, Italy
[11] INFN - Laboratori Nazionali di Frascati, I-00044, Frascati, Rome, Italy
INFN - Torino, I-101
[12] INRiM - Istituto Nazionale di Ricerca Metrologica, I-10135 Turin, Italy
[13] IFN-CNR, I-38123 Povo, Trento, Italy
[14] Polytechnic University of Turin, I-10129 Turin, Italy
[15] University of Sannio, Department of Science and Technology, I-82100, Benevento
[16] University of Trento, Department of Physics, I-38123, Povo, Trento, Italy
[17] University of Sannio, Department of Engineering, I-82100 Benevento, Italy
[18] INFN - Torino, I-10125 Turin, Italy

Noise at the quantum limit over a large bandwidth is a fundamental requirement for future applications operating at millikelvin temperatures, such as the neutrino mass measurement, the next-generation x-ray observatory, the CMB measurement, the dark matter and axion detection, and the rapid high-fidelity readout of superconducting qubits. The read out sensitivity of arrays of microcalorimeter detectors, resonant axion-detectors, and qubits, is currently limited by the noise temperature and bandwidth of the cryogenic amplifiers. The DARTWARS (Detector Array Readout with Traveling Wave AmplifieRS) project has the goal of developing high-performing innovative traveling wave parametric amplifiers (TWPAs) with a high gain, a high saturation power, and a quantum-limited or nearly quantum-limited noise. The practical development follows two different promising approaches, one based on the Josephson junctions and the other one based on the kinetic inductance of a high-resistivity superconductor. The long-term goal is to demonstrate, for the first time, the readout with different sensors (Transition Edge Sensors, Microwave Kinetic Inductance Detectors, microwave cavities, and qubits) opening the concrete possibility to increase the sensitivity of the next generation of particle physics and quantum computing experiments. In this contribution, we present the aims of the project, the adopted design solutions, and preliminary results from simulations and measurements.

Acknowledgements: This work is supported by the Italian Institute of Nuclear Physics (INFN) within the Technological and Interdisciplinary research commission (CSN5).

Session: Poster P2-7: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Kazuhiro Sakai - NASA/Goddard Space Flight Center

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Developments of Laboratory-Based Transition-Edge Sensor Readout Electronics using Commercial-Off-The-Shelf Modules

K. Sakai, J. S. Adams, S. R. Bandler, S. Beaumont, J. A. Chervenak, F. M Finkbeiner, R. Hummatov, R. L. Kelley, C. A. Kilbourne, A .M. Miniussi, F. S. Porter, S. J. Smith, N. A. Wakeham, E. J. Wassell

NASA/Goddard Space Flight Center

We are developing lab-based readout electronics for Transition-edge sensors (TES) using commercial-off-the-shelf (COTS) modules. At Goddard, we are providing a kilo-pixel array of TES microcalorimeters for the X-Ray Integral Field Unit (X-IFU) of the European X-Ray Observatory Athena, and during the development, various types of prototype arrays need to be characterized. Those array sizes are from a few tens to over three thousands of pixels, and it is crucial to characterize them effectively and promptly. We are therefore developing in- house readout electronics. These electronics are utilizing COTS modules, such as FPGA modules and ADC/DAC modules, as much as possible to increase development speed and keep the cost low. We have developed a readout system for single-pixel as well as time- division multiplexing (TDM) and frequency-division multiplexing (FDM) readout systems. These electronics support Ethernet remote control, and many types of measurements can be automated. Most of the recent decent results at Goddard, such as 1.58 eV@5.9 keV (Miniussi 2018) and 0.25 eV@3 eV (Sakai 2020), were taken with these electronics. The TDM system supports row-settling times down to 160 ns, with sample rates as high as 250 Msps, and we have achieved 2.3 eV@7 keV with 1-column × 32-row multiplexing. We will be using this system to carry our 136-column multiplexing for use in the characterization of X-IFU detectors. The TDM system can be easily adapted to a code-division multiplexing (CDM) readout system, and it can also be reconfigured to support microwave multiplexing (uMux) with an ADC/DAC module replacement and firmware upgrade. In this presentation, we show the technical details of these readout electronics, their performances, new characterization capabilities enabled by these electronics, and our future development plan.

Session: Poster P2-8: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Jean-Marc Martin - GEPI - Observatoire de Paris

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Estimation of the TiNx critical temperature at room temperature

Jean-Marc Martin, Paul Nicaise, Christine Chaumont, Josiane Firminy, Jie Hu, Florent Reix, Thibaut Vacelet, Piercarlo Bonifacio, Faouzi Boussaha

GEPI - Observatoire de Paris

TiN_x is one of the most promising superconductors for many MKID-based applications. Its critical temperature can be tuned through the nitrogen concentration in the material from T_c∼0.4 K, which is almost the pure Ti critical temperature,to the stoichiometric TiN critical temperature of T_c∼4.6 K. In order to reach a T_c∼1 K that is suitable for our ongoingdetector development, we will show in this work that one can estimate the TiN critical temperature through a mechanical stress dependence, which is a signature of nitrogen concentration. This room-temperature estimation is therefore a low-cost and timesaving method to achieve 1K TiN_x layers as it avoids cooling down the detector to measure its T_c.

Session: Poster P2-9: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Ari Helenius - University of Jyväskylä

Finite-element simulations for geometry optimization of an X-ray absorber for the superconductor-ferromagnet thermoelectric detector

A. P. Helenius, Z. Geng, I. J. Maasilta

University of Jyväskylä

We discuss simulations of the optimization of a superconducting absorber geometry, intended primarily for the novel superconductor-ferromagnet thermoelectric detector (SFTED) [1]. The SFTED can be operated without the need of additional bias lines, and it potentially offers a performance rivaling the state of the art transition-edge sensors [2]. In order to achieve the best possible energy resolution, all the components of the detector and measurement chain should be optimized for the application. The main focus in this study is on a series of quasiparticle diffusion simulations for the absorber using finite-element modeling (FEM) with COMSOL Multiphysics® software. We discuss various possible geometries for the absorber-detector contact and their implications on the position dependence, speed, resolution etc., keeping in mind realistic solutions from the fabrication perspective. The main question to be answered is: how much can we improve the energy resolution through geometry of the absorber without making the fabrication process too complex?

[1] Z. Geng, A.P. Helenius, T.T. Heikkilä, and I.J. Maasilta, J. Low. Temp. Phys. 199, 585 (2020)

[2] A.R Miniussi, J.S. Adams, S.R. Bandler, J.A. Chervenak, A.M. Datesman, M.E. Eckart, A.J. Ewin, F.M. Finkbeiner, R.L. Kelley, C.A. Kilbourne, F.S. Porter, J.E. Sadleir, K. Sakai, S.J. Smith, N.A. Wakeham, E.J. Wassell, and W. Yoon , J. Low. Temp. Phys. 193, 337 (2018)

Session: Poster P2-10: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Eoin Baldwin - Dublin Institute for Advanced Studies

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Frequency Domain Multiplexing for MKIDs: Comparing the Xilinx ZCU111 RFSoC with their new 2x2 RFSoC board

Eoin Baldwin, Mario De Lucia, Colm Bracken, Gerhard Ulbricht, Oisín Creaner, Jack Piercy, Tom Ray

Dublin Institute for Advanced Studies

The Xilinx ZCU111 Radio Frequency System on Chip (RFSoC) is a promising solution for reading out large arrays of microwave kinetic inductance detectors (MKIDs). The board boasts eight on-chip 12-bit / 4.096 GSPS analogue-to-digital converters (ADCs) and eight 12-bit / 6.554 GSPS digital-to-analogue converters (DACs), as well as field programmable gate array (FPGA) resources of 930,000 logic cells and 4,272 digital signal processing (DSP) slices. While this is sufficient data converter bandwidth for the readout of 8,000 MKIDs, with a 2 MHz channel-spacing, and a 1 MHz sampling rate (per channel), additional FPGA resources are needed to perform the DSP needed to process this large number of MKIDs. A solution to this problem is the new Xilinx RFSoC 2x2 board. This board costs only one fifth of the ZCU111 while still providing the same logic resources as the ZCU111, albeit with only a quarter of the data converter resources. Thus, using multiple RFSoC 2x2 boards would provide a better balance between FPGA resources and data converters, allowing the full utilization of the RF bandwidth provided by the data converters, while also lowering the cost per pixel value of the readout system, from approximately €2.50 per pixel with the ZCU111, to €1 per pixel. This talk will detail the progress which we have made at DIAS in developing a readout system for MKIDs based on the ZCU111 board, as well as further plans to adapt this readout system to the Xilinx RFSoC 2x2 board.

Session: Poster P2-11: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Louis R. Rodriguez - CEA -Commissariat à l'energie Atomique et energies alternatives

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High sensitivity and high dynamic range polarimetric detectors arrays for space and ground based cameras.

Louis R. Rodriguez

CEA -Commissariat à l'energie Atomique et energies alternatives

Large bolometer all-silicon arrays are manufactured for high sensitivity imaging from space in the sub-millimeter domain. The detector design allows to measure, inside the pixel, the polarization amplitude in two orthogonal directions. Every other pixel in the array has absorbers rotated by 45°, and a set of 2 by 2 contiguous pixels constitute a Stokes Pixel, able to retrieve intensity and linear Stokes parameters. The shape of absorbers is designed to minimize cross-polarization well below 1%. The pixel structure is also tailored to cope with a large dynamic range: four orders of magnitude without saturation. Arrays can be butted on two sides to constitute larger focal planes. Thermometers and shape can be adapted to ground and balloon applications. First performances measurements are reported.

Session: Poster P2-12: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Andrea Giachero - University and INFN of Milano-Bicocca

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High speed microwave rf-SQUID multiplexing read-out for neutrino mass experiment

A. Giachero [1,2], D. T. Becker [3], D. A. Bennett [3], M. Borghesi [1,2] M. De Gerone [4], M. Faverzani [1,2], M. Fedkevych [4], E. Ferri [1,2], J. W. Fowler [3], G. Gallucci [4] , J. D. Gard [3], F. Gatti [5,4], G. C. Hilton [3], J. A. B. Mates [3], A. Nucciotti [1,2], G. Pessina [2] C. D. Reintsema [3], D. R. Schmidt [3], D. S. Swetz [3], J. N. Ullom [3], L. R. Vale [3]

[1] University of Milano-Bicocca, Department of Physics, Milan, Italy
[2] INFN of Milano-Bicocca, Department of Physics, Milan, Italy
[3] National Institute of Standards and Technology, Boulder, CO, USA
[4] INFN - Sezione di Genova, Genova I-16146 - Italy
[5] Dipartimento di Fisica, Università di Genova, Genova I-16146 - Italy

HOLMES is an experiment with the aim to directly measure the neutrino mass. HOLMES will perform a precise calorimetric measurement of the end point of the Electron Capture (EC) decay spectrum of Ho in order to extract information on neutrino mass with a sensitivity below 2 eV. In its final configuration, HOLMES will deploy 1000 detectors of low temperature microcalorimeters with implanted 163Ho nuclei. The baseline sensors for HOLMES are Mo/Cu TESs (Transition Edge Sensors) on SiNx membrane with gold absorbers. Considering the large number of pixels and an event rate of about 300 Hz/pixel a large multiplexing factor and a large bandwidth are fundamental requirements to assure a time resolution of 3 µs, in order to contain the background coming from unresolved pile-ups. To fulfill this requirement, HOLMES will exploit recent advances on microwave multiplexing, techique that offers several gigahertz of readout bandwidth per pair of coaxial cables. In this contribution we present a fully scalable 32-channel readout system optimized to acquire high speed and high resolution TES detectors. This system is based on a ROACH2 board coupled to a remotely programmable semi-commercial up- and down-conversion circuitry, specifically designed for HOLMES. A detailed explanataion of the system together with the obatained performances, in terms of noise, time and energy resolutions, are presented and discussed. A 64-channel version is currently in development and the measure- ment with the first 4×16 sub-array implanted with 163 Ho is expected to start during 2021.

Acknowledgements: This work was supported by the European Research Council (FP7/2007-2013), under Grant Agreement HOLMES no.340321, and by the INFN Astroparticle Physics Commission 2 (CSN2). We also acknowledge the support from the NIST Innovations in Measurement Science program for the TES detector development.

Session: Poster P2-13: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Laurent Dussopt - CEA

High-Impedance Surfaces for Above-IC Integration of Cooled Bolometer Arrays at the 350-µm Wavelength

L. Dussopt [1], A. Aliane [1], H. Kaya [1], V. Goudon [1], L. Rodriguez [2], C. Delisle [2], V. Revéret [2], A. Poglitsch [3], E. Gümüs [4], C. B. Winkelmann [4]

[1] CEA-Leti, Université Grenoble Alpes, F-38000 Grenoble, France
[2] IRFU, CEA, Université Paris-Saclay, F 91191Gif-sur-Yvette, France
[3] Max-Planck-Institut für Extraterrestrische Physik, Garching, Germany
[4] Institut Néel, CNRS-Université Grenoble Alpes, F-38042 Grenoble, France

Silicon bolometers cooled at 50-300 mK have been demonstrated as high-performance detectors for astrophysics. In the frame of the SPICA space observatory project, bolometer detector arrays operating in the 100 um band have been developed. They are integrated on a CMOS read-out integrated circuit (ROIC) for low noise detection and signal multiplexing to the higher temperature stages. This above-IC integration scheme, i.e. fabrication on CMOS ROIC wafers, does not allow thick film processes, which would be normally required to scale the design to longer wavelengths since these detectors use a classical quarter-wavelength optical cavity.

High Impedance Surfaces (HIS) have been demonstrated to enable the above-IC integration of detectors designed for the 350 µm (λ0) band with an optical cavity no thicker than 13 µm, i.e. less than $\lambda_0/25$. HIS are sub-wavelength periodic metallic structures designed to generate a reflection coefficient close to +1. They are manufactured with standard metals and the optical absorption is performed with superconducting thin-film Ti/TiN bi-layers.

Prototypes have been designed, manufactured and characterized at 300 mK (optical absorption at 100-600 µm wavelengths) to demonstrate the feasibility and performance in the targeted wavelength and temperature range. They include both broadband (grids) and resonant (dipoles) absorbers. An accurate EM finite-element model demonstrates a very good agreement with the absorption measurements.

Session: Poster P2-14: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Bruno Buijtendorp - TU Delft

Hydrogenated amorphous silicon carbide: A low-loss deposited dielectric for millimeter-submillimeter astronomy

B.T.Buijtendorp [1], A. Endo [1,2], , K. Karatsu [1,2], D. J. Thoen [1], V. Murugesan [3], K. Kouwenhoven [1,3], S. Hähnle [1,3], J. J. A. Baselmans [1,3], S. Vollebregt [1]

[1] Faculty of Electrical Engineering, Mathematics and Computer Science, Delft University of Technology, Delft, The Netherlands
[2] Kavli Institute of NanoScience, Faculty of Applied Sciences, Delft University of Technology, Delft, The Netherlands
[3] SRON – Netherlands Institute for Space Research, Utrecht, The Netherlands

Millimeter-submillimeter (mm-submm) astronomical instruments will greatly benefit from a low-loss deposited dielectric. For example, integrated superconducting spectrometers use a filterbank of microstrip resonators to disperse the mm-submm astronomical signal of distant galaxies. Unfortunately, part of the radiation from these faint galaxies is absorbed in the filters' dielectric before reaching the detectors.

We introduce hydrogenated amorphous silicon carbide (a-SiC:H) as a novel dielectric that exhibits low loss at mm-submm wavelengths. We fabricated Fabry-Pérot microstrip resonators with NbTiN electrodes and the a-SiC:H dieletric that was deposited by plasma enhanced chemical vapor deposition at 400°C. We measured an internal quality factor (Qi) of 0.8e4–1.4e4, in the frequency range of 250–400 GHz, at 120 mK and at single photon energies. This is the best low-power cryogenic Qi that has been reported to date for microstrip resonators in this frequency range.

In addition to the low mm-submm loss, other beneficial properties of the a-SiC:H films are the low stress (-20 MPa at 200 nm thickness, 60 MPa at 1000 nm thickness), low 7-GHz loss (Qi of 8.5e5 at 60 mK and at -40 dBm internal power), and the absence of blisters. From the measured resonance frequencies we determined the dielectric constant of the a-SiC:H to be 8.5, in the 250–400 GHz frequency range. These properties make a-SiC:H a promising material that enables more efficient mm-submm astronomical instruments.

Session: Poster P2-15: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Jake Connors - NIST-Boulder QSG

Magnetic Field Sensitivity of Microwave SQUID Multiplexers

Jake Connors [1,2], J. Austermann [1], E. V. Denison [1], B. Dober [1,2], G. C. Hilton [1], J. Hubmayr [1], J. A. B. Mates [1], M. Niemack [3], L. Vale [1], E. M. Vavagiakis [3], J. Ullom [1,2]

[1] National Institute of Standards and Technology, 325 Broadway, Boulder, Colorado 80305, USA
[2] Department of Physics, University of Colorado Boulder, Boulder, Colorado 80309,USA
[3] Department of Physics, Cornell University, Ithaca, NY 14853, USA

We present magnetic field sensitivity measurements of NIST microwave SQUID multiplexers designed and fabricated for bolometric applications, μmux100k [1]. These devices are often used in environments with changing external magnetic fields, due to either motion through Earth's field or radiation from other pieces of instrumentation. To reduce the sensitivity to external fields, μmux100k utilizes a second-order gradiometric SQUID with a high degree of symmetry. Previous studies of magnetic shielding on these devices have indicated gradiometric failure on the level of 1-3x10^{-4} or approximately 2-4 μm^2 [2]. Multiple μmux100k devices across varying microwave readout frequencies were mounted as near to coil-center as possible to minimize field gradients. Measurements were made with AC magnetic fields for a range of frequencies from 0.1-10Hz, with the Helmholtz coil, μmux packaging, and bracketing designed to mitigate the AC shielding effects of induced eddy currents. In particular, we have mounted the devices in a thin microwave package made from gold-plated cartridge brass, which simultaneously provides a low microwave-loss environment for the devices while keeping the package thickness much smaller than a skin depth at the AC magnetic field frequencies of interest. We report the effective levels of gradiometric failure for the μmux100k device design, both as a function of AC B-field frequency and readout frequency.

[1] B. Dober et al. "A microwave SQUID multiplexer optimized for bolometric applications". In: Applied Physics Letters 118.6 (2021), p. 062601. doi: 10.1063/5.0033416.
[2] E. Vavagiakis et al. "The Simons Observatory: Magnetic Sensitivity Mea- surements of Microwave SQUID Multiplexers". In: IEEE Transactions on Applied Superconductivity (2021), pp. 1–1. doi: 10 . 1109 / TASC . 2021 . 3069294.

Session: Poster P2-16: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Zachary Huber - Cornell University

Magnetic Shielding Measurements for the Simons Observatory Universal Multiplexing Module

Z. Huber, Y. Li, E. Vavagiakis

Cornell University

The Simons Observatory (SO) consists of a series of telescopes that will study the temperature and polarization of the cosmic microwave background using over 60,000 highly sensitive transition edge sensors (TESs). These multichroic TES detectors are read out by SQUID-based systems with large multiplexing factors. Given that both TESs and SQUIDs are sensitive to magnetic field pickup and that it is hard to predict how they will respond to such fields, it is important to characterize the magnetic response of these systems empirically. This information can then be used to limit systematics by designing packaging for the detectors and readout that screens magnetic fields. Here, we focus on measurements of different magnetic shielding configurations for the universal multiplexing module (UMM) that contains the SQUIDs, associated resonators, and other readout and biasing circuitry. We test the magnetic pickup of the UMM under three different shielding configurations: no shielding (copper packaging), aluminum packaging for the UMM, and a tin-plated shield surrounding the entire dilution refrigerator 100 mK cold stage, and we report on the results.

Session: Poster P2-17: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Yuki Nakashima - Physikalisch-Technische Bundesanstalt (PTB), Braunschweig

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Microwave-SQUID multiplexer for TES array readout: fabrication process development and noise analysis

Yuki Nakashima, Oliver Kieler, Alexander Kirste, Satoshi Kohjiro, and Joern Beyer

Physikalisch-Technische Bundesanstalt (PTB), Braunschweig

We are reporting on the development and fabrication of a microwave SQUID multiplexer (mSQmux) for reading out large-scale arrays of transition-edge sensor (TES) X-ray microcalorimeters. This activity is carried out in collaboration with the National Institute of Advanced Industrial Science and Technology (AIST) of Japan. The first circuit concept and design are based on the mSQmux developed at AIST. Microfabrication of the circuits at PTB uses an adaptation of the standard AIST STP2 process and employs electron beam lithography and chemical mechanical polishing for planarization. A second design variant is being developed that is compatible with the PTB multilayer process for Nb/Al-AlO$_x$/Nb-based Josephson circuits. Here, the ground plane is patterned at the top (second Nb wiring layer) instead of the bottom Nb layer. In addition to fabrication process and design developments, we are analyzing correlations of measured noise in individual mSQmux channels. Here, the goal is to potentially improve the overall mSQmux noise performance by using differential signal inputs and employing cross correlation analysis of the output signals of corresponding channels. The presentation will discuss process and design details as well as first results of experimental evaluation of mSQmux circuits fabricated at PTB.

The research leading to these results has received funding from the European Union's Horizon 2020 Program under the AHEAD project (grant agreement n. 654215).

Session: Poster P2-18: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Danielius Banys - University of Manchester

Millimetre wave kinetic inductance parametric amplification using ridge gap waveguide

Danielius Banys, Mark A. McCulloch, Valerio Giles, Thomas Sweetnam, Lucio Piccirillo

University of Manchester

The last decade has seen a great deal of interest in parametric amplifiers that are based on the non-linear kinetic inductance of superconducting thin films. These kinetic inductance paramps (KIPs) have demonstrated over 20dB of gain, and noise temperatures near to the quantum noise limit. However, these amplifiers have been fabricated using planar transmission lines, which due to increasing lithographic resolution requirements and dielectric losses become increasingly unattractive as the operating frequency increases. Traditionally, waveguide has been the preferred transmission medium at these higher frequencies, but waveguide possesses at best a negligible kinetic inductance fraction, which makes it unsuitable for use in parametric amplifiers. We present a study of a hybrid architecture for high frequency paramps that is based on ridge gap waveguide with metamaterial bed of nails structures. This architecture can be machined and then coated in a superconducting thin film, which allows for a kinetic inductance fraction of more than 70%. The practicality of ridge-gap waveguide KIPs at W-band and above is explored in terms of the microwave and packaging design, fabrication, film coating, and operation. The parametric gain of these KIPs is predicted via circuit analysis of user-defined non-linear inductor components in Keysight's ADS simulation suite. The simulation results are compared to the best available amplifiers at these frequencies.

Session: Poster P2-19: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Joshua Fuhrman - Northwestern University

Modeling a Three-Stage SQUID System in Space with the First Micro-X Sounding Rocket Flight

J. Fuhrman, E. Figueroa-Feliciano, A. J. F. Hubbard, R. E. Manzagol-Harwood, N. Bastidon, D. Jardin, J. Fuhrman, S. Bandler, J. S. Adams, M. E. Eckart, R. L. Kelley, C. A. Kilbourne, T. Okajima, F. S. Porter, S. J. Smith, D. C. Goldfinger, C. D. Reintsema, D. McCammon

The Micro-X sounding rocket is a NASA funded X-ray telescope payload that completed its first flight on July 22, 2018. This event marked the first operation of Transition Edge Sensors (TESs) and their SQUID-based multiplexing readout system in space. Unfortunately, due to a unique ACS pointing failure, the rocket was spinning during its 5 minute observation period and no scientific data was collected. However, data collected from the internal calibration source marked a partial success for the payload and offers a unique opportunity to study the response of TESs and SQUIDs in space. Of particular interest is the magnetic field response of the NIST MUX06a SQUID readout system, caused by tumbling through Earth's magnetic field. We present a model to explain the baseline response of the SQUIDs, which lead to a subset of pixels failing to lock for the full observational period. Future flights of the Micro-X rocket will include the NIST MUX18b SQUID system with dramatically reduced magnetic susceptibility.

Session: Poster P2-20: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Constantin Schuster - Karlsruhe Institute of Technology

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Monte-Carlo Simulation Framework for optimizing Microwave SQUID Multiplexers

Constantin Schuster (KIP), M. Wegner (IMS), S. Ihssen (KIP), C. Enss (KIP), and S. Kempf (IMS)

For the readout of large cryogenic detector arrays, microwave SQUID multiplexers are being developed worldwide. Using non-hysteretic rf-SQUIDs, each multiplexer channel transforms the detector signal into a change of amplitude or phase of a microwave signal probing the resonance frequency of a superconducting resonator. By using a large number of such channels each with a unique resonance frequency, many detectors can be read out using a single transmission line.

Multiplexer optimization is crucial for the overall system performance. However, due to the complexity of the underlying physics as well as the various readout concepts stacked on top of each other, this optimization can't be performed with analytical approaches. For this reason, we have developed a software package enabling multiplexer optimization by means of Monte-Carlo simulations fully reconstructing the operation of a single resonator channel. Nearly all known effects of the operation of a µMUX are included, such as finite resonator response time, screening currents in the rf-SQUID, and dependence of the SQUID response on the probe tone power. Various sources of noise can be included. As a first step towards a full device optimization, we have applied this package to find optimized values for three important device- and readout parameters, i.e. the hysteresis parameter, the probing frequency as well as the readout power. Additionally, we validate the software framework by comparison to experimental results.

Session: Poster P2-21: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Jan van der Kuur - SRON Netherlands Institute for Space Research

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Multiplexing the room temperature electronics of frequency domain multiplexed (FDM) TES readout

J. van der Kuur, A. Nieuwenhuizen, H. Akamatsu, L. Gottardi, D. Vaccaro, M. de Wit, K. Nagayoshi, E. Taralli, K. Ravensberg, M. L. Ridder, M. P. Bruijn, B. Jackson, J-W. den Herder

SRON Netherlands Institute for Space Research

FDM is one of the established readout schemes for cryogenic TES-based detector arrays. FDM relies on biasing the TES with an alternating current (AC) in the 1 - 5 MHz range, where light-weight shielding against electromagnetic disturbances is possible because of the nature of the skin effect, as well as individual pixel optimisation because of the mutliplexed TES bias. Recent improvements in the pixel design of imaging X-ray microcalorimeter arrays optimised for MHz AC bias have shown a performance level which is on par with DC biased detector arrays.

Specifically for space-based operation, power and mass needs of an instrument including electronics limit the achievable pixel count. The current generation of electronics for FDM readout has not yet been fully optimised with respect to mass and power. When we consider the Shannon-Hartley channel capacity of the electronics, and compare it with the actual amount of information throughput, we conclude that significant higher efficiencies must be possible.

In this paper we explore the optimisation options provided by adding an extra layer of multiplexing in the room temperature electronics, so that the available channel capacity is used more efficiently. We will show that efficiency improvements of at least a factor of 2 in amount of electronics are possible for microcalorimeter applications, and that larger factors are possible for bolometer applications, where the information bandwidth is typically much smaller.

Session: Poster P2-22: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Nick Karcher - KIT - IPE

Online Demodulation and Trigger for Fluxramp Modulated MMC Signals

Nick Karcher, Timo Muscheid, Thomas Wolber, Daniel Richter, Christian Enss, Sebastian Kempf, Oliver Sander

KIT - IPE

Due to the non-linear characteristics of SQUIDs, a suitable linearization technique is required for SQUID-based TES or MMC readout. Flux ramp modulation is a common linearization technique and can be applied for the readout of a microwave-SQUID-multiplexer as well as for a novel frequency-division multiplexing scheme with dc-SQUIDs in series.

This modulation scheme requires another stage in the signal processing chain to demodulate the sensor signals before further processing the sensor events. Events in a calorimeter occur as exponentially decaying pulses which shall be detected and recorded. Therefore a trigger engine and storage logic are required. Since data rate can be decreased significantly by demodulation and event detection, it is desirable to calculate both online in fast FPGA logic before passing the data to a general-purpose processor.

In this contribution, we show the implementation of an efficient multichannel flux ramp demodulation computed at runtime on an SoC-FPGA. Furthermore, a concept and implementation for an online trigger and buffer mechanism with its theoretical trigger loss rates depending on buffer size is presented. Both FPGA modules can be operated with up to 500 MHz clock frequency and comprise a time-division multiplex processing of 32 channels. Correct functionality and data reduction capability of the modules are demonstrated in measurements utilizing MMCs with an Iron-55 source for event generation read out by a Microwave-SQUID-Multiplexer.

Session: Poster P2-23: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Sasha Sypkens - Arizona State University

Optimization of Flux and Magnetic Field Sensitive Kinetic Inductance Magnetometer (KIM)

Sasha Sypkens [1], Farzad Faramarzi [1,2], Marco Colangelo [3], Peter Day [4], Karl K. Berggren [3], Philip Mauskopf [1,2]

[1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85281 USA
[2] Department of Physics, Arizona State University, Tempe, AZ 85281 USA
[3] Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, MA 02139, USA
[4] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA

We describe progress on development of arrays of Kinetic Inductance Magnetometers (KIMs), multiplexable magnetic field sensors based on non-linear kinetic inductance in superconducting nanowires. The KIM is a LEKID-type device that is sensitive to magnetic field and flux perturbations due to its loop geometry. It can be optimized for flux measurements by reducing the effective area of the superconducting loop within the circuit and optimizing the dimensions of the nanowire section. We describe characterization of KIMs with different dimensions and superconducting materials. We compare responsivity and magnetic field noise measurements for two versions of the KIM and achieve a measured flux noise comparable to the sensitivity of a typical SQUID using a similar effective loop area. Magnetic field measurements thus far have involved biasing an in-house Helmholtz coil to excite the KIMs. We describe the design of an integrated on-chip inductive coupling loop for future current and field measurements.

Session: Poster P2-24: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Madhujith Madhukuttan - IJC Lab

Optimization of the CUPID detector structure via bolometric measurements in the CROSS cryogenic facility at the Canfranc underground laboratory

Madhujith Madhukuttan on behalf of the CUPID and CROSS collaborations

IJC Lab

CUPID is a proposed next-generation double-beta decay experiment – investigating the nucleus ^{100}Mo – based on dual-readout low-temperature detectors. Each module consists of a large cubic scintillating bolometer based on a $Li_2{}^{100}MoO_4$ crystal (45x45x45 mm and ∼0.28 kg) coupled to a bolometric light detector based on a Ge wafer. Both channels use neutron transmutation doped Ge thermistors (NTDs) for the detection of the phonon pulses. Several modules of these types were operated in the CROSS cryogenic facility at the Canfranc underground laboratory in Spain. The measurements were performed at 14 mK in a pulse-tube dilution refrigerator which uses the same technology as that of CUORE cryostat, which will host the final CUPID detector. Satisfactory energy resolutions down to 7 keV FWHM were achieved at the 2615 keV γ line, in proximity of the double-beta decay region of interest. Full separations of $\gamma(\beta)$ and α events above 2 MeV was achieved through the detection of scintillation light for several modules. Study of different configurations were carried out to compare and optimize performances. In particular, NTDs with different size were used both for the $Li_2{}^{100}MoO_4$ crystal and the Ge wafer. Different light-collection configurations were also investigated, comparing detectors with and without reflective foils and light detectors with circular or square shapes. Light collection efficiencies in different options were estimated, with results ranging from ∼0.2 to ∼0.6 keV/MeV. The achieved results are used for design and optimization of the final configuration of the CUPID elementary modules.

Session: Poster P2-25: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Valerio Gilles - The University of Manchester

Parametric amplification via superconducting contacts in a Ka band niobium pillbox cavity

V. Gilles, D. Banys, M. A. McCulloch, L. Piccirillo, T. Sweetnam

The University of Manchester

Recent superconducting parametric amplifiers are commonly fabricated using planar transmission lines with a non-linear inductance provided by either Josephson junctions or the intrinsic kinetic inductance of the thin film.

However, Banys et al. (2019) reported non-linear behaviour in a niobium pillbox cavity, hypothesising that below T_c, the pair iris-bulk resonator would act as a superconducting contact surface exploiting a Josephson-like non-linearity. This work investigates this effect further by applying Keysight's Advanced Design System to simulate the cavity using an equivalent circuit model that includes a user defined Josephson inductance component. The simulations show that for a resonance centered at ν_0 = 30.64GHz, when two tones (pump and signal) are injected into the cavity, mixing and parametric gain occur. The maximum achievable gain is explored when the resonator is taken to its bifurcation energy. Multiple methods for sweeping the pump and signal tones are outlined. These results are compared to cryogenic measurements where the pump and signal are provided by a vector network analyzer.

These results lead to the development of a new parametric amplifier based on multiple superconducting surface contacts that are formed from a stack of superconducting sheets. This series combination should increase the non-linearity and result in improved gain.

Session: Poster P2-26: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Fabio Columbro - Sapienza, University of Rome

Polarization Modulator Unit Harness design for the mid- and high- frequency telescopes of the LiteBIRD space mission

F. Columbro [1,2], P. de Bernardis [1,2], S. Masi [1,2]

[1] Sapienza University of Rome, Italy
[2] INFN Roma 1, Italy

Polarization modulator units (PMUs) represent a critical and powerful component in CMB polarization experiments to suppress 1/f noise contribution and mitigate systematic uncertainties induced by detector gain drifts. The LiteBIRD mission (expected launch in the late 2020s) will be equipped with 3 PMUs, one for each of the 3 telescopes, and aims at detecting the primordial gravitational waves with a sensitivity of $\delta r \sim 0.001$.

Each PMU is based on a continuous transmissive rotating half-wave plate (HWP) held by a superconducting magnetic bearing in the 5K environment. To achieve and monitor the rotation a number of subsystems is needed: clamp and release system and motor coils for the rotation; optical encoder, capacitive, Hall and temperature sensors to monitor its dynamic stability.

As a result, we need a non-standard harness configuration to connect the room temperature electronics to the cryogenic devices. A careful harness optimization is mandatory for a space mission, both to minimize the power load on the coldest cryogenic stage and to accomplish each subsystem requirement.

In this contribution we present a preliminary design of the harness configuration for the PMUs of the mid- and high-frequency telescopes. It is based both on the spacecraft constraints for the PMUs thermal budget (500µW at 5K) and on the requirements of each component: coils currents up to 10mA, 12 optical fibers for encoder readout, 25MHz drive for temperature and levitation monitor.

Session: Poster P2-27: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Abdelkader Aliane - CEA-LETI

Polarization sensitive silicon bolometers cooled at 50 mK for millimetre wave absorption

A. Aliane [1], E. Hérault [2], L. Dussopt [1], L. Rodriguez [3], O-A. Adami [3], J. Meilhan [1], V. Goudon [1], H. Kaya [1], J-L. Sauvageot [3], C. Delisle [3], G. Lasfargues [1], M. Le Cocq [1], V. Reveret [3], A. Poglitsch [4]

[1] CEA, LETI, MINATEC Campus, F-38054 Grenoble, France
Univ. Grenoble Alpes, F-38000 Grenoble France
[2] IMEP-LAHC, University Savoie Mont Blanc, 73376 Le Bourget du Lac Cedex, France
[3] IRFU, CEA, Université Paris-Saclay, F 91191Gif-sur-Yvette, France
[4] Max-Planck-Institut für Extraterrestrische Physik, Garching, Germany

The study of the temperature and polarization of cosmic microwave background (CMB) in the millimeter and sub-millimeter bands ($\sim$70 µm – 3 mm) is a key to understand the initial conditions of our universe. In this context, we present two bolometer detectors with a pixel size of 500 µm and 1200 µm to address respectively the 0.6 mm and 1.5 mm wavelengths. The pixels are polarization sensitive using Ti/TiN superconducting absorbers with a critical superconducting transition temperature (T_c) in the range of 600-800 mK. They are deposited on suspended doped silicon thermometers operating at low temperature, typically in the range 50 to 100 mK. The optical cavity of these pixels is adapted for an absorption around 120 µm. In order to address the millimeter band, we have used a silicon antireflective layer placed closer to absorbers to shift the absorption band to larger wavelengths. In this paper, we have conducted finite-element (FEM) electromagnetic simulations of the two pixel designs with and without the silicon antireflective layer and compared to measurements to examine the optical performances. The optical absorption measurements of the pixels were performed at room temperature using a terahertz time-domain spectrometer (THz-TDS) and at 300 mK with a fourier transform spectrometer (FTS). Measurements of doped silicon thermometers are presented and an estimation of performances is discussed showing, an expected high responsivity of 10^{11} V/W and a NEP of 10^{-18} W/$\sqrt{\text{Hz}}$.

Session: Poster P2-28: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Robert Gartmann - KIT - IPE

Progress of the ECHo SDR readout hardware for multiplexed MMCs

Robert Gartmann, Nick Karcher, Richard Gebauer, Oliver Krömer, Oliver Sander

KIT - IPE

The Electron-Capture-Holmium (ECHo) experiment seeks to determine an upper limit of the neutrino mass through inverse beta decay in cryogenic metallic magnetic calorimeters. A frequency multiplexing room temperature software-defined radio system is in development to scale up the number of sensors per cable.

A custom FPGA platform provides signal generation and analysis capabilities, while tailored signal conversion and analog conditioning frontend electronics enable the room-temperature-to-cryogenic interface. Ultimately, the system will read out 800 detectors of the cryo stage through a bandwidth of 4 GHz (IEEE C band). To maintain signal fidelity, the C-band is split into five sub-bands using a heterodyne mixing method. Each sub-band is up-, and down-converted by narrowband IQ mixers for individual digital-to-analog and analog-to-digital converters.

In this contribution, a prototype of the heterodyne RF design is presented. It comprises one of the five 800 MHz sub-bands for a target frequency range between 4-12 GHz. We will show results of its characterization in the lab and a measurement with superconducting qubit microwave resonators. The two evaluation methods yield suggestions for improvements to be implemented in the 5-way PCB design. Furthermore, the second version of the A/D converter stage is presented, capable of generating and digitizing up to five complex base bands using 1 GS/s converters, the reference clocks, and a flux-ramp signal.

Session: Poster P2-29: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Kelsey Morgan - University of Colorado Boulder

Readout of thermally multiplexed transition-edge sensors with a microwave SQUID multiplexer

Kelsey M. Morgan, Daniel T. Becker, Joseph W. Fowler, Johnathon D. Gard, Abigail L. Wessels
University of Colorado, Boulder, Boulder, CO 80309, USA
Douglas A. Bennett, John A. B Mates, Gene C. Hilton, Jozsef Imrek, Carl D. Reintsema, Daniel R. Schmidt, Daniel S. Swetz, Joel N. Ullom, Leila R. Vale
National Institute of Standards and Technology, Boulder, CO 80305, USA
Simon R. Bandler, James A. Chervenak, Ruslan Hummatov, Stephen J. Smith
NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

Future x-ray spectroscopic instruments, like the Lynx x-ray microcalorimeter planned for the Lynx satellite mission, will require good energy resolution, high photon collection efficiency, and large numbers of pixels for high resolution imaging. Microcalorimeters, like the transition-edge sensor (TES), provide the necessary energy resolution and efficiency, and they can be multiplexed. Traditionally, this is accomplished by electrically multiplexing the signals from the sensors. Microwave SQUID multiplexing has already been used to demonstrate multiplexing factors of 100 for x-ray TESs. Thermal multiplexing, where multiple x-ray absorbers are attached to a single sensor through varying thermal conductances, can be used to increase the multiplexing factor of imaging arrays. Combining these techniques will enable 100 kilopixel-scale arrays for applications like Lynx.

We demonstrate the readout of 25-pixel thermally multiplexed TES microcalorimeters with a microwave SQUID multiplexer. The microwave resonators have 2 MHz bandwidth, which provides a maximum effective sampling rate of 500 kHz. For a thermally multiplexed TES, both the signal slew rate and trigger jitter affect the ability to identify the individual absorbers and achieve good energy resolution. We explore this parameter space using x-rays of different energies and by varying the sampling rate, showing how future microwave SQUID multiplexers can be optimized to read out large arrays of thermally multiplexed TESs.

Session: Poster P2-30: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Matteo Borghesi - INFN, sezione di Milano Bicocca

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Signal processing and data analysis for the HOLMES experiment

M. Borghesi [1,2], D. Becker [3], D. Bennett [3], M. De Gerone [5], R. Dressler [6], M. Faverzani [1,2], M. Fedkevych [5], E. Ferri [1,2], J. Fowler [3], G. Gallucci [5], J. Gard [3], F. Gatti [4,5], A. Giachero [1,2], G. Hilton [3], J. Mates [3], A. Nucciotti1, [2], L. Origo1 G. Pessina [2], C. Reintsema [3], D. Schmidt [3], D. Swetz [3], J. Ullom [3], L. Vale [3]

[1] Dipartimento di Fisica, Università di Milano-Bicocca, Milano, Italy
[2] Istituto Nazionale di Fisica Nucleare, Sezione di Milano-Bicocca, Milano, Italy
[3] National Institute of Standards and Technology, Boulder, CO, USA
[4] Dipartimento di Fisica, Università di Genova, Genova, Italy
[5] Istituto Nazionale di Fisica Nucleare, Sezione di Genova, Genova, Italy
[6] Paul Scherrer Institut, Villigen, Switzerland

The absolute neutrino mass is still a missing parameter in the modern landscape of particle physics.The HOLMES experiment aims to perform a direct measurement of the neutrino mass with a sensitivity of the order of 2 eV. The neutrino mass will be studied through the calorimetric measurement of the decay products of the weak process decay of 163 Ho. To achieve the target sensitivity, HOLMES will combine the use of 1000 low temperature TES microcalorimeters with the use of a sophisticated software, designed for the signal processing and data analysis.

The analysis of pulses from microcalorimeters designed for X-rays requires great care, because their excellent intrinsic energy resolution can hardly be achieved without an accurate analysis. Even more important, the study of the effects of undesidered systematics, pile-up identification and rejection are crucial aspects to achieve a sensitive measurement of the neutrino mass. In this contribution I will describe the essential parts of our analysis and the algorithms used for pulse processing, which have allowed us to achieve an energy resolution below 5 eV at 6 keV and a time resolution of 1.5 µs, lower than our sampling time of 2 µs. The obtained results match the specification of the HOLMES experiment.

Session: Poster P2-31: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Thomas Sweetnam - University of Manchester

Simulating travelling wave kinetic inductance parametric amplifiers using a commercial circuit simulator

Thomas Sweetnam, Danielius Banys, Valerio Gilles, Mark A. McCulloch, Lucio Piccirillo

University of Manchester

We present Keysight Advanced Design System (ADS) simulations of travelling wave kinetic inductance parametric amplifiers (TKIPs). By using a lumped element model of a transmission line with current dependent nonlinear inductor elements, the kinetic inductance is integrated into the transmission line structure, allowing mixing between signal and pump tones to occur. This approach provides a fast, simple and easily modifiable method to analyse such amplifiers and predict their parametric gain, while also allowing the accompanying RF network to be optimised. Using this architecture, the behaviour of a TKIP in the 3-wave mixing (3WM) and 4-wave mixing (4WM) regimes is studied. The mixing products and gain of the simulated device are compared to those obtained from the coupled mode equations that can also be used to describe the parametric process. In addition, the model is tested by comparing the results to those of parametric amplifiers found in literature.

Session: Poster P2-32: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Amin Aminaei - SRON

Simulation and measurement of out-of-band resonances for the FDM readout of a TES bolometer

Amin Aminaei, Hiroki Akamatsu, Ad Nieuwenhuizen, Alec McCalden, Dick Boersma, Damian Audley, Jan van der Kuu, Marcel Ridder, Pourya Khosropanah, Qian Wang, Saad Ilyas, Gert de Lange, Jian-Rong Gao

SRON

Frequency-division multiplexing (FDM) proved to be a viable readout for transition-edge sensors (TESs). We investigate the occurrence of out-of-band resonances (OBR) which could constrain the bandwidth of the FDM readout of TES bolometers. The study includes LT-SPICE modelling of the entire setup including the cryogenic harness, LC filters, SQUID and room-temperature amplifier. Simulation results show that the long harness (for flight model) could cause multiple reflections that generate repetitive spikes in the spectrum. Also, peaks of the OBR are mainly due to the input capacitance of the SQUID. Implementing a low-pass RC filter (snubber) at the input of the SQUID dampened the OBR so the first peak was shifted to about 20 MHz which is a safe margin for the 4MHz FDM in use in our prototype. Using a spectrum analyzer and a broadband LNA, we also measured the OBR for the prototype FDM readout in the lab up to 500 MHz. The measurement was conducted at temperatures of both 50 mK and 4 K and for various biasing of the DC SQUID. It turns out that OBR are more intense at 50 mK and are caused by the harness impedance mismatch rather than the SQUID. Next, we plan to continue the test with a broadband cryogenic LNA.

Session: Poster P2-33: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Sam Rowe - Cardiff University

The MUSCAT readout electronics backend: design and pre-deployment performance.

S. Rowe, M. Tapia, P. S. Barry, K. S. Karkare, A. Papageorgiou, P. A. R. Ade, T. L. R. Brien, E. Castillo-Domínguez, D. Ferrusca, V. Gómez-Rivera, P. Hargrave, J. L. Hernández-Rebollar, A. Hornsby, D. H. Hughes, J. M. Jáuregui-García, P. Mauskopf, D. Murias, E. Pascale, A. Pérez, M. W. L. Smith, C. Tucker, M. Velázquez, S. Ventura, S. Doyle

Cardiff University

MUSCAT is a new large-format 1.1mm continuum camera scheduled for imminent deployment at the 50m Large Millimeter Telescope Alfonso Serrano, LMT. The focal plane is populated with 1458 feedhorn coupled Aluminium LEKIDs, cooled to 100 mk, and read out with 6 frequency division multiplexed RF readout chains, each with a 500MHz bandwidth. The nominal mux ratio is 250 resonators per chain with an average spacing of 2 MHz between resonators.

In each RF chain, the multiplexed waveform generation/decomposition is performed with the BLAST firmware on a ROACH2 FPGA board with a MUSIC DAC/ADC. The quadrature modulated IF signals are mixed to and from the LEKID readout band on a custom card that houses IQ mixers, a programmable synthesiser, and additional programmable input and output gain control and filtering. Within the cryostat, the RF signals are attenuated prior to reaching the focal plane arrays, and then amplified at 4K.

The digital electronics and programmable components are initialised and managed by the Python Control Program, PCP, which provides tools for the recording and inspection of frequency sweeps and time ordered data, as well as the automated retuning of readout tone frequencies and amplitudes, as required.

The MUSCAT backend software is integrated with the existing LMT Instrument Control System and will listen for instructions from a telescope operator to perform observations, feeding back results of quick look analysis for streamlined operation.

Session: Poster P2-34: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Matthew Herbst - Kirchhoff-Institute for Physics, Heidelberg University

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Thermodynamic Properties of Silver Erbium Alloys for Use in Metallic Magnetic Calorimeters

Matthew Herbst, Neven Kovac, Federica Mantegazzini, Arnulf Barth, Daniel Hengstler, Andreas Reifenberger, Andreas Fleischmann, Christian Enss, Loredana Gastaldo

Kirchhoff-Institute for Physics, Heidelberg University

The use of dilute silver erbium alloys as paramagnetic sensor in metallic magnetic calorimeters (MMCs) has the advantage of the host material not having a nuclear magnetic moment, in contrast to gold erbium alloys. We present numerical calculations of the specific heat and magnetization of Ag:Er between 15 mK and 400 mK at magnetic fields of up to 60 mT and erbium concentrations ranging from 0 to 2000 ppm. Additionally, we present experimental data from an MMC using Ag:Er sensors with an erbium concentration of 440 ppm, from which we obtain the temperature dependence of the sensor magnetization and heat capacity at different static magnetic fields. A comparison of calculation and experiment shows good agreement, allowing us to use the developed numerical calculations for the optimization of future MMCs.

Session: Poster P2-35: Readout, Other Devices, Supporting Science 1

Schedule: Wednesday 21 July 01:05 - Wednesday 21 July 02:30

Submitted by: Si Chen - Astroparticle and Cosmology laboratory

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Warm ASIC for the SQUID/TES Readout of ATHENA's X-IFU Instrument

Si Chen [1], Damien Prêle [1], Manuel Gonzalez [1], Bernard Courty [1], Didier Charrier [2], Jean Mesquida [1], Jean Lesrel [1]

[1] Université de Paris, CNRS, AstroParticule et Cosmologie, F-75013 Paris, France
[2] SUBATECH, IMT Atlantique, CNRS/IN2P3, Université de Nantes, Nantes 44307, France

This paper updates the development of a Warm Front-End Electronics (WFEE) dedicated to cryogenic sensors readout. It belongs to the X-ray Integral Field Unit (X-IFU) instrument of ESA's future space observatory ATHENA. This instrument integrates cryogenic elements such as 3168 Transition Edge Sensors (TES) as detectors, read out by two Superconducting Quantum Interference Device (SQUID) stages, followed by the WFEE and, finally, a digital readout system.

The instrument adopts Time-Division Multiplexing (TDM) as the multiplexing baseline since the preliminary definition phase. In the WFEE, 96 TDM channels will be evenly distributed in 48 Application-Specific Integrated Circuits (ASICs). Each channel includes one Low-Noise Amplifier (LNA) for amplifying voltage signals, 5 configurable current sources for biasing the SQUIDs and TES in the cryogenic stages. Additionally, two channels within the same ASIC share a serial bus "RS485/I2C" for configuring the current sources and housekeeping elements that monitor the temperature, current and voltage of the ASIC.

The ASIC presented in this paper, "AwaXe_v3", is the fifth ASIC developed for the WFEE using a SiGe BiCMOS technology. It is the first prototype of the WFEE integrating two complete TDM channels. The main components as well as some representative measurement results will be introduced in this paper as an update on the WFEE microelectronics.

Session: Oral O3-1: Instruments

Schedule: Wednesday 21 July 22:00 - Wednesday 21 July 22:30

Submitted by: Sae Woo Nam - NIST

Single optical photon detection using low temperature detectors

Sae Woo Nam

NIST

Optical single-photon detectors are increasingly becoming an essential tool for a wide range of applications in physics, chemistry, biology, communications, medicine, and remote sensing. Ideally, a single photon detector generates a measurable signal only when a single photon is absorbed. Furthermore, the ideal detector would have 100% detection efficiency, no false positive (dark counts), and transform-limited timing resolution. There has been tremendous progress in the development of superconducting devices (Superconducting Nanowire Single Photon Detector (SNSPD or nSSPD), superconducting Transition-Edge Sensor (TES), and microwave kinetic inductance detector (MKID)) that nearly achieve this ideal performance. Superconducting detectors offer unprecedented performance not achievable using photomultiplier tubes and semiconducting devices. Yet, there is still tremendous room for improvement to these devices to make them more accessible for even more applications. I will briefly highlight a selection of recent advances in detectors and applications.

Session: Oral O3-2: Instruments

Schedule: Wednesday 21 July 22:30 - Wednesday 21 July 22:45

Submitted by: Nathan Nakamura - National Institute of Standards and Technology

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TOMographic Circuit Analysis Tool (TOMCAT) – An instrument for 3D x-ray imaging of nanoscale integrated circuits using a TES spectrometer

Nathan Nakamura, Bradley K. Alpert, Dan Becker, Douglas A. Bennett, Amber L. Dagel, Gabriella Dalton, W. Bertrand Doriese, Malcom Durkin, Joseph W. Fowler, Edward J. Garboczi, Johnathon D. Gard, James Zachariah Harris, Jozsef Imrek, Edward S. Jimenez, Kurt Larson, Zachary H. Levine, John A. B. Mates, Daniel McArthur, Kelsey M. Morgan, Galen C. O'Neil, Nathan J. Ortiz, Christine G. Pappas, Daniel R. Schmidt, Daniel S. Swetz, Paul Szypryt, Kyle R. Thompson, Joel N. Ullom, Leila Vale, Christopher Walker, Joel C. Weber, and Jason W. Wheeler

Modern integrated circuits (ICs) are comprised of nanoscale features and many fabrication layers, leading to a high level of structural complexity. This makes precise imaging and characterization of subsurface layers challenging, particularly as IC feature sizes continue to decrease. As part of IARPA's Rapid Analysis of Emerging Nanoelectronics (RAVEN) program, we are developing the TOMographic Circuit Analysis Tool (TOMCAT), a tabletop instrument that utilizes a TES spectrometer to enable 3D tomographic imaging of ICs with nanometer-scale features.

TOMCAT achieves this spatial resolution by combining an SEM electron column that generates a highly focused x-ray spot in a metal target with the precise, broadband x-ray detection of a TES spectrometer. The electron beam and target parameters are chosen to maximize imaging speed based on Monte Carlo forward modeling of electron-induced x-ray generation. Then, the excellent energy resolution of the TES spectrometer allows individual fluorescence lines from the target to be identified with high signal-to-noise and used for tomographic imaging. In addition to TOMCAT setup, we will discuss recent tomographic scans of nanoscale layered structures and a path towards 20 nm spatial resolution in 3D imaging of ICs via the use of nanopatterned targets and next-generation TES arrays.

Session: Oral O3-3: Instruments

Schedule: Wednesday 21 July 22:45 - Wednesday 21 July 23:00

Submitted by: Paul Szypryt - National Institute of Standards and Technology

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An update on the TES-based x-ray microcalorimeter project at the NIST EBIT

P. Szypryt, T. J. Burke, Dipti, D. S. La Mantia, A. S. Naing, G. C. O'Neil, Yu. Ralchenko, S. Sanders, R. Silwal, D. S. Swetz, E. Takacs, J. N. Tan, J. N. Ullom, and Y. Yang

National Institute of Standards and Technology

In November 2018, we installed a transition-edge sensor (TES) x-ray spectrometer on the electron beam ion trap (EBIT) at the National Institute of Standards and Technology (NIST). An EBIT is a tool capable of creating almost any charge state of almost any element. The 192-pixel spectrometer was optimized for x-ray energies between 500 eV and 8000 eV and achieves an energy resolution of 3.7 eV to 5.0 eV within this range. The TES spectrometer produced a 30-fold improvement in collection area and 2-fold improvement in resolution over the previously used 4-pixel NTD germanium spectrometer. Since the installation, the TES spectrometer has been utilized for a number of measurement projects including precise determination of F-like M1 line energies, dielectronic resonances in Fe and Ar, intensity ratios of He-like to H-like Fe transitions, and nuclear radius estimation with Na-like Os and Ir. Here, we provide an update on these measurements as well as discuss lessons learned from the operation of this instrument. We also discuss planned upgrades for the system, including an integrated x-ray calibration source. Finally, we deliver an update on the construction of a miniaturized EBIT optimized for the characterization of soft x-ray TES microcalorimeters. Because an EBIT is capable of generating extremely sharp and well-known x-ray transitions, it can be a useful tool for measuring the calibration curve and response function of cryogenic sensors in the soft x-ray regime.

Session: Oral O3-4: Instruments

Schedule: Wednesday 21 July 23:00 - Wednesday 21 July 23:15

Submitted by: Abigail Wessels - University of Colorado Boulder

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A gamma-ray TES spectrometer for the analytical laboratory of a working nuclear facility based on a new, scalable detector architecture

A. L. Wessels, D. T. Becker, J. W. Fowler, J. D. Gard, J. Imrek, J. N. Ullom
University of Colorado
D. A. Bennett, J. W. Fowler, J. A. B. Mates, G. C. O'Neil, N. J. Ortiz, D. R. Schmidt, D. Swetz, L. R. Vale, A. L. Wessels, D. Yan, J. N. Ullom
National Institute of Standards and Technology
M. P. Croce, M. H. Carpenter, K. E. Koehler, D. G. McNeel, K. A. Schreiber, C. M. Smith, S. L. Weidenbenner
Los Alamos National Laboratory

Transition-edge sensor (TES) microcalorimeters are cryogenic energy dispersive detectors that can achieve exceptionally high resolving powers. TESs can be assembled into arrays of hundreds-to-thousands of pixels, extending the photon collecting area of the instrument and increasing photon count rates. At gamma-ray energies, TESs achieve resolutions an order of magnitude better than more commonly used High Purity Germanium detectors, allowing the collection of spectra which can be used to more accurately determine the relative amounts of different isotopes in a sample. As a result, TES gamma-ray spectrometers are emerging as important and unique tools for characterizing materials in the nuclear fuel cycle.

We are developing a gamma-ray spectrometer for the analytical laboratory of Idaho National Laboratory. This instrument will be the first to use a new detector packaging scheme known as the 'micro-snout.' The micro-snout architecture provides a high fraction of active area ($\sim$15%) and incorporates both sensor and readout circuitry in a fully modular fashion to facilitate scaling to large arrays. The instrument contains four 96-pixel micro-snouts and is targeting 100 eV energy resolution at 100 keV.

We report on the design of the instrument and the benefits of the micro-snout architecture, including early measurements of TES array performance in the micro-snout geometry. We also show data regarding the effects of ionizing radiation on microwave SQUID multiplexing chips.

Session: Oral O3-5: Instruments

Schedule: Wednesday 21 July 23:25 - Wednesday 21 July 23:40

Submitted by: Guillaume Stankowiak - CNRS

The QUBIC experiment : Readout Detection Chain

Guillaume Stankowiak

CNRS

The Q & U Bolometric Interferometer for Cosmology (QUBIC) Technical Demonstrator (TD) aiming to shows the feasibility of the combination of interferometry and bolometric detection. The electronic readout system is based on an array of 128 NbSi Transition Edge Sensors cooled at 350mK readout with 128 SQUIDs at 1K controlled and amplified by an Application Specific Integrated Circuit at 40K. This readout design allows a 128:1 Time Domain Multiplexing. We report the design and the performance of the detection chain in this paper.

The technological demonstrator underwent a campaign of test in the lab. Evaluation of the QUBIC bolometers and readout electronics includes the measurement of I-V curves, time constant and the Noise Equivalent Power. Currently the mean Noise Equivalent Power is $\sim 2\times10^{-16}\mathrm{W}/\sqrt{\mathrm{Hz}}$

Session: Oral O3-6: Instruments

Schedule: Wednesday 21 July 23:40 - Wednesday 21 July 23:55

Submitted by: Fabien Defrance - Caltech

Flat low loss silicon optics for millimeter and submillimeter wavelengths

F. Defrance, C. Jung-Kubiak, S. Rahiminejad, J. Gill, T. Macioce, J. Sayers, G. Chattopadhyay, S. Golwala

Caltech

Many applications in mm/submm astronomy and cosmology, such as CMB polarization studies and Sunyaev-Zeldovich effect observations, would benefit from silicon optics with broadband antireflection treatment. Silicon's high refractive index (3.4) and low loss make it an ideal optical material at these wavelengths. We use deep reactive ion etching (DRIE) to etch subwavelength features (posts or holes) at the surface of 100 mm diameter high-resistivity silicon wafers to locally vary silicon's effective refractive index. By creating multiple layers with different homogeneous refractive indices, we obtain a very wide-bandwidth antireflection (AR) treatment, while by varying the index of a silicon wafer radially we can create flat low-loss gradient index (GRIN) lenses. As we cannot use DRIE to etch vertical holes deeper than a few hundreds of um with a high aspect ratio, the GRIN lenses are built by stacking many identical etched GRIN wafers. The desired thickness and focusing power are achieved by stacking enough wafers together.

We present our results to date, which include the design, simulation, fabrication and test of a flat multi-wafer stack assembly GRIN lens (about 3 mm thick and 200 mm focal length), and progress on 4-layer AR structures designed to operate between 100 GHz and 400 GHz with less than 1% reflectance. We will also present the design of our next 6-layer AR design, with electromagnetic simulation results.

Session: Oral O3-7: Instruments

Schedule: Wednesday 21 July 23:55 - Thursday 22 July 00:10

Submitted by: Alessandro Paiella - Dipartimento di Fisica, Università di Roma Sapienza

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MISTRAL and its KIDs

A. Paiella [1,2], E. Barbavara [1], E. S. Battistelli [1,2,3], P. de Bernardis [1,2], A. Coppolecchia [1,2], E. Carretti [4], F. Columbro [1,2], G. D'Alessandro [1,2], M. De Petris [1,2], F. Govoni [3], G. Isopi [1], L. Lamagna [1,2], P. Marongiu [3], S. Masi [1,2], L. Mele [1,2], E. Molinari [3], M. Murgia [3], A. Navarrini [3], A. Orlati [5], G. Pettinari [6], F. Piacentini [1,2], T. Pisanu [3], S. Poppi [3], G. Presta [1,2], F. Radiconi [1]

[1] Dipartimento di Fisica, Sapienza Università di Roma, 00195 Roma, Italy
[2] INFN, sezione Roma1, 00195 Roma, Italy
[3] INAF - Osservatorio Astronomico di Cagliari, Via della Scienza 5, 09047 Selargius (CA), Italy
[4] INAF - Istituto di Radioastronomia, via P. Gobetti 101, 40129 Bologna, Italy
[5] INAF - Istituto di Radioastronomia, Via Fiorentina 3513, 40059 Medicina (BO), Italy
[6] Istituto di fotonica e nanotecnologie, Consiglio Nazionale delle Ricerche IFN-CNR, 00156 Roma, Italy

The MIllimetric Sardinia radio Telescope Receiver based on Array of Lumped elements KIDs, MISTRAL, is a cryogenic W-band (77-103 GHz) LEKID camera which will be integrated at the Gregorian focus of the 64 m aperture Sardinia Radio Telescope (SRT), in Italy, in Spring 2022. This instrument, thanks to its high angular resolution ($\sim$ 13 arcsec) and the wide instantaneous field of view ($\sim$ 4 arcmin), will allow continuum surveys of the mm–wave sky with a variety of scientific targets, spanning from extragalactic astrophysics to solar system science.

In this contribution, we will describe the design of the MISTRAL camera, with a particular focus on the optimization and test of the focal plane: a 400-pixel array of lumped element kinetic inductance detectors.

Session: Oral O3-8: Instruments

Schedule: Thursday 22 July 00:10 - Thursday 22 July 00:25

Submitted by: Joseph Redford - California Institute of Technology

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SuperSpec: On-Chip Spectrometer Design, Characterization, and Performance

J. Redford, P. S. Barry, C. M. Bradford, S. Chapman, J. Glenn, S. Hailey-Dunsheath, R. M. J. Janssen, K. S. Karkare, H. G. LeDuc, P. Mauskopf, R. McGeehan, E. Shirokoff, J. Wheeler, J. Zmuidzinas

California Institute of Technology

SuperSpec is an integrated, on-chip spectrometer for millimeter and sub-millimeter astronomy intended to pave the way for large-scale, multi-beam spectrometer instruments. SuperSpec is demonstrating a three beam, dual-polarization instrument for observing star formation in distant galaxies on the Large Millimeter Telescope (LMT), a 50 m telescope on Volcan Sierra Negra in Mexico.

SuperSpec provides moderate resolution (R $\sim$ 270-290) in the 1 mm atmospheric window (200 - 300 GHz) with a lithographically patterned filterbank on a 3.5 cm x 5.5 cm chip. The filterbank intended for deployment is implemented in niobium, fed by a lensed antenna, and an extremely low-volume ($2.6\mu m^3$) titanium nitride lumped element kinetic inductor detectors (LEKIDs) as the sensor. The small size of the spectrometer and inherent multiplexibility of the kinetic inductance detectors will allow the future use of SuperSpec in larger, multi-pixel/multi-object spectrometers far beyond the three pixel spectrometer being demonstrated soon.

We report the design of the spectrometer, lab characterization, expected performance of the devices on-sky in the upcoming SuperSpec deployment. This involves lab testing of the filterbank spectral response, assessment of the efficiency do the instrument, and characterization of the various noise sources in our titanium nitride LEKIDs.

Session: Oral O3-9: Instruments

Schedule: Thursday 22 July 00:25 - Thursday 22 July 00:40

Submitted by: Ramiro Hernan Rodriguez - Flux Quantum Lab, Collège de France

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Superconducting on-chip spectrometer for mesoscopic quantum systems

Joël Griesmar, Ramiro H. Rodriguez, Vincent Benzoni, Jean-Damien Pillet, Jean-Loup Smirr, Fabien Lafont, Çağlar Girit

Flux Quantum Lab, Collège de France

Presented by Ramiro Hernan Rodriguez

We propose an on-chip absorption spectrometer for mesoscopic systems functioning well into the millimeter wave band which is based on a voltage-biased superconducting quantum interference device, with the absorption spectrum conveniently measured in the spectrometer DC current-voltage characteristic. We demonstrate the capabilities of the spectrometer by coupling it to a microscopic tunable non-linear resonator in the 40-50 GHz range, surpassing the capabilities of conventional spectrometers. The bandwidth of a Josephson junction spectrometer fabricated in aluminum spans 1 GHz up to 180 GHz and it can be extended up to 1.4 THz using niobium. A careful design of the on-chip biasing circuit allows decoupling the spectrometer from environmental noise and parasitic resonances, resulting in an emission linewidth of 100 MHz and an intrinsic sensitivity of 20 kHz, corresponding to a noise equivalent power of 1.3×10^{-18} W/$\sqrt{\text{Hz}}$ at 100 GHz. Additionally, the spectrometer emission power can be tuned in-situ with and applied magnetic field allowing to explore the linear and non-linear spectroscopy regimes.

Session: Oral O3-10: Instruments

Schedule: Thursday 22 July 00:40 - Thursday 22 July 00:55

Submitted by: Erin Healy - Princeton University

The Simons Observatory Ultra-High Frequency Focal-Plane Module: Design and Initial Characterization

Erin Healy

Princeton University

The Simons Observatory (SO) will detect and map the temperature and polarization of the millimeter-wavelength sky from Cerro Toco, Chile with telescopes across multiple angular scales, providing rich data sets for cosmological and astrophysical analysis. The SO focal planes will be tiled with compact hexagonal packages, called Universal Focal-Plane Modules (UFMs), in which the transition-edge sensor (TES) detectors are coupled to 100 mK microwave-multiplexing (uMux) electronics. Three different types of dichroic TES detector arrays – a 30/40 GHz low frequency (LF), a 90/150 GHz mid frequency (MF), and a 220/280 GHz ultra-high frequency (UHF) – will be implemented across the 49 planned UFMs. Each UHF and MF UFM contains 1,756 TESes, which are read out with two 910x multiplexer circuits, two orders of magnitude improvement in multiplexing factor compared to alternative TES readout architectures. To build such a powerful detector device, we have designed a series of densely routed silicon chips, which are packaged together in a controlled RF environment with robust heat-sinking to 100 mK. Following an overview of the module design, I will report on early results from the first SO UHF UFM, including detector yield, optical efficiency measurements, and readout and detector noise levels.

Session: Poster P3-1: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Miguel Daal - UC Santa Barbara

A high resolution fiber-fed spectrometer based on a MKID integrated with a photonic circuit

Miguel Daal, Renan Moreira, Gopi Meena, Jeb Baily, Nick Zobrist, Nemanja Jovanovic, Ben Mazin

UC Santa Barbara

We describe the design and some initial data from our program to develop a high resolution spectrometer where a photonic circuit replaces the optical components that spit the input light, an MKID serves as the photo-detector and resolves the various Bragg orders resulting in significant miniaturization in comparison to conventional spectrometers. Such a spectrometer is an integrated monolithic chip on the order of 10 square centimeters in area and is intended for use at telescopes with adaptive optics systems that allow for inject of light into a single more fiber or those using a lantern to feed the single more fibers.

Session: Poster P3-2: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Zachary Whipps - Simons Collaboration

A High-Capacity Microwave SQUID Multiplexer Chip Screening System

Zachary Whipps

National Institute of Standards and Technology

The microwave SQUID multiplexer (μMUX) is a high channel-count multiplexer that, when coupled to low-temperature detectors such as Transition Edge Sensor (TES) Bolometers, has applications across astronomy and physics. Our primary application is for the Simons Observatory, an array of CMB imagers utilizing over 60,000 μMUX readout channels, located in the Atacama Desert. Due to the high volume of devices that need to be fabricated and screened for the Simons Observatory, it is necessary to have a system that can characterize μMUX chips efficiently so that deployment quality multiplexers can be selected for further integration. Here we present the full hardware design of a high-capacity screening system comprising a 100 millikelvin 2-stage ADR-based cryostat, the microwave packages that allow us to screen up to 28 chips per cooldown, and the microwave readout chain necessary to do these measurements. The measurement system is intended for the 4 to 8 GHz frequency range. We identify each frequency channel and its response from a sweep of S21 versus the applied flux to the device making use of measurement and analysis automation. We also present the full screening process from assembly to cryogenic measurement and discuss our timing and throughput with representative data products from recent measurements.

Session: Poster P3-3: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Matthijs Gouwerok - TU Delft

A Reproduceable Setup to Evaluate Wideband Sub-mm Detectors

Matthijs Gouwerok, Kenichi Karatsu, Akira Endo, David Thoen, Vignesh Murugesan, Jochem Baselmans

TU Delft

A gas-cell based calibration setup is designed to evaluate the wideband frequency response of a submm spectrometer, DESHIMA (DEep Spectroscopic High-redshift MApper), for long integration time tests using low pressure room temperature gas emission spectra. The setup can be used to understand and evaluate possible systematic errors and noise profiles of submm astronomical spectrometers before their telescope campaigns. The setup consists of a low pressure gas at 300K in a high vacuum gas chamber (10^{-3} mbar) in front of a cold 77K N2 background. A mechanical chopper is used for signal modulation to reduce the low-frequency noise profile. We have demonstrated frequency stability of this system for observation times up to $\sim 10^2$ seconds before environmental noises become dominant.

The setup has been able to successfully resolve the emission spectra of nitrous oxide at 30 mbar and methanol at 1 mbar in the frequency range of 330 to 380 GHz with the prototype DESHIMA spectrometer. Furthermore, detailed analysis has shown the importance of anti-reflective (AR) coatings on the main optical interfaces to reduce standing waves in the setup and improve the resolvability of the emission spectra. A submm triangular grating is CNC machined into the main optical interfaces to reduce the standing wave. In this presentation the impact on the system stability will be discussed as an effect of the AR coating and several other improvements on the setup.

Session: Poster P3-4: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Rong Nie - University of Illinois at Urbana-Champaign

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Absorber design and optimization of Kinetic Inductance Detectors for the Terahertz Intensity Mapper

R. Nie [1], R. M. J. Janssen [2,3], C. M. Bradford [2,3], J. P. Filippini [1], S. Hailey-Dunsheath [3], C. M. McKenney [4], J. E. Aguirre [5], J. S. Bracks [5], A. J. Corso [5], J. Fu [1], C. Groppi [6], J. Hoh [6], R. P. Keenan [7], L. -J. Liu [3], I. N. Lowe [7], D. P. Marrone [7], P. Mauskopf [6], J. Redford [3], I. Trumper [8], J. Vieira [1]

[1] University of Illinois at Urbana-Champaign, Urbana, IL 61801 USA
[2] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109 USA
[3] California Institute of Technology, Pasadena, CA 91125 USA
[4] Center for Astrophysics and Space Astronomy, University of Colorado, Boulder, CO 80303 USA
[5] University of Pennsylvania, Philadelphia, PA 19104 USA
[6] Arizona State University, Tempe, AZ 85281 USA
[7] University of Arizona, Tucson, AZ 85721 USA
[8] Intuitive Optical Design Lab LLC, Tucson, AZ 85705 USA

The Terahertz Intensity Mapper (TIM) is a balloon-borne far-infrared (FIR) spectrometer designed to observe the peak of cosmic star formation. With continuous spectral coverage from 240–420 μm, TIM will map the 158 μm line of [CII] over 5 billion years of cosmic history, at redshifts where [CII] is mostly or entirely unobservable from the ground. TIM will make a pioneering demonstration of the line intensity mapping (LIM) technique by observing the spectral and spatial distribution of this FIR line, as well as demonstrating key technologies for future FIR observations. To approach photon-noise-limited performance with high scalability, TIM employs feedhorn-coupled aluminum kinetic inductance detector (KID) arrays operated at 250 mK. These KIDs employ a lithographically patterned aluminum absorber coupled to a waveguide to absorb the incoming radiation. In this work we present an optimized absorber design using a 'chain-link' geometry. Relative to our initial TIM mesh-style demonstration, this approach utilizes reactive aspects in a novel periodic meandered structure to achieve a combination of better absorption efficiency, reduced volume, and improved robustness to fabrication non-idealities. We present EM simulation results indicating 80% absorption efficiency in both polarizations for both long-wavelength (317–420 μm) and short-wavelength (240–317 μm) bands, as well as current test results.

Session: Poster P3-5: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Dan McCammon - U of Wisconsin-Madison

An Interesting Problem

Dan McCammon, C.V. Ambarish, Felix Jaeckel, and Avirup Roy

U of Wisconsin-Madison

Recently, while making some careful investigations of extraneous noise sources in our XQC microcalorimeter sounding rocket instrument, we noticed a very low rate of X-ray-like pulses in the range from 0.05 to 10 keV that occurred only when the temperature was being held constant by slowly ramping down the field in the ADR. It was quickly established that the pulses could be produced by either decreasing or increasing the field, and that the count rate was proportional to dB/dt. Experiments with an external Helmholtz coil showed that it took a change of roughtly 10 μT to produce one count. Harvey Moseley said the only thing he could think of was little superconducting loops on the pixels, where the circulating current would build up as the field changed and dump the stored energy when it reached Ic. But this is a Hitomi-like array with implanted silicon thermometers and doesn't involve any superconductors. We considered inter-granular mercury precipitation in the HgTe absorbers, but the size scales didn't work out. Then it was noticed that the affected pixels correlated almost perfectly with the ones that had small shards of an infrared blocking filter film (20 nm of Al on 45 nm polyimide) irreversibly deposited on them following a turbo-pump failure almost eight years ago. This poster shows by crude calculation that Harvey's model is at least plausible. We can't imagine why this information would ever be useful to anyone, but it was fun to figure it out.

Session: Poster P3-6: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Tejas Guruswamy - Argonne National Laboratory

Beamline TES characterization with monochromatic X-rays up to 80 keV at the Advanced Photon Source

T. Guruswamy [1], D. Yan [3], O. Quaranta [1], L. Gades [1], U. Patel [1], M. Wojcik [2], J. Baldwin [1], A. Miceli [1]

[1] Detectors Group, X-ray Science Division, Advanced Photon Source, Argonne National Laboratory
[2] Optics Group, X-ray Science Division, Advanced Photon Source, Argonne National Laboratory
[3] Quantum Sensors Group, National Institute of Standards and Technology

The 1-BM-C experimental endstation at the Advanced Photon Source is now in use for the testing, characterization, and scientific application of hard X-ray Transition Edge Sensor (TES) arrays. The synchrotron bending magnet source and double-crystal Si monochromator provide a flux of X-ray photons with an energy bandwidth 5 eV. One can tune the crystal position and angle to provide a very bright flux of photons from the Si(111) reflection, with energies between 6 and 30 keV. Higher energies up to 80 keV are available by filtering out the lower energy photons, transmitting primarily the Si(333) reflection. The available flux after filtering is still sufficient to saturate typical TES designs with scattered photons from samples such as thin (100um) metal foils. Our cryostat and readout hardware allows for microwave multiplexed readout of up to 128 TES pixels continuously for several days. We present emission spectra recently collected at the beamline by a number of different Argonne and NIST X-ray TES designs, and discuss details of the experimental techniques used for these high energy measurements.

Session: Poster P3-7: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Camille Gennet - CEA Saclay

Building an optical test facility for very low flux : testing the B-BOP detectors

C. Gennet, X. de la Broise [1], C. Delisle [2], A. Demonti [1], D. Desforge [1], S. Dubos [1], D. Dubreuil [2], J. Martignac [2], X-F. Navick [1], A. Poglitsch [2, 3], V. Revéret [2], L. Rodriguez [2], F. Visticot[2]

[1] Universite Paris-Saclay, DEDIP, CEA-Irfu, Gif-Sur-Yvette , France
[2] Universite Paris-Saclay, DAP-AIM, CEA-Irfu, Gif-Sur-Yvette , France
[3] Max-Planck Institut fur extraterrestrische Physik, Garching bei Munchen, Germany

The B-BOP detectors are a new generation of Herschel/PACS-like bolometers, with the ability to measure light polarization in the far-infrared and to operate at photon noise level over a wide range of flux (from 1pW down to 1 fW). These detectors were developed for B-BOP, a submillimeter polarimeter camera of the SPICA mission.

As these new bolometers are sensitive to very low flux, they need a specific facility to fully characterize them. In order to ensure a very low optical background environment around our detectors, we designed a dedicated setup inside a dilution fridge cryostat that hosts all the tests. A submillimeter light source with adjustable power was also designed and characterized in order to control the flux sent to the detector. This source was designed as an absorbing surface tiled with emitting areas of increasing size to make sure the emitting spectrum wouldn't change with the power. The emission temperature of the source was chosen thanks to Planck's law following a few constraints: having the highest radiance possible and the lowest dispersion of said radiance inside the spectrum. This way, the emitted spectrum will stay as flat as possible whatever power is sent to the detector.

This new facility enables us to make some measurements on bolometers manufactured by CEA-LETI: we measured the I(V) and R(P) of a few test samples and compared them to the simulations made previously.

Session: Poster P3-8: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Matteo De Gerone - INFN Genova

Commissioning of the ion implanter for the HOLMES experiment

M. De Gerone [1], M. Biasotti [1,2], M. Borghesip3,4], G. De Bodin De Galembert [5], M. Faverzani [3,4], M. Fedkevych [1,2], E. Ferri [3,4], G. Gallucci [1], F. Gatti [1,2], A. Giachero [3,4], E. Maugeri [5], A. Nucciotti [3,4], G. Pessina [4] D. Schumann [5]

[1] Istituto Nazionale di Fisica Nucleare, Sezione di Genova, Genova, IT.
[2] Dipartimento di Fisica, Università degli Studi di Genova, Genova, IT.
[3] Dipartimento di Fisica, Università degli Studi di Milano-Bicocca, Milano,IT.
[4] Istituto Nazionale di Fisica Nucleare, Sezione di Milano-Bicocca, Milano, IT.
[5] Paul Scherrer Institute, Villigen, CH.

The HOLMES experiment aims to directly measure the ν mass measuring the ^{163}Ho electron capture decay spectrum developing arrays of TES based micro-calorimeters implanted with $\mathscr{O}$(300 Bq/detector) Ho atoms. The embedding of the source inside detectors is a crucial step of the experiment. Because of ^{163}Ho production process (neutron irradiation of a ^{162}Er sample), Ho source must be separated from a lot of contaminants. A chemical process removes every species other than Ho, but it is not sufficient to remove all background sources: indeed, ^{166m}Ho beta decay can produce fake signal in the region of interest. For this reason a dedicated implantation system has been set up. It is designed to achieve more than 5σ separation @163/166 a.m.u. allowing an efficient Ho ions implantation inside micro-calorimeter absorbers. Its main components are a 50kV sputter-based ion source, a magnetic dipole and a target chamber. A specially designed co-evaporation system been designed in such a way to “grow” the gold micro-calorimeter absorber during the implantation process, increasing the maximum achievable activity which can be implanted. The machine performances have been evaluated by means of calibration runs using ^{63}Cu/^{65}Cu and ^{197}Au beams. A special care has been given to the study of the more effective way to populate source plasma with Ho ions obtained from different Ho compound by sputtering process. In this work, the machine development and commissioning will be described.

Session: Poster P3-9: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Lorenzo Mele - Sapienza University of Rome

COSMO: Measuring CMB spectral distortions from Antarctica

L. Mele [1,2], E. S. Battistelli [1,2], P. de Bernardis [1,2], M. Bersanelli [3,4], F. Columbro [1,2], G. Coppi [5], A. Coppolecchia [1,2], G. D'Alessandro [1,2], M. De Petris [1,2], C. Franceschet [3,4], M. Gervasi [5,6], L. Lamagna [1,2], A. Limonta [5,6], E. Manzan [3], E. Marchitelli [1], S. Masi [1,2], A. Mennella [3,4], F. Nati [5], A. Paiella [1,2], G. Pettinari [7], F. Piacentini [1,2], L. Piccirillo [8], G. Pisano [1], S. Realini [3,4], C. Tucker [9], M. Zannoni [5,6]

[1] Università di Roma - La Sapienza, Roma, Italy
[2] INFN sezione di Roma, 00185 Roma, Italy
[3] Università degli studi di Milano, Milano, Italy
[4] INFN sezione di Milano, 20133 Milano, Italy
[5] Università di Milano - Bicocca, Milano, Italy
[6] INFN sezione di Milano - Bicocca, 20126 Milano, Italy
[7] Istituto di fotonica e nanotecnologie, Consiglio Nazionale delle Ricerche IFN-CNR, 00156 Roma, Italy
[8] Jodrell Bank Centre for Astrophysics, School of Physics and Astronomy, University of Manchester, Manchester, UK
[9] School of Physics and Astronomy, Cardiff University, Queens Buildings, The Parade, Cardiff, CF243AA, UK

COSMO (COSmic Monopole Observer) is a ground based cryogenic differential Fourier transform spectrometer (DFTS), to be operated at Dome-C, Antarctica, which aims at measuring the isotropic y-distortions of the Cosmic Microwave Background (CMB). This is produced by physical processes along the thermal history of the Universe which imply energy exchange with CMB photons. To date, no isotropic spectral distortions have been detected at mm wavelengths, and the upper limit for y is still 10^{-5}, from COBE-FIRAS (1990). COSMO exploits a cryogenic DFTS to measure the absolute brightness of the sky in the 120-280 GHz range. A cryogenic blackbody calibrator is used as a reference. The atmospheric emission with its fluctuations is measured and removed performing fast sky dips while scanning the interferogram. This strategy requires relatively fast detectors, so the two focal planes are equipped with small arrays of multi-mode Kinetic Inductance Detectors ($\tau \sim 50$ µs). The cryogenic roof mirror scan is obtained via a frictionless assembly enabling smooth and fast motion. A room temperature spinning wedge mirror allows for fast sky modulation (2500 rpm). We assess the performance of the instrument via ILC-based simulations, showing that COSMO can extract the isotropic comptonization parameter (assumed y=1.77 10^{-6}) as y=(1.76+/-0.26) 10^{-6}, in the presence of the main Galactic foreground (thermal dust) and of CMB anisotropy, and assuming perfect atmospheric emission removal.

Session: Poster P3-10: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Kevin D. Crowley - Princeton University

Cryomechanical Design and Validation of the Simons Observatory's Ultra-High Frequency Small Aperture Telescope

Kevin D Crowley

Princeton University

The Simons Observatory is an upcoming array of microwave polarimeters that will be located in Cerro Toco, Chile, and will measure the polarization of the Cosmic Microwave Background (CMB). In this work, we present some progress on the integration of the Simons Observatory's Ultra-High Frequency Small Aperture Telescope (SAT-UHF), which will measure the polarization of the CMB on large angular scales at 220 and 270 GHz. We begin by discussing the cryogenic and mechanical design of the instrument, and specifically discuss design choices related to heat straps, multi-layer insulation (MLI), and thermally insulating trusses. We will also discuss the implementation of the microwave multiplexing architecture at the 4 Kelvin, 1 Kelvin, and 100 milliKelvin stages of the instrument. We then present results from the first two cryogenic tests of the instrument, and conclude by offering an outlook for the rest of the integration and deployment.

Session: Poster P3-11: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Farzad Faramarzi - Arizona State University

Design of a mm-Wave Kinetic Inductance (Kineticon) Qubit

Farzad Faramarzi [1,2], Peter Day [3], Sasha Sypkens [2], Kevin Schmidt [1], Ralph Chamberlin [1], Marco Colangelo [4], Karl K. Berggren [4], Philip Mauskopf [1,2]

[1] Department of Physics, Arizona State University, Tempe, AZ 85281 USA
[2] School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85281 USA
[3] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA
[4] Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, MA 02139, USA

Realization of a quantum error correction scheme requires at least thousands of qubits which would be challenging to implement at milli-Kelvin temperatures. A mm-wave superconducting kinetic inductance (Kineticon) qubit that can operate at much higher frequencies than conventional superconducting Josephson junction based qubits may be advantageous in two ways: (1) a higher operating frequency can pave the way for smaller sized devices and relax the dilution refrigerator temperature requirements, and (2) a higher readout frequency may enable a larger number of qubits to be read out. A Kineticon device could also have applications in Quantum sensing such as mm-wave quantum radiometry and two-level system single-photon detection. Here we present the design and classical and quantum electromagnetic simulations of a Kineticon using niobium and niobium nitride thin films.

Session: Poster P3-12: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Lunjun Liu - California Institute of Technology

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Design of Kinetic Inductance Detector Packaging for The Terahertz Intensity Mapper

L. -J. Liu [1], R. M. J. Janssen [1,2], J. Fu [3], J. E. Aguirre [4], J. S. Bracks [4], C. M. Bradford [1,2], A. J. Corso [4], J. P. Filippini [3], C. Groppi [5], S. Hailey-Dunsheath [1,2], J. Hoh [5], R. P. Keenan [6], I. N. Lowe [6], D. P. Marrone [6], P. Mauskopf [5], R. Nie [3], J. Redford [1], I. Trumper [7], J. Vieira [3]

[1] California Institute of Technology, Pasadena, CA 91125 USA
[2] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109 USA
[3] University of Illinois at Urbana-Champaign, Urbana, IL 61801 USA
[4] University of Pennsylvania, Philadelphia, PA 19104 USA
[5] Arizona State University, Tempe, AZ 85281 USA
[6] University of Arizona, Tucson, AZ 85721 USA
[7] Intuitive Optical Design Lab LLC, Tucson, AZ 85705 USA

The Terahertz Intensity Mapper (TIM) is a balloon-borne line intensity mapping experiment designed to unravel the formation and evolution of galaxies around the peak of cosmic star formation. TIM will perform spectroscopic intensity mapping measurements of far-infrared bright lines such as the redshifted [CII] line to trace the star formation history in dust-obscured galaxies. TIM employs two longslit grating spectrometers covering the 240-317 um and 317-420 um wavelength band at R$\sim$250, where each band is equipped with a focal plane unit containing four subarrays of aluminum kinetic inductance detectors (KIDs). Here we report on the packaging design of these arrays which incorporates new features. High absorption efficiency of KIDs in the far-IR requires a small gap between the array chip and the feedhorn. Our approach embraces this aspect and adopts the feedhorn horn block surface as the ground of the readout line microstrip. In this microstrip architecture, we enable a well-controlled 50 micron spacing with an array of spring-loaded pins pushing the chip against a matching array of precision-machined bosses on the bottom of the horn block. The approach offers compliance to thermal deformations on cooldown, while maintaining only front-side circuitry. We also present the design of a compact 3-stage thermal suspension for the large arrays which handles both mechanical and thermal load, as well as the packaging setups which enable the testing of individual quadrant KID arrays.

Session: Poster P3-13: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Nikita Klimovich - Caltech

Development of a Ka band superconducting on-chip Fourier transform spectrometer

Nikita Klimovich [1], Shibo Shu [1], Ritoban Basu Thakur [1], Peter Day [2], Aaron Steiger [3], Eric Shirokoff [3,4], Pete Barry [5], Farzad Faramarzi [6,7], Philip Mauskopf [6,7]

[1] California Institute of Technology, Pasadena, CA 91125, USA
[2] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA
[3] Department of Astronomy and Astrophysics, University of Chicago, 5640 S. Ellis Ave., Chicago, IL 60637, USA
[4] Kavli Institute for Cosmological Physics, University of Chicago, 5640 S. Ellis Ave., Chicago, IL 60637, USA
[5] High-Energy Physics Division, Argonne National Laboratory, 9700 South Cass Ave., Argonne, IL 60439, USA
[6] Department of Physics, Arizona State University, Tempe, AZ 85281 USA
[7] School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85281 USA

We present the development of a Ka band (26.5-40 GHz) superconducting on-chip Fourier transform spectrometer. The design is based on two non-linear kinetic inductance transmission lines, realized by a 50 Ohm stub-shunted NbTiN microstrip line design. Applying DC current in one of the transmission line provides the phase difference for interference, due to the high nonlinearity of the kinetic inductance in this NbTiN transmission lines. 90-degree hybrids are used to add and separate the signals in the two lines. Bandpass filters are used to define the band at each port. The device is based on a 25 nm thick NbTiN film and a 60 nm thick amorphous Si as dielectric with a 200 nm thick NbTiN ground plane. Details of the design and development status will be discussed in this presentation.

Session: Poster P3-14: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Sophie Beaumont - IRAP / UMBC - NASA GSFC

Development of an end-to-end demonstration readout chain for Athena/X-IFU

S. Beaumont [1,2,3], F. Pajot [1], G. Roudil [1], J. S. Adams [2,3], S. R. Bandler [2], B. Bertrand [1], G. Betancourt-Martinez [1], F. Castellani [1], J. A. Chervenak [2], C. Daniel [4], E. V. Denison [5], W. B. Doriese [5], M. Dupieux [1], M. Durkin [5], H. Geoffray [4], G. C. Hilton [5], Y. Parot [1], P. Peille [4], L. Ravera [1], C. D. Reintsema [5], K. Sakai [2,3], R. W. Stevens [5], J. N. Ullom [5], L. R. Vale [5], N. A Wakeham [2,3]

[1] IRAP
[2] NASA Goddard Space Flight Center
[3] University of Maryland Baltimore County
[4] CNES
[5] NIST

The X-IFU (X-ray Integral Field Unit) of the Athena (Advanced Telescope for High-ENergy Astrophysics) telescope, scheduled for launch in the early 2030's, will provide X-ray spectroscopy data with unprecedented spectral and spatial resolution. This will be achieved by a 3 kilo-pixel array of TES (transition-edge sensor) microcalorimeters. The complete detection chain is under development by a large international collaboration. The detector array will be provided by NASA Goddard Space Flight Center, the cold TDM (time domain multiplexing) electronics by NIST, the cold amplifier by VTT, the cold focal-plane assembly by SRON, the warm front-end electronics by APC, and the DRE (digital readout electronics) by IRAP. In order to perform an end-to-end demonstration of the X-IFU readout chain, a 50 mK test bench is being developed at IRAP in collaboration with CNES.

The test bench is based on a two-stage ADR cryostat from Entropy GmbH and a 1024-pixel array from Goddard associated with its cold TDM readout from NIST. The setup will initially be validated using a warm electronic chain from NIST and Goddard. We will describe the complete system being installed in the cryostat and the first results obtained with these electronics. We will also review the status of the integration of the DRE prototype in the demonstration chain and the way forward in the integration and testing of the complete X-IFU readout chain.

Session: Poster P3-15: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Maryam Rahmani - NASA Goddard Space Flight Center

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EXCLAIM Mission Review

Maryam Rahmani on behalf of the EXCLAIM collaboration

NASA Goddard Space Flight Center

Submillimeter and far-IR spectroscopy provides insight into galaxy evolution through atomic and molecular line emission. The EXperiment for Cryogenic Large-Aperture Intensity Mapping (EXCLAIM) is a cryogenic balloon-borne instrument designed to carry out an intensity mapping to measure the cumulative redshifted line emission from carbon monoxide and singly-ionized carbon to probe star formation in windows from the present to z=3.5. During this time, the rate of star formation dropped dramatically, while dark matter continued to cluster. Intensity mapping permits a blind and complete survey of emitting gas through statistics of cumulative brightness fluctuations. EXCLAIM achieves high sensitivity using a cryogenic telescope coupled to six integrated spectrometers with spectral resolving power R = 512 and employing kinetic inductance detectors. Here we summarize the status of the mission.

Session: Poster P3-16: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Sophie Weidenbenner - LANL

Gamma ray spectrometers based on modular arrays of superconducting transition-edge sensors

S. L. Weidenbenner, M. P. Croce, D. T. Becker, D. A. Bennett, M. H. Carpenter, J. D. Gard, K. E. Koehler, J. A. B. Mates, D. G. McNeel, N. J. Ortiz, D. R. Schmidt, K. A. Schreiber, C. M. Smith, D. Swetz, L. Vale, A. L. Wessels, J. N. Ullom

With developments in cryogenics and transition-edge sensor array readout, microcalorimeter gamma spectroscopy technology has advanced sufficiently to enable practical instruments designed for routine measurements in analytical laboratories as well as field testing in nuclear facilities. We will describe the design of two spectrometers optimized for gamma spectroscopy in the 30-300 keV range based on large microwave frequency division multiplexed arrays of superconducting transition edge sensors. SOFIA is a compact, ultra-high-resolution microcalorimeter gamma spectrometer built for field testing in analytical laboratories and nuclear facilities. The instrument design minimizes infrastructure requirements for easy relocation and installation and includes the SLEDGEHAMMER detector array, a 256-pixel transition edge sensor array designed for microwave readout on two circuits. The platform for this spectrometer is a low-power pulse tube cryocooler with an adiabatic demagnetization refrigerator which overcomes many limitations of previous instruments. The second spectrometer was designed for permanent installation in an analytical laboratory and was optimized for high measurement throughput. This instrument was built in a dilution refrigerator cryostat system capable of providing continuous high-power cooling below 100 mK, and includes four Microsnout detector modules, each with approximately 100 superconducting transition-edge sensors and components for multiplexed readout.

Session: Poster P3-17: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Matthew Carpenter - Los Alamos National Laboratory

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Hyperspectral X-ray Imaging: Next-Generation TES Microcalorimeters on the SEM

Matthew H. Carpenter [1], Katrina E. Koehler [1], Christopher J. Fontes [1], Daniel McNeel [1], Katherine Schreiber [1], Chandler M. Smith [1], Gregory L. Wagner [1], Ben Stein [1], Eric Bowes [1], Ping Yang [1], Enrique R. Batista [1], Joel N.Ullom [2], Galen C. O'Neil [2], Carl D. Reintsema [2], Douglas A. Bennett [2], Gene C. Hilton [2], Daniel S. Swetz [2], Daniel R. Schmidt [2], Daniel T. Becker [3], John A. B. Mates [3], Johnathon D. Gard [3], Kelsey M. Morgan [3], Jozsef Imrek [3], Daikang Yan [3], Abigail L. Wessels [3], Joel Weber [3], Mark P. Croce [1]

[1] Los Alamos National Laboratory (LANL), Los Alamos, NM, USA
[2] National Institute of Standards and Technology (NIST), Boulder, CO, USA
[3] University of Colorado, Boulder, CO, USA

The Hyperspectral X-ray Imaging (HXI) project at LANL is a new capability for lab-based X-ray chemical state analysis and mapping. At the core is a new transition edge sensor (TES) spectrometer coupled to a scanning electron microscope (SEM) to achieve high-rate measurements at high spatial and energy resolution. The key improvements in this generation of SEM-based TESs are the detector efficiency provided by a higher number of pixels and high per-pixel count rate, and band-targeted energy resolution from multiple pixel types in simultaneous operation. The 256-pixel TES array has 3 pixel types, each with a different saturation energy that determines its operating range and energy resolution. With targeted resolutions of 2, 3, and 6 eV full-width at half-maximum and saturation energies of 2, 5, and 20 keV, the three pixel types give optimum performance in spectral bands corresponding to light element K, actinide M, and actinide L emission energies respectively. This array is read out with microwave SQUID multiplexing with 1 MHz/channel bandwidth to allow for high per-pixel count rates, with a goal of 200 ct/s/pixel. This combination of active area, energy resolution, and count rate capability is key to enable practical chemical-state determination from X-ray emission spectra in a reasonable time, critical for nuclear safeguards applications that require high throughput. We report here on the design of this HXI detector and progress towards its commissioning.

Session: Poster P3-18: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Jeffrey Filippini - University of Illinois, Urbana-Champaign

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In-flight gain monitoring of SPIDER transition-edge sensor arrays

Jeffrey Filippini (Illinois), Anne Gambrel (U. Chicago), Alexandra Rahlin (Fermilab), Edward Young (Stanford), on behalf the SPIDER collaboration

Experiments deploying large arrays of transition-edge sensors (TESs) often require a robust method to monitor gain variations with minimal loss of observing time. We propose a sensitive and non-intrusive method for monitoring variations in TES responsivity using small square waves applied to the bias line. This method constructs an estimator for TES power response from its electrical response that is exact in the limit of strong electrothermal feedback, and tracks variations in responsivity over fairly wide ranges of TES loading. We discuss the application and validation of this method using flight data from SPIDER, a balloon-borne telescope that observes the polarization of the cosmic microwave background with more than 2000 TESs. This method may prove useful for future balloon- and space-based instruments, where observing time and ground control bandwidth are limited.

Session: Poster P3-19: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Renee Manzagol-Harwood - Northwestern University

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Micro-X Sounding Rocket Payload Re-flight Progress

R. Manzagol-Harwood, E. Figueroa-Feliciano, A. J. F. Hubbard, R. E. Manzagol-Harwood, N. Bastidon, D. Jardin, J. Fuhrman, S. Bandler, J. S. Adams M. E. Eckart, R. L. Kelley, C. A. Kilbourne, T. Okajima, F. S. Poster, S. J. Smith, D. C. Goldfinger, C. D. Reintsema, D. McCammon

The Micro-X project is an X-ray sounding rocket payload that had its first flight on July 22, 2018. The aim of the first flight was to operate a transition edge sensor (TES) X-ray microcalorimeter array in space and take a high-resolution spectrum of the Cassiopeia A supernova remnant. The first flight was considered a partial success; due to a failure in the attitude control system, no time on-target was acquired. A re-flight has been scheduled for 2022. Since the first flight, modifications have been made to the detector systems to improve noise and reduce the susceptibility to magnetic fields. The three-stage SQUID circuit, NIST MUX06a, has been replaced by a two-stage SQUID circuit, NIST MUX18a. The initial laboratory results for the new detector system will be presented.

Session: Poster P3-20: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Matus Rybak - TU Delft / Leiden Observatory

MKID spectroscopic surveys of physical conditions in extreme galaxies

M. Rybak [1,2], T. J. L. C. Bakx [3,4], J. Baselmans [5,1], K. Karatsu [5,1], K. Kohno [6,7], T. Takekoshi [6,8], Y. Tamura [3], A. Taniguchi [3], P. van der Werf [2], A. Endo [1]

[1] Faculty of Electrical Engineering, Mathematics and Computer Science, Delft University of Technology, Delft, the Netherlands
[2] Leiden Observatory, Leiden University, Leiden, the Netherlands
[3] Division of Particle and Astrophysical Science, Graduate School of Science, Nagoya University, Japan
[4] National Astronomical Observatory of Japan, Mitaka, Tokyo, Japan
[5] SRON—Netherlands Institute for Space Research, Utrecht, The Netherlands
[6] Institute of Astronomy, Graduate School of Science, The University of Tokyo, Tokyo, Japan.
[7] Research Center for the Early Universe, Graduate School of Science, The University of Tokyo, Tokyo, Japan
[8] Graduate School of Informatics and Engineering, The University of Electro-Communications, Tokyo, Japan

Half of all the stars were born within just three billion years after the Big Bang, often in massive, dust-enshrouded galaxies. These dusty galaxies represent the most extreme mode of star formation and challenge the theories of how galaxies and stars form and evolve. The answer lies in the physical conditions of their gas, which determine the spectra we observe. Inferring the physical conditions in dusty galaxies is thus critical for our understanding of the cosmic history. However, such studies are very time-consuming, as often only a single emission line can be observed within a given receiver tuning.

This bandwidth bottleneck will soon be broken by the upcoming ultra-wideband MKID spectrometers such as DESHIMA. While primarily aimed at measuring redshifts via the [CII] line from C+, these instruments will also detect spectral lines of, e.g., CO, C, and H_2O, either in blind redshift surveys or targeted observations. Such rapid multi-line spectroscopy will allow us to rapidly determine physical conditions in galaxies in the early Universe.

We present a feasibility study for a pilot survey with the 220-440 GHz DESHIMA 2.0 spectrometer, mounted on the 10-m ASTE telescopes. We identify possible targets, evaluate the potential for detecting various emission/absorption lines, and main science questions to be addressed. Commencing in early 2022, this survey will open door to large-scale studies of the physical conditions of galaxies in the early Universe.

Session: Poster P3-21: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Farzad Faramarzi - Arizona State University

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mm-Wave Superconducting Circuits and Components for Observational Astrophysics

Farzad Faramarzi [1,2], Pete S. Barry [3], Sasha Sypkens [2], Matthew Underhill [2], Philip Mauskopf [1,2], Peter Day [4], Nikita Klimovich [5], Shibo Shu [5], Ritoban Basu Thakur [5], Aaron Steiger [6], Eric Shirokoff [6,7]

[1] Department of Physics, Arizona State University, Tempe, AZ 85281 USA
[2] School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85281 USA
[3] High-Energy Physics Division, Argonne National Laboratory, 9700 South Cass Ave., Argonne, IL 60439, USA
[4] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA
[5] California Institute of Technology, Pasadena, CA 91125, USA
[6] Department of Astronomy and Astrophysics, University of Chicago, 5640 S. Ellis Ave., Chicago, IL 60637, USA
[7] Kavli Institute for Cosmological Physics, University of Chicago, 5640 S. Ellis Ave., Chicago, IL 60637, USA

Non-linear kinetic inductance-based superconducting devices such as Superconducting On-chip Fourier Transform Spectrometers (SOFTS) and Kinetic Inductance Travelling Wave Parametric Amplifiers (KIPA/ KI-TWPA) can provide on-chip solutions for mm-wave astronomy and cosmology. We describe the development of key superconducting circuit elements required for the SOFTS and KIPA operating around 90 GHz (w-band) including a wide-band superconducting quadrature hybrid, a superconducting diplexer and current controllable superconducting transmission line phase shifters. The superconducting devices are designed to be fabricated from Nb, NbN and NbTiN and are coupled to waveguides using radial probes or coupled to broad-band planar antennas.

Session: Poster P3-22: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: John Bailey - University of California at Santa Barbara

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MMOST – The MKID Multi-Object Spectrograph Testbed

John I Bailey III [1], Neelay Fruitwala [1], Christian Schwab [2], Jacob Pember [2], Nicholas Zobrist [1], Miguel Daal [1], Bruce Bumble [3], Gregoire Coiffard [1], Benjamin A. Mazin [1]

[1] University of California at Santa Barbara, USA
[2] Department of Physics and Astronomy Macquarie University Balaclava Road, NSW 2109 North Ryde Australia
[3] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California 91125, USA

High resolution spectrographs (R10,000) are one of the most important tools in astronomy, but their design has been nearly static for decades. A high-resolution spectrograph usually contains a collimator, echelle grating, cross disperser, and finally a camera and science detector. The 2D nature of the resulting light – the echellogram – makes long slits practical but prevents spectral coverage of more than a few orders at the high multiplex factors demanded by modern spectroscopic observations, particularly large surveys, due to issues in packing the full echellogram onto detectors. This means that observations with these instruments are limited to lower (R6,000) resolutions or narrow spectral orders at higher resolution, hindering detailed chemical abundance analysis of targets. MMOST – The MKID Multi-Object Spectrograph Testbed – is a testbed for a radically new type of high-resolution multi-object spectrograph using Microwave Kinetic Inductance Detectors (MKIDs). MKIDs can determine the wavelength of each arriving photon without read noise or dark current and with microsecond temporal resolution. We employ the wavelength discrimination of the MKID detector in place of the optical cross disperser, eliminating it and considerably simplifying the optical design of an echelle spectrograph. The resulting spectrograph is capable of simultaneously measuring the full echellogram of the output of many fibers using a series of parallel linear strips of MKIDs.

Session: Poster P3-23: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Luca Lamagna - Physics Dept. Sapienza University of Rome

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Modeling and characterization of quasi-optical elements in the optical system of LSPE/SWIPE

L. Lamagna, M. Basilicata, A. Occhiuzzi, F. Columbro, A. Coppolecchia, G. D'Alessandro, P. de Bernardis, S. Masi, L. Mele, A. Paiella, G. Pisano

Physics Dept. Sapienza University of Rome

SWIPE is a microwave polarimeter devoted to the search of tiny curl-like features of cosmological origin in the linear polarization pattern of the Cosmic Microwave Background anisotropies.

Given the ambitious observational target, every subsystem in the receiver must be carefully modeled and tested to assess compliance with the tight requirements on calibration and systematics.

We here describe the broadband modeling and characterization of horns, filters and polarizers and absorber coatings for the LSPE/SWIPE receiver, reporting the preliminary results of the spectro-polarimetric characterization of such elements at room temperature through polarization-sensitive Fourier Transform Spectrometry.

Session: Poster P3-24: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Nahuel Ferreiro - Max-Planck Institut für Physik

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Operation of an archaeological lead PbWO crystal to search for neutrinos from astrophysical sources with a Transition Edge Sensor

N. Ferreiro Iachellini, L. Canonica, G. Angloher, D. Fuchs, A. Garai, D. Hauff, M. Mancuso, F. Petricca, F. Pröbst
Max-Planck Institut für Physik, 80805 München, Germany
L. Pattavina
INFN Laboratori Nazionali del Gran Sasso, 67100 Assergi, ItalybPhysik-Department and Excellence Cluster Origins, Technische Universität München, 85747Garching, Germany:
F. Danevich
Institute for Nuclear Research of NASU, 03028 Kyiv, Ukrain

The experimental detection of the CEνNS allows the investigation of neutrinos and neutrino sources with all-flavor sensitivity. Given its large content in neutrons and stability, Pb is a very appealing choice as target element. The presence of the radioisotope ^{210}Pb ($T_{1/2} \sim 22$ yrs) makes natural Pb unsuitable for low-background, low-energy event searches. This limitation can be overcome employing Pb of ar- chaeological origin, where several half-lives of ^{210}Pb have gone by. We present results of a cryogenic measurement of a 15g $PbWO_4$ crystal, grown with archae- ological Pb (older than $\sim$ 2000 yrs) that achieved a sub-keV nuclear recoil detec- tion threshold. A ton-scale experiment employing such material, with a detection threshold for nuclear recoils of just 1 keV would probe the entire Milky Way for SuperNovae, with equal sensitivity for all emitted neutrino flavors, allowing the study of the core of such exceptional events.

Session: Poster P3-25: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Angiola Orlando - SRON Netherlands Institute for Space Research

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Optical characterisation of ultra-sensitive far-infrared TES bolometer arrays with frequency-domain multiplexed readout

Angiola Orlando [a], Michael D. Audley [a], Gert de Lange [a], Marcel L. Ridder [b]

[a] SRON Netherlands Institute for Space Research, Groningen, The Netherlands
[b] SRON Netherlands Institute for Space Research, Utrecht, The Netherlands

We are performing optical characterisation of prototype SPICA/SAFARI Transition-Edge Sensor (TES) bolometer arrays with frequency-domain multiplexed readout, with the goal of improving the technology readiness level in preparation for future space-borne, far-infrared astrophysics missions. Each array consists of Ti/Au TES bolometers with thin-film Ta absorbers, targeting TES transition temperatures of $\sim$ 100mK and per-pixel dark Noise Equivalent Power (NEP) of $\sim 10^{-19}$ W/$\sqrt{\text{Hz}}$.

We will describe our optical test facility, test configuration and results. We will discuss these in terms of requirements for future missions.

Session: Poster P3-26: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Riccardo Gualtieri - Argonne National Laboratory

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Optical leakage mitigation in ortho-mode transducer detectors formicrowave applications

R. Gualtieri [1], P. Barry [1], T. Cecil [1], A. Bender [1,2], C. Chang [1,2], J. Hood [2,3], M. Lisovenko[1], V. Yefremenko [1]

[1] HEP, Argonne National Laboratory, Lemont, IL 60439, USA
[2] KICP, Department of Astronomy and Astrophysics, University of Chicago, Eckhardt Research Center 5640 South Ellis Avenue Chicago, IL, 60637
[3] Department of Astronomy and Astrophysics, Vanderbilt University, 6301 Stevenson Center, Nashville, Tennessee 37240

Future CMB experiments will require exquisite control of systematics due to the instrument design and scan strategy. One of the main effects on the polarized data is a temperature to polarization leakage. A potential source for this leakage in detector systems using ortho-mode transducers (OMT) coupling is optical leakage occurring in the gap between the optical waveguide and the detector wafer. We are developing new OMT structures with the goal of reducing leakage at the horn-to-detector-wafer interface. The pixel to pixel optical leakage due to the gap between the coupling waveguide and the backshort is reduced by means of a protrusion that passes through the OMT membrane and connects the waveguide sections on each side of the wafer. High frequency electromagnetic simulations indicate that these protrusions can reduce optical leakage in the gap by $\sim$ 80% percent for a $\sim$ 50% filling factor, with respect to an ordinary OMT coupling without protrusion, using designs that are compatible with current fabrication processes. We describe the design of the new coupling structure including the impact of varying two key parameters: wafer to optical coupling gap and protrusion fill factor. Prototype devices have been designed that will characterize the performance of the new design using a relative measurement with varying filling factors. We describe the design of the detector andtest module and present initial measurement results.

Session: Poster P3-27: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: David Arrazola - University of Alcalá

Optomechanical design for optical performance characterization of kinetic inductance detectors in the W-Band

D. Arrazola [1], M. C. de Ory [2,3], B. Aja [4], L. de la Fuente [4], J. P. Pascual [4], E. Artal [4], D. Granados [3], A. Gómez [2]

[1] Dpt. Physics and Mathematics, University of Alcalá, 28805 Alcalá de Henares, Spain
[2] Centro de Astrobiología (CSIC-INTA), Ctra. Torrejón-Ajalvir km.4, 28850, Torrejón de Ardoz, Madrid, Spain
[3] IMDEA-Nanociencia, Cantoblanco, E-28049 Madrid, Spain
[4] Dpt. Ing. Comunicaciones, University of Cantabria, 39005 Santander, Spain

Kinetic Inductance Detectors (KIDs) are a new generation of millimeter wavelength detectors that achieve high sensitivity and are compatible with frequency-domain multiplexing. These properties allow KIDs to be an alternative to classical bolometers for future CMB experiments. With the aim of characterizing KIDs, identifying pixel sensitivities, potential noise sources and evaluating imaging response, a prototype optimized for the W-band (75 – 110 GHz) of opto-mechanical design is presented.

The millimetre band signal is generated using a microwave signal generator followed by a multiplier, and it is focused on the system using a horn antenna specially designed for the W-band. Then, a compact collimator optical design, composed of two lenses with a pupil stop at room temperature, has been developed using geometrical and physical optics. The collimator optics requirements accomplish the fraunhofer distance with the horn antenna and the spillover efficiency. Due to the cryostat window aperture of 50 mm, a lens in the room temperature space is included to reduce the percentage of beam intercepted by the aperture. Beam propagation analyses let us to evaluate energy losses.

Collector optics in the coldest stage of the cryostat work with an f/0.9 in the image space. From the optical point of view, the main requirements related with the detector are coupling efficiency and telecentricity. To avoid spurious radiation that can degrade the detector performance a field stop is incorporated, which implies to define three lenses, being one of them a by-hyperbolic lens. PSF and Encircled Energy are merit functions used in the optimization step. The requirement of percentage of energy enclosed in one pixel is around 50%.

The complete opto-mechanical design will be analysed and presented. Based on the simulations results, all the lenses are fabricated in HDPE and installed in the cryostat. In addition, a set of IR and low pass filters are installed at all the intermediate temperature stages to avoid background radiation. Preliminary results on the room temperature performance and alignment tolerances will be presented.

Session: Poster P3-28: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Jie Hu - GEPI, Paris Observatory; APC, Universite de Paris

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Preliminary Characterization of the first 2000-pixel array for SPIAKID

Jie Hu, Samir Beldi, Christine Chaumont, Faouzi Boussaha, Paul Nicaise, Jean-Marc Martin, Florent Reix, Shan Mignot, Thibaut Vacelet, Michel Piat, Elisabetta Caffau and Piercarlo Bonifacio

GEPI, Paris Observatory; APC, Universite de Paris

SPIAKIDs aims to develop a kinetic inductance detector (KID) based near-infrared and optical camera with up to 80000 pixels, divided into 4 arrays of up 20000 pixels each. They are designed to resonate over 4-8 GHz band. The used material for the meander is Titanium Nitride. We will present the preliminary measurement results of one of the feedlines with 2000 pixels in one of the 20000-pixel arrays in an adiabatic demagnetization refrigerator (ADR), including the array yield, the quality factor, the noise spectrum and the optical response at different wavelengths.

Session: Poster P3-29: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Daniel McNeel - Los Alamos National Laboratory

Progress toward absolute calibration of x-ray transition edge sensors (TESs)

D. G. McNeel, M. H. Carpenter, B. Stein, K. E. Koehler, C. J. Fontes, G. L. Wagner, Z. K. Baker, M. L. Handley, M. W. Rabin, P. Yang, E. R. Batista, K. A. Schreiber, E. G. Bowes, M. P. Croce
Los Alamos National Laboratory, Los Alamos, NM 87545, USA
J. N. Ullom, G. C. O'Neil, C. D. Reintsema, D. A. Bennett, G. C. Hilton, D. Swetz, D. R. Schmidt, J. A. B. Mates
National Institute of Standards and Technology Boulder, Boulder, CO 80305, USA
D. T. Becker, J. C. Weber, J. D. Gard, K. M. Morgan, J. Imrek, D. Yan, A. L. Wessels
University of Colorado Boulder, Boulder, CO 80309, USA

Absolute calibration of TES detector arrays is necessary for their application to the study of chemical shifts in the x-ray spectrum. Because of the non-linear response, sub-eV shifts in the energy spectrum must be referenced to the positions of un-shifted peaks. So far, such TES systems have also shown a time dependent drift large enough to obscure eV scale chemical shifts. Therefore, we have developed a motorized sample switcher to allow switching between calibration samples and samples under study on a timescale faster than the relevant drift. This will allow us to derive the relative peak shift in cases where the absolute energy of the peak is not known to high precision. By alternating between the sample and a standard of the same element, we can eliminate the effect of time-dependent drift of the detectors and measure chemical shifts of less than 0.2 eV. This real-time calibration method will rely on NIST's DASTARD data acquisition system to record the state of the sample switcher for sample and reference measurements. Analysis of the pulses will be performed in real time with several filtering options, and will be used for drift correction of the reference sample and the sample of interest. We will present results of these data analysis techniques and the sample switching method.

Session: Poster P3-30: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Alessandro Coppolecchia - University of Rome SAPIENZA

Pulse tube cooler with >100 m flexible lines optimized for operation of cryogenic detector arrays at large radiotelescopes

A. Coppolecchia [1,2], E. S. Battistelli [1,2], S. Masi [1,2], P. Marongiu [3], E. Barbavara [1], P. de Bernardis [1,2], E. Carretti [4], F. Columbro [1,2], G. D'Alessandro [1,2], M. De Petris [1,2], F. Govoni [3], G. Isopi [1], L. Lamagna [1,2], L. Mele [1,2], E. Molinari [3], M. Murgia [3], A. Navarrini [3], A. Orlati [5], A. Paiella [1,2], G. Pettinari [6], F. Piacentini [1,2], T. Pisanu [3], S. Poppi [3], G. Presta [1,2], F. Radiconi [1]

[1] Dipartimento di Fisica, Sapienza Università di Roma, P.le A. Moro 2, 00185 Roma, Italy
[2] Istituto Nazionale di Fisica Nucleare, Sezione di Roma, P.le A. Moro 2, 00185 Roma, Italy
[3] INAF - Osservatorio Astronomico di Cagliari, Via della Scienza 5, 09047 Selargius (CA), Italy
[4] INAF - Istituto di Radioastronomia, via P. Gobetti 101, 40129 Bologna, Italy
[5] INAF - Istituto di Radioastronomia, Via Fiorentina 3513, 40059 Medicina (BO), Italy
[6] Consiglio Nazionale delle Ricerche, Istituto di Fotonica e Nanotecologie, Via Cineto Romano 42, 00156 Roma, Italy

Large radio and mm-wave telescopes use very sensitive detectors requiring cryogenic cooling to reduce detector noise. The use of pulse tubes to reach temperatures of a few K, and often as a base stage for further sub-K cooling, represents an effective solution for continuous operation, featuring high stability and reduced vibration levels on the detectors. However, the compressor used for the operation of the pulse tube is a significant source of microphonic and electrical noise, and the operation of the PT compressor at the focus of a large steerable telescope is not advisable. This calls for long flexible Helium lines between the compressor, operated at the base of the radiotelescope, and the cold-head, mounted in the receivers cabin with the receiver detectors. The distance between the receiver cabin and the base can be 100 m for large radiotelescopes. In the framework of our development of MISTRAL, a W-band camera working at the Gregorian focus of the 64 m aperture Sardinia Radio Telescope (SRT) with an array of LEKID detectors, we have developed a cryogenic system based on a pulse tube refrigerator as the first cooling stage. Here we describe the cryogenic system and focus on the validation of the use of a commercial Pulse Tube (PT) Cryocooler with 100 m helium lines running from the cold head to the compressor unit. We find that in these conditions our 0.9 W PT works at below 4.2 K with 0.5 W dissipation.

Session: Poster P3-31: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Giuseppe D'Alessandro - University Sapienza of Rome, Physics department

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QUBIC experiment towards the first light

G. D'Alessandro, E.S. Battistelli, P. de Bernardis, M. De Petris, M.M. Gamboa Lerena, L. Grandsire, J.-Ch. Hamilton, S. Marnieros, S. Masi, A. Mennella, L. Mousset, C. O'Sullivan, M. Piat, A. Tartari, S.A. Torchinsky, F. Voisin, M. Zannoni, P. Ade, J.G. Alberro, A. Almela, G. Amico, L.H. Arnaldi, D. Auguste, J. Aumont, S. Azzoni, S. Banfi, A. Bau, B. Bélier, D. Bennett, L. Bergé, J.-Ph. Bernard, M. Bersanelli, M.-A. Bigot-Sazy, J. Bonaparte, J. Bonis, E. Bunn, D. Burke, D. Buzi, F. Cavaliere, P. Chanial, C. Chapron, R. Charlassier, A.C. Cobos Cerutti, F. Columbro, A. Coppolecchia, G. De Gasperis, M. De Leo, S. Dheilly, C. Duca, L. Dumoulin, A. Etchegoyen, A. Fasciszewski, L.P. Ferreyro, D. Fracchia, C. Franceschet, K.M. Ganga, B. García, M.E. García Redondo, M. Gaspard, D. Gayer, M. Gervasi, M. Giard, V. Gilles, Y. Giraud-Heraud, M. Gómez Berisso, M. González, M. Gradziel, M.R. Hampel, D. Harari, S. Henrot-Versillé, F. Incardona, E. Jules, J. Kaplan, C. Kristukat, L. Lamagna, S. Loucatos, T. Louis, B. Maffei, W. Marty, A. Mattei, A. May, M. McCulloch, L. Mele, D. Melo, L. Montier, L.M. Mundo, J.A. Murphy, J.D. Murphy, F. Nati, E. Olivieri, C. Oriol, A. Paiella, F. Pajot, A. Passerini, H. Pastoriza, A. Pelosi, C. Perbost, M. Perciballi, F. Pezzotta andF. Piacentini, L. Piccirillo, G. Pisano, M. Platino, G. Polenta, D. Prêle, G. Presta, R. Puddu, D. Rambaud, E. Rasztocky, P. Ringegni, G.E. Romero, J.M. Salum, A. Schillaci, C.G. Scóccola, S. Scully, S. Spinelli, G. Stankowiak, M. Stolpovskiy, A.D. Supanitsky, J.-P. Thermeau, P. Timbie, M. Tomasi, G. Tucker, C. Tucker, D. Viganò, N. Vittorio, F. Wicek, M. Wright, A. Zullo

The Q&U Bolometric Interferometer for Cosmology (QUBIC) is a cosmology experiment that aims to measure the B-mode polarization of the Cosmic Microwave Background (CMB). Measurements of the primordial B-mode pattern of the CMB polarization is in fact among the most exciting goals in cosmology as it would allow testing the inflationary paradigm. Many experiments are attempting to measure the B-modes, from the ground and the stratosphere, using imaging Stokes polarimeters. The QUBIC collaboration developed an innovative concept to measure CMB polarization using bolometric interferometry. This approach mixes the high sensitivity of bolometric detectors with accurate control of systematics due to the interferometric layout of the instrument. We present the calibration results for the Technological Demonstrator, before the commissioning in the Argentinian observing site and the preparation for the first light.

Session: Poster P3-32: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Kenichi Karatsu - SRON - Netherlands Institute for Space Research

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Scalable Lens Array Assembly for Millimeter/Submillimeter Astronomical Instrument

K. Karatsu, R. Huiting, H. Kutsuma, M. Hattori, O. Tajima, A. Endo, V. Murugesan, T. Coppens, and J. J. A. Baselmans

SRON - Netherlands Institute for Space Research

Fabrication of a lens array for a large-format detector array is one of issues for the modern millimeter/submillimeter astronomy. Here, scalability is a key as the number of detectors will increase to 1,000–100,000 in coming decades. Depending on the target band and the material used for the lens array, the tolerance requirement could easily be less than a few tens of µm. It is also usually required to have anti-reflection coating (ARC) to avoid standing wave and achieve a good efficiency.

We have developed an easily scalable method to fabricate a Si lens array with mixed epoxy based ARC. The assembly tool mainly consists of three components: a base part with three alignment pins, a mask plate, and a mold for the ARC. Firstly Si carrier wafer is placed on the base part using the alignment pins, and Si lenses are put on it. Then, by using the precisely machined mask plate aligned to the alignment pins, all Si lenses are positioned in the desired locations at once. Finally, the ARC is applied using the mold that is also aligned to the base part by the alignment pins. The amount of the epoxy in each pockets of the mold corresponds to the desired ARC thickness. In this way, the ARC to all lenses can be also applied at once. Determined by the machining tolerance of the mask plate and the mold, the accuracy of $\sim$20 µm in both the lens position and the ARC thickness can be achieved.

Session: Poster P3-33: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Kaiwen Zheng - Princeton University

Simons Observatory Focal-Plane Modules: In-lab Testing and Characterization Program

Kaiwen Zheng, Yuhan Wang

Princeton University

Simons Observatory (SO) is a ground-based cosmic microwave background instrument to be sited in the Atacama Desert in Chile. SO will deploy 60,000 transition-edge sensor bolometers in 49 separate focal-plane modules across a suite of four telescopes covering 30/40 GHz low frequency (LF), 90/150 GHz mid-frequency (MF), and 220/280 GHz ultra-high frequency (UHF). Each MF and UHF focal-plane module packages 1720 optical detectors and corresponding 100mK microwave SQUID multiplexing readout components. Here we describe the testing program we have developed for high-throughput validation of the modules after they are assembled. The validation requires measurement of yield, saturation powers, time constants, noise properties and optical efficiencies. Additional measurements will be performed for further characterization as needed. We describe the methods and demonstrate results from the initial testing of prototype modules.

Session: Poster P3-34: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Christian Kirsch - Remeis-Observatory & ECAP, FAU Erlangen-Nuernberg

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Simulating the effect of Time-Division Multiplexing readout on the energy scale calibration of TES microcalorimeters

C. Kirsch [1], M. Durkin [2], P. Peille [3], B. Jackson [4], R. H. den Hartog [4], W. B. Doriese [2], C. A. Kilbourne [5], S. J. Smith [5], M. Lorenz [1], T. Dauser [1], J. Wilms [1]

[1] Dr. Karl Remeis-Observatory & ECAP, Sternwartstr. 7, 96049 Bamberg, Germany
[2] National Institute for Standards and Technology, 325 Broadway, Boulder, Colorado, USA
[3] CNES, 18 Av. Édouard Belin, 31401 Toulouse Dedex 9, France
[4] SRON Netherlands Institute for Space Reseach, Sorbonnelaan 2, 3584 CA Utrecht, Netherlands
[5] NASA Goddard Space Flight Center, 8800 Greenbelt Rd, Greenbelt, Maryland

We present a full readout-chain simulation of a Transition-Edge Sensor (TES) X-ray microcalorimeter array read out via Time-Division Multiplexing on a two-stage SQUID. Here, we focus on the effects of instrument physics and readout-chain bandwidths on the instrument's energy scale calibration, with the goal of constraining system parameters for the X-ray Integral Field Unit (X-IFU) aboard the planned Athena mission.

In these simulations, the first, multiplexing stage contains two types of SQUIDs: signal SQUIDs and flux-actuated switches. We model this stage as a full electrical circuit using resistively-shunted junction models for both components. This stage is followed by additional amplification and digitization components, each with its own modeled signal bandwidth. Both the feedback and row-select signals generated by the readout electronics are also subject to bandwidth limitations. The switching transients produced by our model are qualitatively well matched to those that we have measured experimentally in a laboratory TDM system.

Our simulations show that the readout produces small-scale residuals in the spectrometer's X-ray energy scale between the reference lines it has been calibrated to. We investigate how these residuals scale with system bandwidths and calibration strategy in order to optimize them with respect to the X-IFUs energy-calibration requirements.

Session: Poster P3-35: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Matteo De Gerone - INFN Genova

Status of the HOLMES experiment

M. De Gerone [1], D. T. Becker [2], D. A. Bennett [2], M. Biasotti [1,3], M. Borghesi [4,5], G. De Bodin De Galembert [6], M. Faverzani [4,5], M. Fedkevych [1,3], E. Ferri [4,5], J. W. Fowler [2], G. Gallucci [1], J. D. Gard [2], F. Gatti [1,6], A. Giachero [4,5], G. C. Hilton [2], J. A. B. Mates [2], E. Maugeri [6], A. Nucciotti [4,5], G. Pessina [5], C. D. Reintsema [2], D. R. Schmidt [2], D. Schumann [6], D. S. Swetz [2], J. N. Ullom [2], L. R. Vale [2]
[1] Istituto Nazionale di Fisica Nucleare, Sezione di Genova, Genova, IT.
[2] National Institute of Standards and Technology, Boulder, CO, USA.
[3] Dipartimento di Fisica, Università degli Studi di Genova, Genova, IT.
[4] Dipartimento di Fisica, Università degli Studi di Milano-Bicocca, Milano,IT.
[5] Istituto Nazionale di Fisica Nucleare, Sezione di Milano-Bicocca, Milano, IT.
[6] Paul Scherrer Institute, Villigen, CH.

The assessment of the absolute ν mass scale is a crucial challenge in today particle physics and cosmology. The only experimental method which can provide a model independent measurement is the investigation of end-point distortion in beta/electron capture spectra. For such a kind of experiment it is mandatory to use an isotopic species with the lowest possible Q-value, because of statistical sensitivity scales as $1/Q^3$. For this reason, electron capture ^{163}Ho decay is a good choice, having a Q-value of 2.8 keV. The HOLMES experiment will exploit a calorimetric measurement of ^{163}Ho decay spectrum deploying a large set of cryogenic micro-calorimeters implanted with ^{163}Ho. In order to get the best experimental sensitivity, it is crucial to combine high activity with very small undetected pileup contribution. Therefore, the main tasks of the experiment are: the development of $\sim$1000 fast (3 μs time resolution) cryogenic micro- calorimeters with energy resolution down to few eV; the embedding inside the arrays of the highest ^{163}Ho compatible with detectors' thermodynamical properties and pile-up issues, avoiding contamination from other species, mainly ^{166m}Ho; the development of an efficient high bandwidth multiplexed readout. The commissioning of the first implanted array is currently on going; the first DAQ is expected to start in 2021. Here, the status of the experiment and the first results about detector commissioning will be discussed.

Session: Poster P3-36: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Christian Kirsch - Remeis-Observatory & ECAP, FAU Erlangen-Nuernberg

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The Athena X-IFU instrument simulator xifusim

C. Kirsch [1], M. Lorenz [1], P. Peille [2], T. Dauser [1], B. Cobo [3], P. E. Merino-Alonso [4], E. Cucchetti [2], L. Gottardi [6], R. H. den Hartog [6], A. Miniussi [5], D. Prêle [8], J. Wilms [1], M. Ceballos [3], S. J. Smith [5], M. Durkin [7]

[1] Dr. Karl Remeis-Observatory & ECAP, Sternwartstr. 7, 96049 Bamberg, Germany
[2] CNES, 18 Av. Édouard Belin, 31401 Toulouse Dedex 9, France
[3] Instituto de Fsica de Cantabria (CSIC-UC), Edificio Juan Jorda, Avenida de los Castros, s/n- E-39005 Santander, Cantabria, Spain
[4] Universidad Politcnica de Madrid, Calle Ramiro de Maeztu 7, 28040 Madrid, Spain
[5] NASA Goddard Space Flight Center, 8800 Greenbelt Rd, Greenbelt, Maryland, USA
[6] SRON Netherlands Institute for Space Reseach, Sorbonnelaan 2, 3584 CA Utrecht, Netherlands
[7] National Institute for Standards and Technology, 325 Broadway, Boulder, Colorado, USA
[8] Université de Paris, CNRS, Astroparticule et Cosmologie, F-75006 Paris, France

We present the instrument simulator xifusim developed for the X-ray Integral Field Unit (X-IFU) aboard the planned Athena mission.

xifusim aims to be an accurate representation of the entire instrument, starting from a full numerical simulation of the Transition-Edge Sensor array receiving impact photons unconstrained by the small signal limit. Its output current is then propagated through the entire readout chain, including multiplexing, amplification and the digital readout. The final output consists of triggered records, which can be post-processed to reconstruct the photon energies.

The readout chain itself is separated into individual, modular blocks with several possible models for each, allowing the simulation of different readout schemes or models of varying physical accuracy at the expense of runtime. New models are implemented as necessary to enable studies of the overall readout chain. Such studies are also facilitated by fine-grained control of the simulation output, including the internal state of intermediate simulation blocks.

In addition to its modularity, xifusim also allows the manipulation of certain internal parameters during a run, enabling the simulation of readout chain characterization measurements, environmental drifts or certain kinds of crosstalk.

Session: Poster P3-37: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Noah Swimmer - University of California, Santa Barbara

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The PICTURE-C MKID Camera: Using MKIDs for High Contrast Direct Imaging on a Balloon-Based Observatory at Optical Wavelengths

Noah Swimmer, Benjamin A. Mazin, Clint Bockstiegel, John I. Bailey III, Gregoire Coiffard, Miguel Daal, Kristina Davis, Rupert Dodkins, Neelay Fruitwala, Isabel Lipartito, Jennifer Smith, Sarah Steiger, Nicholas Zobrist, Timothy Cook, Supriya Chakrabarti, Christopher Mendillo, Jason Martel, Kuravi Hewawasam

University of California, Santa Barbara

The Planetary Imaging Concept Testbed Using a Recoverable Experiment-Coronagraph (PICTURE-C) experiment is a balloon-borne high contrast direct imaging project whose goal is to image debris disks and around nearby stars at optical wavelengths. This mission will use a 10 kilopixel Microwave Kinetic Inductance Detector (MKID) instrument as its science camera. The PICTURE-C MKID camera is an integral field spectrograph that will sit behind a modest adaptive optics system and coronagraph and promises to achieve contrasts as deep as 10^{-7} at 0.35" and 2.1" separation from λ=540-660 nm. Each MKID is a photon counting detector that can resolve the energy of an incident photon. The ability to count single photons will allow the MKID camera to double as a Focal Plane Wavefront Sensor and distinguish circumstellar objects from optical aberrations which show up as 'speckles' in the astronomical images in real time and post processing. Additionally the instrument's promised spectral resolution will enable further characterization of any circumstellar disks or exoplanets that are observed during this mission. The PICTURE-C mission to perform high contrast direct imaging at optical wavelengths from a balloon telescope aims to provide observations that are complementary to typical infrared observations from ground-based telescopes. The use of an MKID camera on this mission will serve to demonstrate MKIDs' usefulness as detectors at optical wavelengths and in a space-like environment.

Session: Poster P3-38: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Gethin Robson - Cardiff University

The Simulation and Design of an On-Chip Superconducting Millimetre Filter-Bank Spectrometer

G. Robson, P. S. Barry, S. Doyle

Cardiff University

On-chip superconducting filter-banks provide a space saving and scalable solution to creating imaging spectrometers at millimetre and submillimetre wavelengths. We present an easy to realise, lithographed superconducting filter design with a high tolerance to fabrication error. Using a capacitively coupled $\lambda/2$ microstrip resonator to define a narrow ($\lambda/\Delta\lambda = 300$) spectral passband, the filtered output of a given spectrometer channel is directly connected to a Lumped Element Kinetic Inductance Detector (LEKID). Here the inductive meander section of the LEKID forms an absorbing microstrip transmission line that senses the power in a highly multiplexable and sensitive detector. We describe the process used to characterise and optimise the filter model which yields the geometries required for a desired channel frequency and width to produce a robust broadband millimeter filter-bank.

Session: Poster P3-39: Instruments, Astrophysics and Cosmology 1

Schedule: Thursday 22 July 01:05 - Thursday 22 July 02:30

Submitted by: Erik Shirokoff - University of Chicago

The SuperSpec Instrument: status and deployment plans

E. Shirokoff, UChicago
P. Barry, ANL
C. M. Bradford, JPL
S. Chapman, Dalhousie
S. Doyle, Cardiff
J. Glenn, GSFC
S. Hailey-Dunsheath, Caltech
R. McGeehan, UChicago
R. M. J. Janssen, Caltech
K. Karkare, UChicago
A. Kovács, Caltech
H. G. LeDuc, JPL
P. Mauskopf, ASU
J. Redford, Caltech
C. Tucker, Cardiff
J. Wheeler, NIST Boulder
J. Zmuidzinas, Caltech

In late 2021 the SuperSpec instrument – a mm-wavelength spectrometer covering the one-millimeter atmospheric window – will be commissioned at the Large Millimeter Telescope in Mexico. This pathfinder instrument includes three dual-polarization spatial pixels coupled to six on-chip spectrometers with a resolving power of R $\sim$ 300 operating in the 1-mm atmospheric window. Each spectrometer consists of a lens-coupled antenna, a filter bank made from superconducting microstrip features, and a series of titanium nitride kinetic inductance detectors. The instrument includes a 225 mK focal plane in a cryostat that consists of a helium sorption refrigerator and a pulse tube cooler, a cooled lens, and several external mirrors designed to couple to the telescope optics. The multitone readout system consists of an array of six CASPER-ROACH boards. Lab results indicate a NEP at the detector of 4x10^{-18} W/Hz$^{-1/2}$, estimated on sky point source sensitivity below 10 mK/sqrt(Hz) per pixel and polarization, and generous dynamic range.

We will present the SuperSpec instrument status and commissioning plans, as well as briefly discussing future observing plans and instrument upgrades, as well as briefly discussing discussing the implications this technology for the development of future large format intensity mapping instruments.

Session: Oral O4A-1: Rare Events 1

Schedule: Thursday 22 July 22:00 - Thursday 22 July 22:30

Submitted by: Matt Pyle - University of California Berkeley

Massive Low Temperature Calorimeters: Developments, Challenges, and Future Prospects

Matt Pyle

University of California, Berkeley

Massive low temperature calorimeters are used by a large number of experimental collaborations to search for the direct detection of dark matter and evidence of neutrinoless double beta decay. In both of these fields there has been enormous progress over the last 2 years. We will discuss this progress, talk about the current challenges that are areas of active research, and highlight potential future prospects.

Session: Oral O4A-2: Rare Events 1

Schedule: Thursday 22 July 22:30 - Thursday 22 July 22:45

Submitted by: Abhijit Garai - Max-Planck Institut für Physik 80805 Munich, Germany

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Direct dark matter search with CRESST-III experiment

Abhijit Garai, on behalf of the CRESST collaboration

Max-Planck Institut für Physik 80805 Munich, Germany

The CRESST-III (Cryogenic Rare Event Search with Superconducting Thermometers) experiment, located deep underground at the Laboratori Nazionali del Gran Sasso (LNGS), is a cryogenic experiment with the primary objective to detect dark matter via elastic scattering of dark matter particles with nuclei. The experiment measures the nuclear recoil energy with cryogenic calorimeters consisting of scintillating crystals and tungsten superconducting transition edge sensors operating at about 15 mK. The CRESST detector modules also measure the light produced in the scintillating crystals due to the particle interaction with separate light detectors, allowing to discriminate the type of incident particles. One of the CRESST-III detector modules achieved a nuclear recoil energy threshold as low as 30.1 eV, which led to improved sensitivity to spin-independent scattering of dark matter masses down to 160 MeV/c^2. This result placed CRESST-III among the most sensitive dark matter experiments in the sub-GeV/c^2 mass regime. Furthermore, the ability of the CRESST technology to choose a wide range of materials as the target, makes it unique and instrumental in the sub-GeV dark matter search.

In this contribution, the current status of the CRESST-III experiment, along with the latest result and future plans will be presented. The possibility of different target materials and sensitivity to spin-dependent dark matter interactions in the framework of CRESST will also be discussed.

Session: Oral O4A-3: Rare Events 1

Schedule: Thursday 22 July 22:45 - Thursday 22 July 23:00

Submitted by: Jules Gascon - IP2I (Universite Lyon 1 / CNRS-IN2P3)

Low-mass Dark Matter searches with EDELWEISS

J. Gascon [1], E. Armengaud [2], Q. Arnaud [1], C. Augier [1], A. Benoît [3], L. Bergé [4], J. Billard [1], A. Broniatowski [4], P. Camus [3], A. Cazes [1], M. Chapellier [4], F. Charlieux [1], M. De Jésus [1], L. Dumoulin [4], K. Eitel [5], E. Elkhoury [1], J.-B. Fillipini [1], D. Filosofov [6], A. Giuliani [4], M. Gros [2], Y. Jin [7], A. Juillard [1], M. Kleifges [8], H. Lattaud [1], S. Marnieros [4], D. Misiak [1], X.-F. Navick [2], C. Nones [2], E. Olivieri [4], C. Oriol [4], P. Pari [9], B. Paul [2], D. Poda [4], S. Rozov [6], T. Salagnac [1], V. Sanglard [1], B. Siebenborn [5], L. Vagneron [1], M. Weber [8], E. Yakushev [6], A. Zolotarova [4]

[1] Univ Lyon, Université Lyon 1, CNRS/IN2P3, IP2I-Lyon, F-69622 Villeurbanne, France
[2] IRFU, CEA, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France
[3] Institut Néel, CNRS/UJF, 25 rue des Martyrs, BP 166, 38042 Grenoble, France
[4] Université Paris-Saclay, CNRS/IN2P3, IJCLab, 91405 Orsay, France
[5] Karlsruher Institut fur Technologie, Institut fur Kernphysik, Postfach 3640, 76021 Karlsruhe, Germany
[6] JINR, Laboratory of Nuclear Problems, Joliot-Curie 6, 141980 Dubna, Moscow Region, Russian Federation
[7] C2N, CNRS, Universite Paris-Sud, Universite Paris-Saclay, 91120 Palaiseau, France
[8] Karlsruher Institut fur Technologie, Institut fur Prozessdatenverarbeitung und Elektronik, Postfach 3640, 76021 Karlsruhe, Germany
[9] IRAMIS, CEA, Universite Paris-Saclay, F-91191 Gif-sur-Yvette, France

The EDELWEISS collaboration searches for light Dark Matter (DM) particles using germanium detectors equipped with a charge and phonon signal readout. Using the Neganov-Trofimov-Luke effect, a rms resolution of 0.56 electron-hole pair was obtained on a massive (33.4g) germanium detector operated underground at the Laboratoire Souterrain de Modane. This record sensitivity made possible a search for Dark Photon DM down to 1 eV and to DM-electron interactions below 1 MeV/c2. This demonstrates for the first time the high relevance of cryogenic Ge detectors in searches at low thresholds and is an important step of the development of Ge detectors with improved performance in the context of the EDELWEISS-SubGeV program.

Session: Oral O4A-4: Rare Events 1

Schedule: Thursday 22 July 23:00 - Thursday 22 July 23:15

Submitted by: Hawraa Khalife - IRFU (CEA Paris-Saclay)

The CROSS experiment: bolometers with metallic film coating capable of rejecting surface α and β events

Hawraa Khalife, on behalf of the CROSS collaboration

IRFU (CEA Paris-Saclay)

Bolometers based on dielectric crystals are among the most promising detectors to search for neutrinoless double-beta decay. In general, bolometers are not sensitive to the particle impact point, especially if the detection is mediated by thermal phonons. However, the CROSS collaboration has demonstrated successfully that these devices can provide pulse shape discrimination between surface and bulk events, by coating the crystal surface with metallic thin layers. This technology is of great importance, as a substantial reduction of the background level in future double-beta decay experiment can be achieved. In fact, a dominant background component is due to superficial radioactive impurities, which emit β and α particles depositing their energy close to the detector surface. The metallic coating affects the phonon energy down-conversion cascade that follows the particle interaction, leading to a modified signal shape for close-to-film events. An efficient identification of surface β and α events was demonstrated with detectors based on a rectangular 20×20×10 mm3 Li_2MoO_4 crystal coated with a Pd normal-metal film (10 nm thick) and with Al-Pd superconductive bi-layers (100 nm-10 nm thick) on a 20×20 mm2 face. An excellent discrimination was achieved both with continuous and grid-shaped films. The discrimination capabilities were tested with ^{238}U sources emitting both α and β particles.

Session: Oral O4A-5: Rare Events 1

Schedule: Thursday 22 July 23:25 - Thursday 22 July 23:40

Submitted by: Claudia Nones - CEA-IRFU

CUPID-Mo: a new world limit on neutrinoless double beta decay of ^{100}Mo

Claudia Nones on behalf of the CUPID-Mo collaboration

CEA-IRFU

The CUPID-Mo experiment is an array of 20 cryogenic scintillating bolometers searching for neutrinoless double-beta decay ($0\nu\beta\beta$) of ^{100}Mo based on enriched $^{100}Li_2MoO_4$ crystals coupled to Ge light detectors, working at 20 mK. The experiment has collected data from spring 2019 to summer 2020 at Laboratoire Souterrain de Modane (France) and its technology has been chosen as a baseline for the next generation ton-scale experiment CUPID. The results achieved with this array are outstanding: a high energy resolution of $\sim$ 7 keV at 2615 keV, a full $\alpha/\beta(\gamma)$ separation (up to 99.9%), and an excellent radiopurity. With an exposure of about 2 kg.yr, it has been possible to set a new world-leading limit on the half-life of $0\nu\beta\beta$ decay of ^{100}Mo ($T_{1/2}$ 1.5 $\times$ 10^{15} yr at 90% C.L.). In this contribution, the detector technology, the experimental set-up, and the performed analysis for the $0\nu\beta\beta$ decay search will be presented.

Session: Oral O4A-6: Rare Events 1

Schedule: Thursday 22 July 23:40 - Thursday 22 July 23:55

Submitted by: Rikhav Shah - JGU Mainz

Characterising a single photon detector for ALPS II

Rikhav Shah [1], Katharina-Sophie Isleif [2], Friederike Januschek [2], Axel Lindner [2], Matthias Schott [1]

[1] JGU Mainz
[2] DESY, Hamburg

The Any Light Particle Search II (ALPS II) is a light-shining-through-a-wall (LSW) experiment at DESY, Hamburg, attempting to detect axions and axion-like-particles (ALPs), which can comprise dark matter and solve long-standing problems in physics. ALPS II can convert photons into axions/ALPs in the presence of a magnetic field, in an optical cavity. After passing through an opaque, light-tight barrier, these particles can reconvert to photons in another optical cavity, and be detected. The detection requires a sensor capable of observing the extremely low regenerated photon rates of $\mathcal{O}(10^{-5})$ Hz, necessitating a very low dark rate and high detection efficiency. This can be achieved by using a TES, a Transition Edge Sensor, a cryogenic calorimeter exploiting the drastic temperature dependence of a material's electrical resistance in its transition region around 140 mK. To achieve this, the setup is housed in a dilution refrigerator cooling it down to a temperature 25 mK. Being sensitive to low-energy 1064 nm photons also makes the detector susceptible to other particles and backgrounds which can hamper the targeted low dark rate.

We present the setup of the TES detector for ALPS II, its current status, and the analysis of its backgrounds and further improvements in the cryogenic environment to reduce the backgrounds. The viability and outlook of such a detector for the ALPS II experiment will be discussed, including future measurements.

Session: Oral O4A-7: Rare Events 1

Schedule: Thursday 22 July 23:55 - Friday 23 July 00:10

Submitted by: Irene Nutini - Milano Bicocca INFN and University

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Latest results from the CUORE experiment

Irene Nutini

Milano Bicocca INFN and University

The Cryogenic Underground Observatory for Rare Events (CUORE) is the first bolometric experiment searching for 0νββ decay that has been able to reach the one-tonne mass scale. The detector, located at the LNGS in Italy, consists of an array of 988 TeO2 crystals arranged in a compact cylindrical structure of 19 towers. CUORE began its first physics data run in 2017 at a base temperature of about 10 mK and in April 2021 released its 3rd result of the search for 0νββ, corresponding to a tonne-year of TeO2 exposure. This is the largest amount of data ever acquired with a solid state detector and the most sensitive measurement of 0νββ decay in 130Te ever conducted, with a median exclusion sensitivity of 2.8×10^{25} yr. We find no evidence of 0νββ decay and set a lower bound of 2.2×10^{25} yr at a 90% credibility interval on the 130Te half-life for this process. In this talk, we present the current status of CUORE search for 0νββ with the updated statistics of one tonne-yr. We finally give an update of the CUORE background model and the measurement of the 130Te 2νββ decay half-life, study performed using an exposure of 300.7 kg · yr.

Session: Oral O4A-8: Rare Events 1

Schedule: Friday 23 July 00:10 - Friday 23 July 00:25

Submitted by: Marco Vignati - Sapienza University and INFN

Final results of CALDER: Kinetic inductance light detectors for double beta decay.

M. Vignati [1], L. Cardani [1], N. Casali [1], I. Colantoni [2,1], A. Cruciani [1], S. Di Domizio [3,4], M. Martinez [5], V. Pettinacci [1], G. Pettinari [6]

[1] INFN - Sezione di Roma, Roma I-00185 - Italy
[2] Consiglio Nazionale delle Ricerche, Istituto di Nanotecnologia (CNR - NANOTEC), c/o Dipartimento di Fisica, Sapienza Universita di Roma, Roma I-00185 - Italy
[3] Dipartimento di Fisica, Universita di Genova, Genova I-16146 - Italy
[4] INFN - Sezione di Genova, Genova I-16146 - Italy
[5] Laboratorio de Fısica Nuclear y Astropartıculas, Universidad de Zaragoza, C/ Pedro Cerbuna 12, 50009 and Fundacion ARAID, Av. de Ranillas 1D, 50018 Zaragoza, Spain
[6] Consiglio Nazionale delle Ricerche, Istituto di Fotonica e Nanotecnologie (CNR - IFN), Via Cineto Romano 42, 00156, Roma - Italy

The development of large-area light detectors is one of the priorities of next generation calorimetric experiments searching for neutrinoless double beta decay. A good energy resolution is required for particle identification, and at the same time a fast response time is needed to reduce pile-ups from background events, which would limit the sensitivity of the experiment. In this talk we summarize the major steps of the CALDER R&D project and present the final prototype, consisting of a silicon substrate of 5x5 cm^2 acting as light absorber and sensed by a single aluminum-titanium-aluminum Kinetic Inductance Detector (KID). The energy resolution of 35 eV RMS, the response time of 120 us, together with the natural multiplexing capabilities and the ease in fabrication of KIDs, make the developed technology a promising alternative to NTD and TES-based light detectors for future and large-scale experiments.

Session: Oral O4A-9: Rare Events 1

Schedule: Friday 23 July 00:25 - Friday 23 July 00:40

Submitted by: Sunil Golwala - California Institute of Technology

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Development of phonon-mediated dark-matter detectors using kinetic inductance phonon sensors

S. Golwala, T. Aralis, R. Basu Thakur, B. Bumble, Y.-Y. Chang, K. Ramanathan, O. Wen

California Institute of Technology

Phonon-mediated particle detectors are a flexible and sensitive technology for dark matter detection, promising extensive reach for sub-GeV dark matter via low thresholds substrate flexibility. Kinetic inductance detectors are an excellent option for the phonon sensing. They are inherently multiplexable, rendering feasible arrays of tens to hundreds of KIDs on a single substrate, truly imaging the phonon flux. They are pair-breaking detectors, rendering them potentially less susceptible to environmental backgrounds. If sources of residual quasiparticles can be addressed, fundamental limits on their sensitivity decrease exponentially with temperature. They are inherently non-dissipative, rendering them amenable to quantum information science techniques to reduce readout noise. We summarize current results from our effort to develop two kinds of KID-based dark-matter detectors. The first design seeks to maximize reach to low mass by employing a single Al KID on a gram-scale substrate, with O(eV) resolution on energy received at the KID achieved (see O. Wen poster). The second design is instead optimized for background rejection, employing an array of KIDs to not only sense position but also discriminate nuclear recoils from electron recoils, and has achieved O(100) eV energy resolution (see K. Ramanathan poster). Both approaches have great promise for improved resolution by reduction of quiescent quasiparticle density and improved readout noise.

Session: Oral O4A-10: Rare Events 1

Schedule: Friday 23 July 00:40 - Friday 23 July 00:55

Submitted by: Scott Hertel - University of Massachusetts - Amherst

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Ricochet Progress and Status

Scott Hertel on behalf of the Ricochet Collaboration

University of Massachusetts - Amherst

The Ricochet experiment aims to preform a precision measurement of the coherent elastic neutrino-nucleus scattering (CEvNS) spectrum at a nuclear reactor with an array of low-threshold (100 eV) cryogenic sensors. These low thresholds enable sensitivity to new physics in the neutrino sector. The project aims for deployment at the Inst. Laue-Langevin in 2022. In addition to describing the project plan and infrastructure at ILL, this presentation will summarize recent detector R&D including: optimization of an NTD readout, development of a new TES readout, a TES multiplexing scheme based on microwave resonators, development and characterization of a HEMT-based charge readout, studies of detector clamping and holder design, and initial characterization of novel superconducting target materials.

Session: Oral O4B-1: Material Analysis, Metrology, Other

Schedule: Thursday 22 July 22:00 - Thursday 22 July 22:30

Submitted by: Katrina Koehler - Los Alamos National Laboratory

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A Review of Decay Energy Spectroscopy

Katrina Koehler

Los Alamos National Laboratory

Low Temperature Detectors have been used to measure embedded radioisotopes in a measurement mode known as Decay Energy Spectroscopy (DES) since the early 1990s. With 4π detection efficiency and the potential to measure total decay energy regardless of decay path resulting in simplified spectra, DES measurements have been used for applications ranging from neutrino mass measurements to metrology to measurements for safeguards and medical nuclides. While the low temperature DES detectors have extremely high intrinsic energy resolution, the energy resolution achieved in practice is strongly dependent on factors such as sample preparation method. We review the history of the field, analyze the published literature for trends relevant to achieved energy resolution, illuminate the importance of sample preparation, and explore various applications of DES.

Session: Oral O4B-2: Material Analysis, Metrology, Other

Schedule: Thursday 22 July 22:30 - Thursday 22 July 23:00

Submitted by: Serena DeBeer - Max Planck Institute for Chemical Energy Conversion

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X-ray spectroscopic studies of biological catalysts - new opportunities with XES spectrometers and LTDs?

Serena DeBeer

Max Planck Institute for Chemical Energy Conversion

Metalloenzymes are remarkable in their ability to effect challenging chemical transformations, ranging from dinitrogen reduction to water oxidation to methane oxidation. In each case, the metal active sites of these enzymes are the sites of substrate binding and transformation. This has placed intense efforts on understanding how the geometric and electronic structure of the metal active sites change during the course of a reaction, with the ultimate goal of using these lessons to inspire rational catalytic design. X-ray spectroscopy has played a longstanding role in elucidating metalloenzyme active site structure, and in recent years X-ray emission spectroscopy (XES) and resonant XES methods have provided added selectivity. In this talk, I will highlight recent examples of XES and RXES/RIXS applied to metalloenzymes and related model complexes. The challenges in performing these experiments and the potential opportunities that low temperature detectors may afford will be discussed.

Session: Oral O4B-3: Material Analysis, Metrology, Other

Schedule: Thursday 22 July 23:00 - Thursday 22 July 23:15

Submitted by: Mark Croce - Los Alamos National Laboratory

Experience from the analytical labs: first results from deployed microcalorimeter gamma spectrometers

M. P. Croce, D. T. Becker, D. A. Bennett, M. H. Carpenter, J. D. Gard, J. Imrek, K. E. Koehler, J. A. B. Mates, D. G. McNeel, N. J. Ortiz, D. R. Schmidt, K. A. Schreiber, C. M. Smith, D. Swetz, L. Vale, A. L. Wessels, S. L. Weidenbenner, D. Yan, J. N. Ullom

The first ultra-high resolution microcalorimeter gamma spectrometers are now being deployed to nuclear facilities and analytical laboratories thanks to extensive recent developments in transition-edge sensor array readout, cryogenics, and software for pulse processing and isotopic analysis. We will present recent results and experience from two spectrometers based on large microwave-multiplexed arrays of superconducting transition-edge sensors. The factor of 5-10 improvement in energy resolution compared with high-purity germanium detectors has direct benefit in precision nondestructive isotopic analysis of the complex materials encountered in advanced nuclear fuel cycles. SOFIA (Spectrometer Optimized for Facility Integrated Applications) is being used for measurement campaigns in multiple United States national laboratory locations this year, with a focus on nuclear material accounting and reference data. The second instrument is a 500-pixel-scale spectrometer designed for permanent installation in an analytical laboratory. These two instruments serve as important testbeds in operational nuclear facility settings, and can access a wide range of samples that are being used to explore limits of nondestructive nuclear material characterization. As use of microcalorimeter gamma spectrometers continues to expand, we anticipate that the technology will be an important component of robust and economical material accountancy for the next generation of nuclear facilities.

Session: Oral O4B-4: Material Analysis, Metrology, Other

Schedule: Thursday 22 July 23:25 - Thursday 22 July 23:40

Submitted by: Galen O'Neil - NIST

NIST TES soft x-ray spectrometers at synchrotron beamlines

G. C O'Neil, J. N. Ullom, D. S. Swetz. W. B. Doriese, M. Durking, H. Whitelock, N. J. Nakamura, Sang-Jun Lee, Jun Sik Lee, Donghui Lu, D. Nordlund, K. D. Irwin. C. J Titus, D. Fischer, K. M. Morgan, J. C. Weber, D. Schmidt

We report on three soft x-ray TES spectrometers located at synchrotron beamlines: SSRL 10-1, SSRL 13-3, and NSLS-II 7-ID. Examples of applications and measurements made over the past few years are provided, and we discuss some lessons learned. We are in the process of updating all three instruments. Two of the instruments will receive major upgrades that allow for better energy resolution (sub eV FWHM at 700 eV), at least 4X increased collection efficiency, detector response closer to an ideal single gaussian, and improved performance at high count rates. These improvements are largely enabled by new TES arrays with larger area and lower transition temperature pixels made with a new fabrication process (hasTES). The improvements are further enabled by new time-division-multiplexing chips and cryogenic circuit boards which reduce readout noise and crosstalk. We will discuss plans to upgrade the software to provide x-ray spectra to beamline users as soon as they are acquired through the existing beamline control user interface.

Session: Oral O4B-5: Material Analysis, Metrology, Other

Schedule: Thursday 22 July 23:40 - Thursday 22 July 23:55

Submitted by: Katherine Schreiber - Los Alamos National Laboratory

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High Resolution Decay Energy Spectroscopy Using Transition Edge Sensor Microcalorimetry

K.A. Schreiber, D.G. McNeel, S. Weidenbenner, K.E. Koehler, C.M. Smith, S. Salazar, M. H. Carpenter, M.P. Croce, J.N. Ullom, D.R. Schmidt

Decay energy spectroscopy is a technique by which nuclear material is encapsulated completely in an absorber, so that energy from decay processes of the material is captured by the absorber. The technique is extremely sensitive, capable of resolving many alpha-decaying nuclides. The absorber is attached to a microcalorimeter operating near 90 mK. Every decay event, which produces a heat pulse, is then recorded as an electrical pulse of amplitude correlated to the decay energy. We then extract an energy spectrum characteristic of the material, even in samples of activity under a becquerel.

In this presentation I will discuss recent progress in decay energy spectroscopy using transition edge sensor microcalorimeters. This includes recent measurement activities and developments in sample preparation. Our measurement campaigns have achieved energy spectra with 1keV FWHM energy resolution at decay energy peaks near 5 MeV. This allows highly precise measurement of radionuclide composition of materials, and permits a path towards a determination of neutrino mass. Recent measurements in our lab include isotopic analysis of materials relevant to the nuclear fuel cycle. We have also been able to characterize composition of radionuclide samples which have particular interest for medical applications, such as actinium. Finally, we have made progress applying ultrasonic welding for the incorporation of radioactive material into the absorber matrix.

Session: Oral O4B-6: Material Analysis, Metrology, Other

Schedule: Thursday 22 July 23:55 - Friday 23 July 00:10

Submitted by: Joseph Fowler - NIST

Absolute energies and emission line shapes of the L x-ray transitions of lanthanide metals

Joseph Fowler

NIST

Using an array of transition-edge sensors (TESs) with 4 eV energy resolution (FWHM), we have measured the L x-ray emission-line profiles of four elements in the lanthanide series. We also surveyed numerous x-ray standards such as 3d transition metals in order to establish an absolute-energy calibration traceable to the International System of Units for the energy range 4 keV to 10 keV and with absolute uncertainty better than 0.3 eV (1-sigma) across most of this range.

New results include emission-line profiles for 97 lines, each expressed as a sum of one or more Voigt functions; improved absolute energy uncertainty on 71 of these lines relative to existing reference data; a median uncertainty on the peak energy of 0.24 eV (1-sigma), which is four to ten times better than the median of prior work; and 6 lines that lack any measured values in existing reference tables. The 97 lines comprise nearly all of the most intense L lines from these elements under broad-band x-ray excitation.

These results constitute an important advance in the absolute calibration of low-temperature microcalorimeters across a broad band of energies. Instrumentation changes central to this work include the use of a gold x-ray absorbing layer on the TES to produce a Gaussian energy-response function, and a sample holder that enables rapid switching between science targets and calibration targets to stabilize the specgtrometer gain across targets.

Session: Oral O4B-7: Material Analysis, Metrology, Other

Schedule: Friday 23 July 00:10 - Friday 23 July 00:25

Submitted by: Philipp Chung-On Ranitzsch - Physikalisch-Technische Bundesanstalt

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Determining decay data from multi-branch electron capture decays using Metallic Magnetic Calorimeters

Philipp Chung-On Ranitzsch [1], Michael Paulsen [2,3], Martin Loidl [4], Matias Rodrigues [4], Jörn Beyer [2], Karsten Kossert [1], Ole J. Nähle [1], Sebastian Kempf [5], Mathias Wegner [5], Dirk Arnold [1], Christian Enss [3]

[1] Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany
[2] Physikalisch-Technische Bundesanstalt (PTB), Abbestrasse 2-12, 10587 Berlin, Germany
[3] Kirchhoff-Institute for Physics, Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany
[4] CEA, LIST, Laboratoire National Henri Becquerel, Bat. 602 - PC111, CEA-Saclay, 91191 Gif-sur-Yvette Cedex, France
[5] Institute for Micro- and Nanoelectronic Systems, Karlsruher Institute of Technology, Hertzstraße 16, 76187 Karlsruhe, Germany

Low temperature detectors with radioactive material embedded in a 4π geometry are well-established tools for high-resolution spectrometry of decay spectra with applications e.g. in nuclear and particle physics or radionuclide metrology. In most cases, only a certain part of the decay is of main interest, e.g. only the α- or β-particles of the decay or a specific energy region, and the measurement can be optimized for that goal.

When determining decay data, which is of particular interest in radionuclide metrology, ideally all decay branches should be measured. In case of electron capture (EC), the situation can become complicated because of the different photonic and electronic de-excitation channels and especially if the decay is accompanied by a β+- or γ-transition. In this case, a detector or absorber optimization needs to be a compromise between different decay branches and their usually different energy ranges. Alternatively, dedicated measurements for each decay branch can be performed, aggregating different data sets for the full spectrum.

In the European metrology project MetroMMC, we use Metallic Magnetic Calorimeters to measure the decay spectra of several EC decaying nuclides, e.g. ^{65}Zn (EC, EC/γ, β+) and ^{109}Cd (EC - ^{109}mAg - IC/γ), where this aggregation method is employed to get the most accurate decay spectra. This contribution will describe the details and pitfalls of the aggregation method along with its experimental application on EC decay spectra.

Session: Oral O4B-8: Material Analysis, Metrology, Other

Schedule: Friday 23 July 00:25 - Friday 23 July 00:40

Submitted by: Daniel Hengstler - KIP, Heidelberg University

X-ray Spectroscopy of Highly Charged Uranium Ions with Metallic Magnetic Calorimeters

Daniel Hengstler [1], Steffen Allgeier [1], Marvin Friedrich [1], Patricia Kuntz [1], Loredana Gastaldo [1], Andreas Fleischmann [1], Christian Enss [1], Günter Weber [2], Philip Pfäfflein [2], Felix Kröger [3], Binghui Zhu [2], Thomas Stöhlker [2,3,4]

[1] KIP, Heidelberg University
[2] HI Jena
[3] IOQ Uni Jena
[4] GSI

An excellent energy resolution combined with a high dynamic range as well as a very good linearity make metallic magnetic calorimeters (MMCs) ideal detectors for different applications in high-resolution X-ray spectroscopy. One of these applications is to probe QED in the regime of extreme fields close to the Schwinger-Limit and, moreover, to test our understanding of the simplest many-electron system at strong fields, namely He-like Uranium

For the investigation of highly charged Uranium ions at CRYRING@FAIR we developed the 2-dimensional maXs-100 detector array within the framework of the SPARC collaboration. It features 8x8 pixels with an active detection area of 1 cm^2. With an absorber thickness of U^{91+} and U^{92+} were produced and decelerated to 10 MeV/u. These ions interacted with an electron beam and resulting X-ray emissions were recorded with two maXs-100 detectors which were mounted under the scattering angles 0° and 180°, respectively, to intrinsically correct for the Doppler shift.

To perform an absolute energy calibration on a sub-eV level calibration sources (^{241}Am, ^{57}Co, ^{169}Yb) were used. We discuss the properties of the maXs-100 array, including the non-linearity of the read-out system as well as results of the beam time.

Session: Oral O4B-9: Material Analysis, Metrology, Other

Schedule: Friday 23 July 00:40 - Friday 23 July 00:55

Submitted by: Lixue Jiang - Carnegie Mellon University

Characterization of the SARS-CoV-2 S1 Spike Protein Using Superconducting Tunnel Junction Cryodetection Mass Spectrometry

Li-Xue Jiang [1], Liam Dugan [1], Raymond B Yurko [2], Kazi Islam [2], Stephan Friedrich [3], Andrea Gambotto [2], Mark E. Bier [1]

[1] Carnegie Mellon University, Pittsburgh, PA, United States
[2] University of Pittsburgh, Pittsburgh, PA, United States
[3] Lawrence Livermore National Laboratory, Livermore, CA, United States

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the causative agent of the coronavirus disease 2019 (COVID-19). The spike (S) protein, a characteristic structural component of the viral envelope, is considered a key target for vaccine development. To support this development, we analyzed purity and molecular weight (MW) of the S1 subunit monomer and trimer using matrix-assisted laser desorption ionization (MALDI) mass spectrometry coupled to a 32-pixel niobium superconducting tunnel junction (STJ) array detector. Compared with ionizing detectors, STJs have the advantage of high sensitivity, high quantum efficiency, and low noise. The MW of a commercial S1 protein (Sino Biological) and our potential vaccine S1 unit was measured at 110.7 kDa and 106.9 kDa, respectively. The S1 trimer immunogen was observed at 354.7 kDa using the STJ detector, but with reduced signal using a lower efficiency microchannel plate (MCP) detector. An additional advantage of the STJ detector is the separation of charge states in the energy scatterplot allowing for easier interpretation of a mass spectrum from a protein mixture. After treatment of the S1 trimer with dithiothreitol, a reducing agent, the S1 monomer peak was observed, which implied that disulfide or other bonds of the trimer were disrupted. The trimer structure is important to best mimic the real structure of S protein in vivo. These characterization results helped in the development of a protein based COVID-19 vaccine.

Session: Poster P4-1: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Colm Bracken - Manynooth University

A Delayed-Choice Quantum Eraser Experiment with Photon-Counting MKIDs

Colm Bracken

Maynooth University

In this updated DCQE (delayed-choice quantum eraser) set-up, we propose to use photon-counting MKIDs as the detector technology at both the primary measurement plane and at the eraser plane. A DCQE set-up allows one to investigate the strange consequences of the classic double-slit experiment by exploiting the effects of quantum entanglement. As shown in previous experiments by Kim, et al. (1999), the DCQE allows the which-path or both-path information of a signal photon to be erased or marked, respectively, by its entangled twin, even after the registration of the signal photon. These past experiments used a moveable detector to scan across the plane of the interference pattern. That approach relied on building-up sufficient photon statistics over time spans of many seconds in order to show the wave-like or particle-like pattern on the detection plane. By substituting the detector technology with optical MKIDs, it will be shown how deeper insights into the physics involved in the DCQE can be gained. The MKIDs' ability to time-stamp the detection of individual photons to better than microsecond precision while also yielding spatial information (along the plane of the interference pattern, for example), will allow the moment-by-moment analysis of the detection and decoherence processes. It will be shown that an MKIDs-based DCQE can be used to generate an apparent measurement paradox, which itself can be solved by the proposed measurements. The system design is presented here.

Session: Poster P4-2: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Dan Becker - University of Colorado

A Quantitative Comparison Of Transition-Edge Sensor Microcalorimeters And High-Purity Germanium Detectors For Plutonium Isotopic Analysis

D. T. Becker, J. W. Fowler, J. D. Gard, J. Imrek, A. Wessels, J. N. Ullom
University of Colorado, Boulder, Colorado, USA
D. A. Bennett,, G. C. Hilton, J. A. B. Mates, G. C. O'Neil, N. J. Ortiz, C. D. Reintsema, D. R. Schmidt, L. R. Vale, J. N. Ullom
National Institute of Standards and Technology, Boulder, Colorado, USA
M. H. Carpenter, M. Croce, A. S. Hoover, K. E. Koehler, D. J. Mercer, K. A. Schreiber, A. D. Tollefson, D .T. Vo, S. L. Weidenbenner, M. D. Yoho
Los Alamos National Laboratory, Los Alamos, New Mexico, USA

Non-destructive analysis of nuclear materials through gamma-ray spectroscopy has wide applications in nuclear safeguards. The detectors most commonly used at present are High Purity Germanium (HPGe) detectors, which can sustain high count rates, but have energy resolutions of at best 500 eV at 100 keV, limiting their ability to make high-precision measurements of plutonium isotopic ratios. Gamma-ray spectroscopy using transition-edge sensor (TES) microcalorimeters has matured significantly in the last few years with the deployment of the SOFIA instrument at Los Alamos National Laboratory. SOFIA contains 256 TES microcalorimeter pixels, and routinely achieves an energy resolution of 60 eV at 97 keV. A next-generation instrument and detector array will be installed at Idaho National Laboratory in 2021, featuring an architecture that can enable total count rates comparable to HPGe. Bettering the precision of HPGe spectra while achieving comparable count rates is critical to the acceptance of TES technology for safeguards applications.

We have acquired high statistics spectra of nine standard Pu reference materials with both SOFIA and HPGe, and extracted isotopic ratios in a consistent way with a newly developed analysis code. We report on a quantitative comparison of these results. We also report on the use of TESs to make improved measurements of fundamental parameters relevant to gamma-ray spectral analysis, including branching ratios and actinide x-ray line widths.

Session: Poster P4-3: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Simone Quitadamo - GSSI - Gran Sasso Science Institute

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A thermal model for low-temperature TeO_2 calorimeters read out by NTD thermistors

Simone Quitadamo

GSSI - Gran Sasso Science Institute

Reaching a complete understanding of thermal pulses formation in low-temperature calorimeters can contribute in their performance improvement, in identification of low energy events and in optimized choice of geometry and materials for future experiments.

We performed dedicated measurements with TeO_2 crystals read-out by Ge-NTDs hosted in copper holder and in acrylic holder. From the load curves acquired at temperatures from 10 to 30 mK we identified the main physical parameters which determine the thermalization processes. For copper system we measured the main conductance of glue between crystals and holder ($\propto T^3$, being an interface conductance) and the subdominant NTD's electron-phonon decoupling ($\propto T^4$, in agreement with metal hot electron model). For acrylic system we measured the conductance of NTDs read-out wires ($\propto T^{2.4}$).

The different materials of the two holders strongly affect how calorimeters are linked to thermal bath, playing a crucial role in the shape and characteristic times constants of the thermal pulses, that are different in the two frames. We are developing a model able to describe the pulse shapes. For copper system, the model can describe the pulse shape and correlate the time constants with a RC pole (for rising edge) and with a C/G pole (for decay tail).

Finally combining the analysis on load curves and pulse shape we can estimate the temperature dependence of the specific heat of NTDs.

Session: Poster P4-4: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Victoria Wagner - Technische Universität München

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Accurate Calibration of Nuclear Recoils at the 100 eV Scale Using Neutron Capture

Victoria Wagner on behalf of the CRAB project

Technische Universität München

Searches for light dark matter (DM) and studies of coherent elastic neutrino-nucleus scattering (CEvNS) imply the detection of nuclear recoils in the 100 eV range. However, an absolute energy calibration in this regime is still missing. The CRAB project proposes a method based on nuclear recoils induced by the emission of an MeV gamma following thermal neutron capture. A detailed feasibility study has shown that this method yields distinct nuclear recoil calibration peaks at 112 eV and 160 eV above background for tungsten. In the first phase, the CRAB project foresees to perform a nuclear recoil calibration of cryogenic $CaWO_4$ detectors read-out by TES, similar to the detectors used in CRESST and NUCLEUS. The low power TRIGA reactor in Vienna provides a clean beam of thermal neutrons well suited for such a measurement. Newly developed and compact sub-keV calibration sources based on X-ray fluorescence (XRF) provide an absolute energy calibration during operation at the research reactor as well as in the DM/ CEvNS experiments. In the second phase, additional tagging of the photons produced in the de-excitation process will allow to extend the calibration method to even lower energies and to a wider range of detector materials, such as Ge. Combined with the XRF source, CRAB may allow to measure energy quenching in the sub-keV regime.

Session: Poster P4-5: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Andrew Jastram - Texas A&M University

Active Inner Veto for Improved Dark Matter Search and Neutrino Detection Sensitivity

Andrew Jastram on behalf of the MINER collaboration

Texas A&M University

Many projects are underway aiming to experimentally detect the elusive dark matter candidate particle, the WIMP. Furthermore, some of these technologies are leveraging their strengths to explore other rare event phenomena, such as Coherent Elastic Neutrino-Nucleus Scattering (CEvNS). Both avenues require aggressively combating sources of background events that are detrimental to the overall sensitivity of the experiment. Two particularly troublesome sources of background events in dark matter and other rare event searches are Compton scattered gammas and events due to radon contamination on detectors and surrounding materials. This talk describes the design, fabrication, and performance of a novel active veto detector instrumented with phonon sensors that immediately surrounds the primary detector to substantially reduce these backgrounds. The first prototype has been commissioned and is currently operating as part of the MINER (Mitchell Institute Neutrino Experiment at Reactor) detector payload.

Session: Poster P4-6: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Nader Mirabolfathi - Texas A&M University

Anisotropy of quantized electronic excitations in semiconductors for directional dark matter searches

Nader Mirabolfathi, Fedja Kadribasic, Nader Mirabolfathi, Kai Nordlund, Andrea E. Sand, Eero Holmström, and Flyura Djurabekova

Texas A&M University

Presented by Matti Heikinheimo

We study the quantum effects that are associated with the nuclear recoil electronic excitations in semiconductor crystals. Our studies exhibit a rate modulation in very low threshold semiconductor detectors, for dark matter (DM) mass 1 GeV/c^2, that is correlated with the target nucleus recoil direction. This anisotropic quantum excitation threshold can be used to perform directional DM search for the range of DM mass that is out of reach for conventional gaseous directional detectors. We will present expected diurnal and annual event rate modulation with conventional Ge/Si semiconductors in a fixed lab location and compare with expected solar neutrino coherent scattering rates.

Session: Poster P4-7: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Beatrice Mauri - CEA/IRFU/DPhP

BASKET innovative bolometers with MMCs for the CEνNS detection

Beatrice Mauri

CEA/IRFU/DPhP

The Coherent Elastic Neutrino-Nucleus Scattering (CEνNS) detection represents an experimental challenge because of its standalone signature: a nuclear recoil with energy typically in range of tens of eV to few tens of keV with some dependence on the chosen target nuclei.

One of the main features of CEνNS is its cross-section, 10 to 1000 times greater if compared to the standard neutrino detection channels, such as the Inverse Double Beta decay.

BASKET (Bolometers At Sub keV Energy Threshold) is an R&D project aiming at the development of cryogenic calorimeters for the CEνNS detection, able to maintain the background noise below the expected signature while being operated in above ground conditions and in close vicinity to a nuclear reactor.

Our goal is to reach an energy threshold of the order of 10 eV for a crystal mass of a few grams ($\sim$ 1 cm^3) and a response time short enough ($\sim$ 0.1-1 ms) to have a reasonable pile-up discrimination.

We coupled different thermal sensors to Li_2WO_4 crystals; in this poster I will present the results obtained with Magnetic Metallic Calorimeters (MMCs).

Session: Poster P4-8: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Hawraa Khalife - IRFU (CEA Paris-Saclay)

BINGO: Bi-Isotope $0\nu2\beta$ Next Generation Observatory

Hawraa Khalife, on behalf of the BINGO group

IRFU (CEA Paris-Saclay)

Neutrinoless double-beta decay ($0\nu\beta\beta$) is a hypothetical rare nuclear transition. Its observation would provide an important insight about the nature of neutrinos (Dirac or Majorana particle) demonstrating that the lepton number is not conserved. BINGO aims to set the technological and conceptual grounds for future bolometric $0\nu\beta\beta$ experiments. It is based on a dual heat-light readout, i.e. a main absorber embedding the double-beta decay isotope faced by a light detector. Dual heat-light readout helps to reject the α background component, thanks to the lower light output of α's compared to β/γ's. BINGO will study two of the most promising isotopes: ^{100}Mo embedded in Li_2MoO_4 and ^{130}Te embedded in TeO_2. BINGO's proposed technology aims at reducing dramatically the background in the region of interest, thus boosting the discovery sensitivity of $0\nu\beta\beta$. This can be achieved by fulfilling the following goals: (i) increasing the light detector sensitivity thanks to Neganov-Luke amplification; (ii) having a revolutionary detector assembly that will reduce the total surface radioactivity contribution; (iii) using an active shield, based on $ZnWO_4$ or BGO scintillator with bolometric readout, to suppress the external gamma background. The proposed solutions will have a high impact on next-generation bolometric tonne-scale experiments, like CUPID.

In this poster we present the first results on innovative light detectors and on the bolometric veto.

Session: Poster P4-9: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Sae Woo Nam - NIST

Constraints on Dark Photon Dark Matter from LAMPOST using superconducting nanowire detectors

Jeff Chiles, Ilya Charaev, Asmina Arvanitaki, Mash Baryakhtar, Junwu Hwang, Robert Lasenby, Ken Van Tilburg, Alexana Roshko, George Burton, Marco Colangelo, Sae Woo Nam, Karl Berggren

Discovering the nature of dark matter is one of the most important goals of current particle physics. Light bosonic particles such as the dark photon are well-motivated candidates. We report on our proof-of-concept search for dark photon dark matter in the eV mass range via coherent absorption in a multi-layer dielectric haloscope. Using a superconducting nanowire single photon detector (SNSPD), we are able to acheive efficient standard photon detection with extremely low background count rate. We will report our progress towards setting new limits for dark photon dark matter mixing parameter in the mass range around 0.8 eV. Our preliminary performance indicates that with feasible upgrades our approach could probe significant new parameter space for dark photon and axion dark matter in the meV to 10 eV mass range.

Session: Poster P4-10: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Matthew Lee - Texas A&M University

Contact-free readout concept and recent progress toward single-electron resolution large-mass semiconductor detectors

M. Lee, V. Iyer, N. Mirabolfathi, G. Agnolet, H. Chen, A. Jastram, F. Kadribasic, V. K. S. Kashyap, A. Kubik, R. Mahapatra, B. Mohanty, H. Neog, M. Platt

Texas A&M University

Semiconductor detectors, particularity those using CCD or Neganov-Trofimov-Luke (NTL) assisted phonon-mediated techniques are the technologies of choice for the experiments seeking rare and very low energy interactions such as low mass dark matter or coherent elastic neutrino nucleus scattering (CEνNS). The ultimate sensitivity reach of the current detector design is hindered by a stochastic carrier leakage that seems to be primarily due to the particular detector contact architecture at use. We will present a new semiconductor bias and readout design wherein the bias electrodes do not have a physical contact with the substrate. We will present recent progress toward single-carrier excitation in large mass Si or Ge of $\sim$ 100 g using this novel design. We will also present the application of this novel technique for fast and non-pervasive prescreening of semiconductor crystals for defect and impurity concentration evaluation.

Session: Poster P4-11: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Karoline Schaeffner - Max-Planck Institut für Physik

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COSINUS – the first NaI-based low-temperature detector for direct dark matter detection

Karoline Schaeffner

Max-Planck Institut für Physik

Dark matter constitutes a main ingredient of the energy content of the Universe, however its nature remains undiscovered to this date.

Most prominently, the positive claim from DAMA/LIBRA, since more than two decades, creates a controversial situation in the field of direct dark matter detection. For a fully model-independent investigation of the nature of the DAMA/LIBRA results, experiments which use the same material as DAMA/LIBRA, sodium iodide (NaI) are absolutely necessary.

COSINUS will use crystals of NaI operated as cryogenic scintillating calorimeters at milli-Kelvin temperatures which provide a simultaneous and independent measurement of both the temperature signal and the scintillation light signal caused by a particle interaction. Since the amount of produced light depends on the particle type (light quenching), this detection technique makes COSINUS detectors incisive probes for the identification of the type of interacting particle in NaI crystals, an information which is inaccessible by other NaI-based experiments.

In this talk I will explain the challenges of NaI absorbers being operated at mK temperatures and introduce in detail the two detector designs we developed in order to optimize the signal readout from particle interactions in NaI using tungsten transition edge sensors. I will report on the installation of the experimental setup at the Gran Sasso underground laboratory which will begin in summer 2021.

Session: Poster P4-12: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Antoine Armatol - CNRS-IJCLAB

CUPID: the next generation neutrinoless double beta decay experiment

Antoine Armatol on behalf of the CUPID collaboration

CEA-IRFU

CUPID is a next-generation tonne-scale bolometric neutrinoless double beta decay experiment to probe the Majorana nature of neutrinos and discover Lepton Number Violation if the effective neutrino mass is greater than 10 meV. CUPID will be built on experience, expertise and lessons learned in CUORE, and will be installed in the current CUORE infrastructure in the Gran Sasso underground laboratory. The CUPID detector technology, successfully tested in the CUPID-Mo experiment, is based on scintillating bolometers of Li_2MoO_4 enriched in the isotope of interest ^{100}Mo. In order to achieve its ambitious science goals, CUPID aims to reduce the backgrounds in the region of interest by a factor 100 with respect to CUORE. This performance will be achieved by introducing the high efficiently alpha/beta discrimination demonstrated by the CUPID-0 and CUPID-Mo experiments, and using a high transition energy double beta decay nucleus such as ^{100}Mo to minimize the impact of the gamma background. CUPID will consist of about 1500 hybrid heat-light detectors for a total isotope mass of 250 kg. The CUPID scientific reach is supported by a detailed and safe background model that uses CUORE, CUPID-Mo and CUPID-0 results. The required performance in terms of energy resolution, alpha rejection factor and crystal purity have already been demonstrated and will be presented.

Session: Poster P4-13: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Arshjot Kaur - CEA Saclay

Determination of fractional electron capture probabilities by means of Metallic Magnetic Calorimeters

Arshjot Kaur [1], Martin Loidl [1], Dirk Arnold [2], Jörn Beyer [3], Christian Enss [4], Sebastian Kempf [5], Karsten Kossert [2], Ole J. Nähle [2], Michael Paulsen [3,4], Philipp Chung-On Ranitzsch [2], Matias Rodrigues [1], Mathias Wegner [5]

[1] CEA, LIST, Laboratoire National Henri Becquerel, Bat. 602 - PC111, CEA-Saclay, 91191 Gif-sur- Yvette Cedex, France
[2] Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany
[3] Physikalisch-Technische Bundesanstalt (PTB), Abbestrasse 2-12, 10587 Berlin, Germany
[4] Kirchhoff-Institute for Physics, Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany
[5] Institute for Micro- and Nanoelectronic Systems, Karlsruher Institute of Technology, Hertzstraße 16, 76187 Karlsruhe, Germany

Electron capture (EC) is probably the least well-studied radioactive decay mode, with the exception of 163Ho. Apart from this nuclide important in neutrino physics, EC nuclides play an increasingly important role in nuclear medicine, and precise decay data on EC are also needed in radionuclide metrology and to assess the low energy background in various nuclear physics experiments. However, precise and rather complete experimental data sets on EC are scarce and theoretical predictions encounter similar difficulties as in beta decay.

The European metrology research project MetroMMC proposes to establish EC decay data, experimentally by means of MMCs and by theoretical calculation, on pure EC nuclides as well as EC nuclides with additional decay branches. MMCs were optimized both for measurements with the radionuclides in 4π geometry and for quantitative low energy X-ray spectrometry.

In this poster we will focus on measurements of EC nuclides embedded in metallic absorbers coupled to MMC sensors, with the aim of determining fractional capture probabilities. Special attention will be paid to both the importance and the difficulties of radionuclide sample preparation and to the difficulties of data analysis, in particular for EC/gamma decays.

Session: Poster P4-14: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Geon-Bo Kim - Lawrence Livermore National Laboratory

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Determining the Sm-146 half-life using Metallic Magnetic Calorimeters for Early Solar System Chronology

Geon-Bo Kim [a], Alexander Kavner [b], Lee Bernstein [c], Stephen Boyd [d], Lars Borg [a], Robin Cantor [e], John Despotopulos [a], Owen Drury [a], Stephan Friedrich [a], Aaron Gallant [a], Andrew Jacobs [f], Igor Jovanovic [b], Peter Kunz [f], Anna Kwiatkowski [f], Dongwon Lee [a], Tobias Murböck [f], Nicholas Scielzo [a], Corliss Sio [a], Andrew Voyles [c], Coulter Walls [f]

[a] Lawrence Livermore National Laboratory, Livermore, CA 94550, USA
[b] University of Michigan, Ann Arbor, MI 48109
[c] Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA
[d] University of New Mexico, Albuquerque, NM 87131, USA
[e] Star Cryoelectronics, Santa Fe, NM 87508, USA
[f] TRIUMF, Vancouver, British Columbia V6T 2A3, Canada

The decay of ^{146}Sm to ^{142}Nd is used in chronological dating of planetary samples. The ^{146}Sm half-life has two controversial reported values of 68 ± 7 Ma and 103 ± 5 Ma, which translates into significant uncertainties in the ages of major solar system events that are primarily constrained by the ^{146}Sm – ^{142}Nd chronometer. We are preparing a definitive measurement of the ^{146}Sm half-life by decay energy spectroscopy, with known amounts of ^{146}Sm and ^{147}Sm fully enclosed inside a Au foil or two sapphire plates that are coupled to metallic magnetic calorimeters (MMCs). This approach simultaneously offers a detection efficiency close to 100%, high energy resolution of a few keV at the ^{146}Sm alpha decay energy, and the ability to measure the half-life from both the absolute activity of ^{146}Sm and its relative activity to ^{147}Sm. To assess uncertainties due to radioactive contaminations, ^{146}Sm is produced by two different methods, at TRIUMF laboratory by ^{146}Eu ($\tau^{1/2}$=4.6 d) implantation, and at the 88" Cyclotron at LBL by ^{139}La(^{11}B,4n)^{146}Sm reaction. Geant4 and signal simulations have been performed to investigate signal losses due to radioactive contaminations and indistinguishable pile-up signals. We will present recent achievements on ^{146}Sm production, source embedment methods, performance of the newly developed large sapphire-plate detector that handled 40 cps without significant performance degradation, and a demonstration experiment with pure ^{147}Sm sources that we have performed.

This work was supported by the LLNL-LDRD program under Project No. 20-LW-024. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. LLNL-ABS-821449

Session: Poster P4-15: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Jules Colas - CNRS Grenoble

Development of a contactless feedline KID detector on massive crystal for direct rare event searches

A. Monfardini [a], J. Goupy [a], J. Colas [b], M. Calvo [a], J. Billard [b], A. Juillard [b], L. Vagneron [b], M. De Jesus [b], A. Catalano [a], F. Levy-Bertrand [a]

[a] Institut Néel - CNRS and University Grenoble Alpes - Grenoble, France
[b] IP2I - CNRS and University of Lyon 1 - Lyon, France

Presented by Jules Colas

In many experiments searching for rare events, such as RICOCHET or EDELWEISS, the expected signal arises from the effect of a nuclear recoil inside a semiconductor material kept at cryogenic temperature. To achieve the best possible sensitivity, a large total mass is required as well as the ability to identify particles using multiple channel sensing, such as heat and ionisation. Highly multiplexable sensors such as KID appear to be very promising in large mass experiments. During the LTD18 conference we have presented a contactless coupling between the feedline and the resonator, lying on a massive absorber. In that way the heat measurement is achieved with a minimal and well controlled thermal link to the reservoir (eg. the cryostat). On top of that, we prevent phonons from being absorbed in other detector elements than the resonator. We investigate here the effect of varying the superconducting material on the energy resolution and sensitivity. We present different results obtained using the same resonator mask, but an improved detector holder and three superconducting materials: a) a mono-layer of pure Al; b) a double-layer of Al-Ti and c) a triple-layer of Al-Ti-Al. Adding Titanium allows us to lower the critical temperature of pure Aluminum and thus the energy gap of the multilayer material. That means that more phonons can get absorbed in our device potentially leading to a better sensitivity and energy resolution.

Session: Poster P4-16: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Jules Colas - IP2I Lyon

Development of a data processing pipeline for RICOCHET

Jules Colas on behalf of the Ricochet collaboration

IP2I Lyon

The RICOCHET reactor neutrinos observatory is planned to be installed at Laue Langevin Institute (ILL) starting in mid-2022. The scientific goal of the RICOCHET international collaboration is to perform a low-energy and percentage-precision CEvNS measurement in order to explore exotic physics scenarios beyond the standard model. To that end, RICOCHET will host two cryogenic detector arrays : the CRYOCUBE (Ge target) and the Q-ARRAY (Zn target), both with unprecedented sensitivity $\mathcal{O}(10)$ eV nuclear recoils.

With its thirty multi-instrumented crystals (heat and charge collection measurements) the CRYOCUBE requires an efficient processing algorithm specifically designed for low energy searches and multi-channel detectors. The architecture of the readout is designed to handle the synchronisation of all $/sim150$ channels with a fast muon veto using a continuous sampling of all channels at a rate of 20 kHz.

We present here the future RICOCHET processing software which relies on a matched filter approach to find and simultaneously fit heat and ionisation pulses at lowest energy scales (and thus lowest amplitudes). It is presently used for the CRYOCUBE research and development, and its performance on actual data as well as simulated ones is also discussed. Each part of the algorithm is described : the matched filter, the trigger and the fitting algorithm.

Session: Poster P4-17: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Andreas Erhart - Technical University of Munich

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Development of an Organic Plastic Scintillator based Muon Veto Operating at Sub-Kelvin Temperatures for the NUCLEUS Experiment

A. Erhart, V. Wagner, L. Klinkenberg, T. Lasserre, D. Lhuillier, C. Nones, R. Rogly, V. Savu, R. Strauss, M. Vivier, on behalf of the NUCLEUS collaboration

Technical University of Munich

The NUCLEUS experiment aims to measure coherent elastic neutrino nucleus scattering of reactor anti-neutrinos using cryogenic calorimeters. Operating at an overburden of 3m.w.e., muon-induced backgrounds are expected to be dominant. For this reason, an efficient muon veto with a muon detection efficiency of more than 99% is indispensable and shall be achieved in NUCLEUS with a compact cube assembly of plastic scintillator panels. In order to prevent a large unshielded area where the cryostat enters the shielding arrangement without unnecessarily increasing the induced detector dead time, a novel and innovative concept has been investigated, consisting of a plastic scintillator based disc-shape active muon veto operating inside the NUCLEUS cryostat at sub-Kelvin temperatures. The required verification of the key physical aspects of the intended cryogenic muon veto detector concept by investigating its low temperature behavior led to the first reported measurements of organic plastic scintillators at sub-Kelvin temperatures. The functionality of the principal scintillation process of organic plastic scintillators at sub-Kelvin temperatures has been confirmed. On the basis of these findings, a disc-shape plastic scintillator based muon veto equipped with wavelength shifting fibers and a silicon photomultiplier to guide and detect the scintillation light has been developed. The NUCLEUS cryogenic muon veto will be the first of its kind to be operated at sub-Kelvin temperatures.

Session: Poster P4-18: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Lorenzo Pagnanini - INFN-LNGS & GSSI

Development of cryogenic calorimeters to measure the spectral shape of Indium-115 beta decay

E. Celi [1,2], Z. Galazka [3], S. Nagorny [4], L. Pagnanini [1,2], S. Pirro [2], A. Puiu [1,2]

[1] Gran Sasso Science Institute, I-67100, L'Aquila - Italy
[2] INFN - Laboratori Nazionali del Gran Sasso, Assergi (L'Aquila) I-67100 - Italy
[3] Leibniz-Institut für Kristallzüchtung, Max-Born-Str. 2, 12489 Berlin - Germany
[4] Queen's University, Physics Department, K7L 3N6, Kingston (ON), Canada

Presented by Lorenzo Pagnanini

The spectral shape of forbidden beta-decays is a crucial benchmark for nuclear physics calculations and has important implications also for astroparticle physics experiments.

In the list of interesting isotopes to be measured, Indium-115 is one of the most suitable due to the relatively high Q-value (497.954 keV) and half-life (4.41 x 10^{14} yr). We propose to exploit a cryogenic calorimeter based on indium oxide crystal to perform a high-precision measurement of the decay energy spectrum. Such a detector is the first step for building an Array of Cryogenic Calorimeter to Evaluate Spectral Shapes (ACCESS). In this contribution, we present the project outline and the results obtained with a preliminary test.

Session: Poster P4-19: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Kai Nordlund - University of Helsinki

Effect of Crystal Defects on The Expected Dark Matter Signal in Phonon Mediated Detectors

Kai Nordlund, Nader Mirabolfathi, Fedja Kadribasic, Flyura Djurabekova, Matti Heikinheimo, Kimmo Tuominen, Sebastian Sassi

University of Helsinki

Frenkel Point defects are expected for the recoil energies larger than threshold displacement energy (TDE) in solid state detectors. The energy stored in these stable defects will be left undetected leading to a missing energy for recoils larger than TDE. We will present the effect of defect creation in solid state phonon-mediated detectors with $\sim$ 10 eV threshold on the expected DM or coherent elastic neutrino-nucleus scattering spectrum. Our studies exhibit a very clear distortion in expected rates from low mass dark matter that strongly depends on the crystal type. We will present current phonon mediated Si, Ge, diamond and sapphire detectors that can benefit from this effect to discriminate nuclear recoil dark matter interactions from backgrounds.

Session: Poster P4-20: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Dounia Helis - CEA/IRFU/DPhP

First dark matter searches with the CUPID-Mo detectors

Dounia Helis on behalf of the CUPID-Mo Collaboration

CEA/IRFU/DPhP

The CUPID-Mo experiment is an array of 20 cryogenic scintillating bolometers searching for neutrinoless double-beta decay ($0\nu\beta\beta$) of ^{100}Mo based on enriched $^{100}Li_2MoO_4$ crystals coupled to germanium light detectors working at 20 mK. The experiment has collected data from spring 2019 to summer 2020 at Laboratoire Souterrain de Modane (France). The CUPID-Mo experiment achieved its goal by setting a new world-leading limit on the half-life of $0\nu\beta\beta$ decay of ^{100}Mo ($T_{1/2}$ 1.5 x 10^{15} yr at 90% C.L.) with 2.16 kg.yr of physics data. Furthermore, CUPID-Mo is also suitable for other rare events searches. Exploiting the presence of ^{7}Li in the crystals, we can perform a dark matter search with the CUPID-Mo detectors. We carried out a low energy analysis to lower the energy threshold of the detectors up to the conservative threshold of 20 keV (analysis threshold). In this poster, we will present the preliminary analysis on 0.2 kg.yr of data using the 10 best performing $^{100}Li_2MoO_4$ crystals to search for WIMPs (Weakly Interactive Massive Particles) nuclear recoils on 7Li. Despite the relatively high energy threshold, we could set a competitive limit on the spin dependent interactions with proton cross-section for WIMP masses higher than 10 GeV.

Session: Poster P4-21: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Stefanos Marnieros - IJCLab - CNRS

Ge bolometers with high impedance TES for the EDELWEISS dark matter experiment

Stefanos Marnieros

IJCLab - CNRS

The EDELWEISS collaboration aims for direct detection of light dark matter using germanium cryogenic detectors with low threshold phonon sensor technologies and efficient charge readout designs. We describe here the development of 200-g Ge bolometers equipped with high impedance thermistors based on a Nb_xSi_{1-x} alloy TES. In order to be optimized with the read-out electronics implemented into the EDELWEISS cryostat, the TES is spiral shaped, allowing its impedance to match with JFET front-end amplifiers. The fabrication process of these devices and their sensitivity optimization to out-of-equilibrium phonons is detailed. We report on the performance of a first prototype that was calibrated using ^{71}Ge activation by neutrons at the LSM underground laboratory. Future development of these detectors for dark matter search is discussed.

Session: Poster P4-22: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Jean-Baptiste Filippini - IP2I/IN2P3/CNRS

High Impedance, low dissipation, and ultra-low noise HEMT-based 1K front-end electronics and readout for the CryoCube detector array of the future RICOCHET experiment

Jean-Baptiste Filippini

IP2I/IN2P3/CNRS

The RICOCHET reactor neutrinos observatory is planned to be installed at the Laue Langevin Institute (ILL) in France starting mid-2022. The scientific goal of the RICOCHET experiment is to perform a low-energy and high precision CEvNS measurement in order to explore exotic physics scenarios beyond the standard model. RICOCHET will host two cryogenic detector arrays: the CRYOCUBE (Ge target) and the Q-ARRAY (Zn target), operated at 10 mK.

The 1 kg Ge CryoCube will be divided in 27 Ge crystals of 38g instrumented with NTD-Ge thermal sensors and charge collection electrodes for a simultaneous heat and ionization readout to identify and reject the overwhelming electromagnetic backgrounds (gamma, beta, x-rays).

We present the status of the front-end electronics developed for the CryoCube and its associated readout chain. The first stage of amplification is made of High Electron Mobility Transistor (HEMT) developed by CNRS/C2N laboratory optimized to achieve ultra-low noise performance at 1K with a dissipation as low as 15 pW per channel.

Our noise model predicts that 10 eV heat and 20 eVee baseline resolution are feasible with a high dynamic (10eV-10MeV deposited energy range) thanks to looped amplification schemes. Such resolution allows for high discrimination between nuclear and electron recoils at low threshold. First results obtained with prototype detectors and electronics will be presented.

Session: Poster P4-23: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Michael Paulsen - PTB Berlin, KIP Heidelberg

High-resolution beta spectrometry of Tc-99 employing Metallic Magnetic Calorimeters

Michael Paulsen [1,2], Philipp Chung-On Ranitzsch [3] , Martin Loidl [4], Matias Rodrigues [4], Jörn Beyer [1], Karsten Kossert [3], Ole J. Nähle [3], Sebastian Kempf [5], Mathias Wegner [5], Dirk Arnold [3], Christian Enss [2]

[1] Physikalisch-Technische Bundesanstalt (PTB), Abbestrasse 2-12, 10587 Berlin, Germany
[2] Kirchhoff-Institute for Physics, Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany
[3] Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany
[4] CEA, LIST, Laboratoire National Henri Becquerel, Bat. 602 - PC111, CEA-Saclay, 91191 Gif-sur-Yvette Cedex, France
[5] Micro- and Nanoelectronic Systems, Karlsruher Institute of Technology, Hertzstraße 16, 76187 Karlsruhe, Germany

To date, most beta spectra were measured with semiconductor detectors, scintillation devices or magnetic spectrometers. These methods suffer from rather low energy resolutions compared to what is achievable with LTD calorimeters. However, precise beta spectra measurements are important for radionuclide metrology, the validation of theoretical calculations and other applications. MMCs with the radionuclide sample embedded in a 4π absorber have proven to be among the best beta spectrometers in terms of energy resolution and threshold, linearity and detection efficiency, notably for low energy beta transitions. In this work, the beta spectrum of Tc-99 (Q- = 297.5 keV) that was independently measured using optimized MMC detectors in two laboratories is presented. The measurements had differences both concerning their experimental setups (sample and absorber preparations, MMC designs, readout SQUIDs, energy calibration sources, detector modules, cryogenic techniques) and data analysis codes. Both spectra feature energy resolutions of approx. 100 eV and two orders of magnitude lower energy thresholds ($\sim$0.5 keV) compared to previously published measurements. The independent results show excellent agreement and suggest a spectrum shape which deviates significantly from hitherto theoretical calculations and semi-empirical extrapolations at lower energies (50 keV). Furthermore, the data analysis codes were validated by one group evaluating the measurement data of the other group.

Session: Poster P4-24: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Guido Fantini - Sapienza Università di Roma

Machine learning techniques for pile-up rejection in cryogenic calorimeters

Guido Fantini on behalf of the CUPID Collaboration

Sapienza Università di Roma

CUPID (CUORE Upgrade with Particle IDentification) is a foreseen tonne-scale array of Li_2MoO_4 (LMO) cryogenic calorimeters with double readout of heat and light signals. Its scientific goal is to fully explore the inverted hierarchy of neutrino masses in the search for neutrino-less double beta decay of ^{100}Mo. Pile-up of standard double beta decay of the candidate isotope is a relevant background. We generate pile-up heat events via injection of Joule heater pulses with a programmable waveform generator in a small array of LMO crystals operated underground in the Laboratori Nazionali del Gran Sasso, Italy. This allows to label pile-up pulses and control both time difference and underlying amplitudes of individual heat pulses in the data. We present the performance of supervised learning classifiers on data and the attained pile-up rejection efficiency.

Session: Poster P4-25: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Valentina Dompè - GSSI / La Sapienza Università di Roma

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Neutrinoless double beta decay search of 128-Te with the CUORE TeO2 cryogenic bolometers

Valentina Dompè on behalf of the CUORE Collaboration

GSSI / La Sapienza Università di Roma

The CUORE experiment is a ton-scale array of TeO2 cryogenic bolometers located at the underground Gran Sasso National Laboratories of INFN, in Italy. The CUORE detector consists of 988 crystals operated as source and detector at a base temperature of $\sim$10 mK. Such cryogenic temperature is reached and maintained by means of a custom built cryogen-free dilution cryostat, designed with the aim of minimizing the vibrational noise and the environmental radioactivity.

The primary goal of CUORE is the search for neutrinoless double beta decay of 130-Te, but thanks to its large target mass and ultra-low background it is suitable for the study of other rare processes as well, such as the neutrinoless double beta decay of 128-Te. This tellurium isotope is an attractive candidate for the search of this process, due to its high natural isotopic abundance of 31.75

As the first ton-scale infrastructure operating cryogenic TeO2 bolometers in stable conditions, CUORE is able to achieve a factor 10 higher sensitivity to the neutrinoless double beta decay of this isotope with respect to past direct experiments.

Session: Poster P4-26: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Holger Kluck - Institute of High Energy Physics (HEPHY) of the Austrian Academy of Sciences

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NUCLEUS – searching for coherent neutrino nucleus scattering at lowest energies

H. Kluck, on behalf of the Nucleus Collaboration

Institute of High Energy Physics (HEPHY) of the Austrian Academy of Sciences

Coherent neutrino-nucleus scattering (CEvNS) is a promising new tool in the toolbox of electroweak precision measurements at low q-transfer. It will enables precise measurements of standard model (SM) physics like the running of the Weinberg angle but also the search for new physics beyond the SM like sterile neutrinos.

The multi-phased NUCLEUS experiment aims for the first fully coherent CEvNS detection at a new experimental site, the Very Near Site (VNS), between the two 4 GWth reactor cores of the Chooz power plant. To be competitive in this challenging environment of a shallow underground site of $\mathcal{O}$(4 m w.e.) rock overburden [1], NUCLEUS developed the novel concept of fiducialised cryogenic bolometers based on $CaWO_4$ monocrystals operated at $\mathcal{O}$(10 mK). The signature of a CEvNS event will be a nuclear recoil at the 10eV-scale. Already in its prototype phase, NUCLEUS successfully demonstrated an unprecedented low detection threshold of 19.7 eV [2]. Currently, the installation of the first phase of NUCLEUS with 10 g of target mass at the VNS is under preparation.

In this contribution, we will first introduce NUCLEUS. Afterwards, we will report its current state in terms of detector development and characterisation of the VNS and its backgrounds. Finally, we will give an outlook to the future of NUCLEUS.

[1] G. Angloher et al., Eur.Phys.J. C79.12 (2019) 1018
[2] R. Strauss et al., Phys.Rev. D96.2 (2017) 022009

Session: Poster P4-27: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Thomas Salagnac - IP2I Lyon

Optimization and performance of the CryoCube detector for the future Ricochet low-energy neutrino experiment

Thomas Salagnac, Jules Colas, on behalf of the Ricochet collaboration

IP2I Lyon

Presented by Thomas Salagnac

The RICOCHET reactor neutrinos observatory is planned to be installed at Laue Langevin Institute starting in mid-2022. The scientific goal of the RICOCHET collaboration is to perform a low-energy and percentage-precision CEvNS measurement in order to explore exotic physics scenarios beyond the standard model. To that end, RICOCHET will host two cryogenic detector arrays : the CRYOCUBE (Ge target) and the Q-ARRAY (Zn target), both with unprecedented sensitivity O(10) eV nuclear recoils.

The CryoCube, which is the subject of this poster, will be composed of 27 Ge crystals of 30g instrumented with NTD-Ge thermal sensor as well as aluminum electrodes operated at 10 mK in order to measure both the ionization and the heat energies arising from a particle interaction. To be a competitive CENNS detector, the CryoCube array is designed to follow the following specifications : a low energy threshold ($\sim$50 eV), the ability to identify and reject with a high efficiency the overwhelming electromagnetic backgrounds (gamma, betas, X-rays) and a sufficient payload ($\sim$1kg).

In this poster we present the electro-thermal modeling and the electrostatic simulations of the CryoCube detector that lead to the optimization of the heat and ionization readouts, respectively. We present our two designs, the so-called planar detector with only 2 electrodes, and the fully interdigitated detector with 4 electrodes.The poster will also include some first experimental results.

Session: Poster P4-28: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Lucia Canonica - Max-Planck Institut für Physik

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Performance of cryogenic diamond detectors for low-mass dark matter searches

L Canonica, A. H. Abdelhameed, A. Bento, E. Bertoldo, A. Bertolini, N. Ferreiro Iachellini, D. Fuchs, A. Garai, D. Hauff, M. Mancuso, A. Nilima, F. Petricca, F. Proebst, F. Pucci, J. Rothe

Max-Planck Institut für Physik

Despite the multiple and convincing evidence of the existence of Dark Matter (DM) in our Universe, its detection is still one of the most pressing questions in particle physics. For this reason, in recent years a consistent fraction of the scientific community started to explore the possibility of detecting DM with mass in the sub-GeV range. Cryogenic diamond detectors have the potential to detect such light DM candidates thanks to their superior cryogenic properties. When operated as low-temperature calorimeters, diamonds could reach an energy threshold in the eV range and would allow for the exploration of novel parameters of the DM-nucleus cross section. Thanks to the recent developments in the growth processes of diamond crystals for Quantum Computing applications, nowadays we can benefit from the production of high-quality large-mass diamonds detectors, that can also be used for the scopes of the astroparticle physics field. In this contribution the preliminary performance of a lab-grown single crystal diamond operated as cryogenic detector with a Transition Edge Sensor will be presented. The potential of such new technology in the current landscape of DM searches will be also illustrated.

Session: Poster P4-29: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Serge Nagorny - Queen's University

Perspectives of scintillating bolometer with ZnO crystal as a detector for rare processes searches

A. Armatol [1], L. Dumoulin [2], A. Giuliani [2], H.Khalife [1], P. Loaiza [2], M. Madhukuttan [2], P. de Marcillac [2], S. Marnieros [2], S. Nagorny [3,4], C. Nones [1], E. Olivieri [2], L. Pagnanini [5,6], S. Pirro [6] , D. Poda [2], T. Redon [2], J.-A. Scarpaci [2], N. Song [3,4,7], A.C. Vincent [3,4,7], A. Zolotarova [2]

[1] IRFU, CEA, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France.
[2] Université Paris-Saclay, CNRS/IN2P3, IJCLab, 91405 Orsay, France.
[3] Department of Physics, Enigneering Physics and Astronomy,Queen's University, K7L 3N6, Kingston (ON), Canada
[4] Arthur B. McDonald Canadian Astroparticle Physics Research Institute, K7L 3N6, Kingston (ON), Canada
[5] Gran Sasso Science Institute, I-67100, L'Aquila (AQ), Italy
[6] INFN - Laboratori Nazionali del Gran Sasso, I-67100, Assergi (AQ), Italy
[7] Perimeter Institute for Theoretical Physics, N2L 2Y5, Waterloo (ON), Canada

Presented by Serge Nagorny

Recently, significant progress was achieved in studies of 2β processes that may occur in natural zinc isotopes, ^{64}Zn and 70Zn. The combination of two experimental approaches – measurements of 10 kg of high purity Zn metal sample with HPGe detector [1] and 10.5 kg of Zn^{82}Se scintillating bolometers in the framework of the CUPID-0 experiment [2] leads to lower limits on 2β processes of Zn isotopes in the range of 10^{21}-10^{22} y. However, experimental sensitivity to these processes could be further enhanced by a selection of the proper detector material and optimization of detector geometry. We report here results on the first performance test of scintillating bolometer with 1 cm^3 ZnO single crystal that contain 81% of zinc, the highest mass fraction among all previously used Zn-containing detectors. Moreover, due to the presence of ^{67}Zn with nonzero spin ($5/2^-$) and 4.1% isotopic abundance, this target material could be used to study the spin-dependent scattering of DM particles. Therefore, bounds on DM particles interaction cross-section obtained from these preliminary surface measurements and perspectives of ZnO crystal as a detector for 2β processes of natural zinc isotopes are discussed.

[1] F. Bellini, et al., Eur. Phys. J. C 81(2), 106 (2021). DOI: 10.1140/epjc/s10052-021-08918-y
[2] O. Azzolini, et al., Eur. Phys. J. C80(8), 702 (2020). doi:10.1140/epjc/s10052-020-8280-4

Session: Poster P4-30: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Alexandre Broniatowski - IJCLab, Université Paris-Saclay and CNRS/IN2P3, 91405 Orsay, France

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Phonon wind effects on charge collection in cryogenic Ge detectors for rare event searches at low energies

Alexandre Broniatowski, Stefanos Marnieros, Louis Dumoulin

IJCLab, Université Paris-Saclay and CNRS/IN2P3, 91405 Orsay, France

Cryogenic Ge detectors have long been known to exhibit a degraded charge collection efficiency for energy deposits within a thin dead layer underneath the collection electrodes (Shutt et al, NIM A 444, 340 (2000)), with potential implications for rare event searches, e.g. the coherent scattering of neutrinos by nuclei. We investigate the nature of this dead layer effect, based on experimental data for the depth profile of the charge collection efficiency for electron recoil events as a function of the deposited energy and the collection field, and for different types of collecting electrodes (implanted contact vs. aluminum electrode on top of an amorphous Ge or Si blocking layer). The data are analyzed in terms of a model for charge collection involving, in addition to the image-charges of the carriers in the electrode, the phonon wind effect, namely the drag of the carriers by the ballistic phonons radiated from the phonon hot spot at the site of energy deposition. Computer simulations according to this model reproduce to an excellent accuracy the depth profiles as obtained by experiment and their dependence on the aforementioned parameters. The dependence on the nature of the electrode in particular is explained by differences in the reflection properties of the ballistic phonons at the interface of the Ge crystal and the electrode, consistent with bolometric studies of phonon scattering at surfaces and interfaces (Northrop and Wolfe, PRL 52, 2156 (1984)).

Session: Poster P4-31: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Hugues Lattaud - Institut de Physique des 2 Infinis de Lyon

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Phonons and charge signal from IR and X excitation in the SELENDIS Ge cryogenic detector

Hugues Lattaud on the behalf of the EDELWEISS collaboration

Institut de Physique des 2 Infinis de Lyon

The aim of the SELENDIS program of the EDELWEISS collaboration is to develop lightweight (4 g) cryogenic germanium bolometers able to sustain biases in the 100V range in order to achieve sub-electron resolutions while keeping a uniform response for bulk events as required for Dark Matter searches. The electrodes of the prototypes are also equipped with a charge readout, making them ideal devices for the detailed characterization of the mechanism of charge creation and collection in the bulk of cryogenic germanium. Electron-hole pairs (e-h+) are produced in the bulk of the detector either by the injection of IR laser pulse, or of the K, L and M lines from ^{71}Ge decay. Preliminary results are used to compare these two modes of charge creation, an important step for the detailed characterization of Ge bolometer for their use in Sub-MeV Dark Matter searches.

Session: Poster P4-32: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Maurice Chapellier - IJCLab/IN2P3/CNRS

Polarized Bolometers, a future tool for neutrino physics?

Maurice Chapellier

IJCLab/IN2P3/CNRS

Polarized target was in the sixties used in nuclear and high energy studies with mass of below hundred grammes at temperature around 1K. With the development of very low temperature one could envisaged to built kg of polarized bolometer.It offers for neutrino physic the unic target with a variable parameter, a cross section depending on the angle between neutrino momentum and the axis of polarization.In this presentation we will recall the principles to polarize a solid with either brute force or better by microwave pumping . We will discuss briefly the range of neutrino energy in which a bolometric measurement is feasible .

Session: Poster P4-33: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Angelina Kinast - Technical University of Munich

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Radiopure CaWO4 Crystals for Direct Dark Matter Search with CRESST-III

Angelina Kinast for the CRESST Collaboration

Technical University of Munich

The CRESST-III (Cryogenic Rare Event Search with Superconducting Thermometers) experiment aims at the direct detection of dark matter particles via their elastic scattering off nuclei in a scintillating $CaWO_4$ target crystal. The $CaWO_4$ crystal is operated together with a light detector at mK temperature and read out by a TES. For many years $CaWO_4$ crystals have successfully been produced in-house at Technical University of Munich with a focus on high radiopurity which is crucial to reduce background originating from radioactive decays. In order to further improve the $CaWO_4$ crystals, an extensive chemical purification of the raw materials and the synthesized $CaWO_4$ powder has been performed. In addition, a temperature gradient simulation of the growth process and subsequently an optimization of the growth furnace with the goal to reduce the intrinsic stress was carried out. This poster presents results on the intrinsic stress in the $CaWO_4$ crystals and on the $CaWO_4$ powder radiopurity. A crystal grown from the purified material was installed in the current CRESST setup. The detector is equipped with an instrumented holder which is used to measure the alpha activity of the crystal. We present a preliminary analysis showing a significantly reduced intrinsic background from natural decay chains.

Session: Poster P4-34: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Sergio Manthey Corchado - INFN Roma

Status of BULLKID, an array of kinetic inductance detectors to search for Dark Matter.

Sergio Manthey Corchado, Martino Calvo, Laura Cardani, Nicola Casali, Ivan Colantoni, Angelo Cruciani, Daniele Delicato, Sergio Di Domizio, Joannes Goupy, Vincenzo Guidi, Helene Le Sueur, Maria Martinez, Andrea Mazzolari, Alessandro Monfardini, Valerio Pettinacci, Giorgio Pettinari, Marco Romagnoni, Marco Vignati, Jin Cheng Zhou

INFN Roma

Cryogenic sensors are used in experiments to detect low-energy nuclear recoils from dark matter or neutrino interactions.

Besides the record energy thresholds, the limit of current technologies in the low energy range resides mainly in the scale-up capabilities.

BULLKID is an R&D supported by the INFN to develop a new detector concept to reach relatively high target masses with high granularity by exploiting the multiplexing capability of Kinetic Inductance Detectors. The detector unit we are designing consists of an array of ~ 60 silicon absorbers sensed by phonon-mediated, microwave-multiplexed kinetic inductance detectors, with an energy threshold around 200 eV and a total target mass of around 20 g. The single detector unit will be engineered to ensure straightforward scalability to a future kg-scale experiment.

We present studies and tests of different KID geometries designed explicitly to optimise the signal conversion in BULLKID.

We also present the expected sensitivity to WIMP interactions for an experiment with ~ 1 kg year exposure. The ambition for BULLKID's technology is to reduce the background in the region of interest with respect to current experiments. Nevertheless, calculations show that, even under similar background conditions, current limits could be improved. The reason for this resides in the higher mass that can be achieved without loss in energy resolution.

Session: Poster P4-35: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Evgeniy Unzhakov - Petersburg Nuclear Physics Institute - NRC Kurchatov Institute

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$Tm_3Al_5O_{12}$ crystal as a perspective cryogenic detector for a solar axion search

A. H. Abdelhameed [1], S. V. Bakhlanov [2], P. Bauer [1], A. Bento [1,7], E Bertoldo [1], L. Canonica [1], A. V. Derbin [2], I. S. Drachnev [2], N Ferreiro Iachellini [1], D. Fuchs [1], D. Hauff [1], A. M. Kuzmichev [2], M Laubenstein [3], D. A. Lis [4], I. S. Lomskaya [2], M. Mancuso [1], V N. Muratova [2], S. Nagorny [5], S. Nisi [3], F. Petricca [1], F. Proebst [1], J Rothe [1], V. V. Ryabchenkov []6 , S. E. Sarkisov [6], D. A. Semenov [2], K A. Subbotin [4], M. V. Trushin [2], E. V. Unzhakov [2], E. V. Zharikov [4]

[1] Max-Planck-Institut für Physik, D-80805 München, Germany
[2] NRC Kurchatov Institute, Petersburg Nuclear Physics Institute, 188309 Gatchina, Russia
[3] INFN, Laboratori Nazionali del Gran Sasso, 67010 Assergi, Italy
[4] Prokhorov General Physics Institute of the Russian Academy of Sciences, 119991 Moscow, Russia
[5] Queen's University, Physics Department, K7L 3N6 Kingston, Canada
[6] NRC Kurchatov Institute, 123182 Moscow, Russia
[7] also at: Departamento de Fisica, Universidade de Coimbra, P3004 516 Coimbra, Portugal

Presented by Evgeniy Unzhakov

The problem of experimental detection of axions (or axion-like particles) remains extremely urgent, being related both to the fact that their detection would testify in favor of proposed solution to the strong CP problem, and also to the axion's ability to constitute all or at least a significant part of the dark matter.

The expected axion-nucleon coupling enables the resonant absorption or emission of axion in nuclear transitions of M1-type. This reaction can be used in laboratory to search for axion-induced resonant excitation of target nuclei by detecting the excess rate of gamma-quanta produced by the relaxation of a given excited state. Our experiment uses ^{169}Tm nuclide with 8.41 keV M1-type transition in order to probe for axions produced in the Sun via axion-electron and axion-photon interactions.

Previous axion searches with Tm target employed the layout with separate target and Si(Li) detector. Since 8.41 keV gamma-line of ^{169}Tm has a high rate of internal conversion it becomes prone to self-absorption of produced electrons by the target material, preventing the effective scaling of experimental setup. A newly developed approach based on ^{169}Tm-containing cryogenic bolometer solves this issue by introducing the target material into the active detector volume. The obtained results prove the feasibility of using the TmAlO crystal in a cryogenic calorimeter detector module and can be can be used to estimate the specifications for a future full-scale installation.

Session: Poster P4-36: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Ryan Fitzgerald - NIST

Towards absolute massic activity (Bq/g) using transition edge sensors

Ryan P. Fitzgerald [1], Bradley Alpert [1], Almamy Bah [1], Daniel T Becker [2], Denis E. Bergeron [1], Richard M. Essex [1], Kelsey Morgan [1,2], Svetlana Nour [1], Galen O'Neil [1] , Dan R. Schmidt [1], Gordon A. Shaw [1], Daniel Swetz [1], R. Michael Verkouteren [1], Daikang Yan [1,2]

[1] National Institute of Standards and Technology
[2] University of Colorado Boulder

We present a new paradigm for the primary standardization of radionuclides by Decay Energy Spectrometry (DES) of gravimetrically-prepared samples. Primary standards (or realizations) form the foundation for producing reference materials, calibration and measurement assurance programs, and nuclear data determinations. Absolute DES as a primary method is enabled by advances in Transition Edge Sensor (TES) design and novel radionuclide embedding methods that together produce high energy resolution and efficiency (up to 100 % for alpha decay) [Hoover et al. 2015]. Challenges for metrology-level DES measurements (uncertainties 0.5 %) include increasing TES speed, accounting for pulse pileup, and optimizing radiation absorbers.

A key challenge is that for many applications, the sample ($\approx$ 1 mg of solution) that is embedded in a metal foil on the TES chip must be gravimetrically linked to a starting material - e.g. Standard Reference Material (SRM). We weigh these small aqueous masses by difference, leveraging the recent redefinition of the kilogram in the SI to realize mass using an electrostatic force balance (EFB), which eliminates the need for calibration masses. Exquisite control over source preparation is achieved by incorporating the balance into an inkjet system. The system is tested by 4π liquid-scintillation counting of SRMs. Next-generation TES and EFB prototype data will be presented, along with simulation results for optimizing TES and radiation absorber design.

Session: Poster P4-37: Rare Events, Materials Analysis, Metrology, Other Applications

Schedule: Friday 23 July 01:05 - Friday 23 July 02:30

Submitted by: Ran Chen - Northwestern University

Transition Edge Sensor Chip Design of Modular CEvNS Detector for the Ricochet Experiment

Ran Chen, Enectali Figueroa-Feliciano

Northwestern University

Coherent elastic neutrino-nucleon scattering (CEvNS) offers a valuable approach in searching for physics beyond the Standard Model. The Ricochet neutrino experiment aims to perform a precision measurement of the CEvNS spectrum at the ILL nuclear reactor with cryogenic solid-state detectors. The experiment requires an array cryogenic thermal detectors, each with a mass of around 30 g and an energy threshold of 50 eV. Our goal is to build up a modular detector based on Transition Edge Sensors (TES) readout with microwave SQUID multiplexers. The design will not only fulfill the requirements for Ricochet, but also acts as a demonstrator for future neutrino experiments that will require thousands of macroscopic sensors and readout channels. In this poster, we will present our version 2 design of our modular TES chip, the predictions from our numerical modeling, and the latest testing results.

Session: Oral O5-1: Devices 2

Schedule: Tuesday 27 July 07:00 - Tuesday 27 July 07:30

Submitted by: Simon Bandler - NASA Goddard Space Flight Center

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Developments in Magnetic Microcalorimeters

Simon Bandler

NASA Goddard Space Flight Center

Arrays of magnetic microcalorimeters are being developed for a variety of applications, with arrays sizes varying from a few pixels to 100 kilo-pixels. In this presentation, as well as introducing the topic of magnetic calorimeters, I will provide an overview of some of the major areas currently being researched associated with magnetic calorimeters worldwide. I will describe work on optimization of performance and read-out and will also provide an overview of their use for different applications. I will provide my perspective on the relative strengths of this technology relative to other sensor technologies.

Session: Oral O5-2: Devices 2

Schedule: Tuesday 27 July 07:30 - Tuesday 27 July 07:45

Submitted by: Nikita Klimovich - Caltech

A high-efficiency superconducting upconverter at microwave frequencies

Nikita Klimovich [1], Shibo Shu [1], Byeong Ho Eom [2], Peter Day [2]

[1] California Institute of Technology, Pasadena, CA 91125, USA
[2] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA

We present experimental results of a high-efficiency superconducting microwave upconverter. The device operates by exploiting the nonlinear kinetic inductance of an NbTiN microstip line to produce the four-wave-mixing process of combining one low-frequency signal photon with two pump photons to produce an up-converted signal at a much higher frequency. Using a 5.4 GHz pump tone, we are able to convert incoming photons from a 1.75 GHz baseband to a 12.55 GHz passband with nearly perfect efficiency. When operated in this mode, we demonstrate the capability of our device to effectively lower the input noise temperature over some frequency range by moving that thermal noise out of band. We further discuss the underlying physical mechanisms, design, and fabrication of these devices, and present simulations for altered designs with increased bandwidth and operation at other frequencies.

Session: Oral O5-3: Devices 2

Schedule: Tuesday 27 July 07:45 - Tuesday 27 July 08:00

Submitted by: Noah Kurinsky - Fermilab

Single Charge and eV-Scale Resolution Detectors for SuperCDMS Dark Matter Searches

Noah Kurinsky on behalf of the SuperCDMS collaboration

Fermilab

The SuperCDMS collaboration has developed Si detectors in the 1-10 gram mass range that achieve resolutions below 3 eV and down to 0.01 electron-hole pairs at high voltage, and can be run in a continuous readout with lossless triggering down to 10 eV. These detectors are used for the SuperCDMS HVeV electron-recoil dark matter program, now embarking on a fourth science run at NEXUS, and nuclear recoil searches, which are now underway at CUTE. I will discuss the current and future R&D program for these detectors as well as recent results from SuperCDMS HVeV detectors run in multiple readout modes, and the implications for detector design and dark matter science. I will also touch upon current results from commissioning of the kg-scale SuperCDMS SNOLAB detectors.

Session: Oral O5-4: Devices 2

Schedule: Tuesday 27 July 08:00 - Tuesday 27 July 08:15

Submitted by: Kenneth Vetter - UC Berkeley

Novel Active Noise Cancellation Algorithms for CUORE

Kenneth Vetter

UC Berkeley

The Cryogenic Underground Observatory for Rare Events (CUORE) experiment is an ongoing search for neutrinoless double beta decay located at the Gran Sasso National Laboratory (LNGS) in Italy. Recent work has found that the CUORE calorimeters are sensitive to acoustic and seismic events originating from outside the detector at LNGS. To measure the effect of these mechanical disturbances on the calorimeter signals, microphones and accelerometers were installed around the CUORE cryostat. Existing adaptive algorithms which use auxiliary devices (e.g. accelerometers) to remove microphonic noise from high-purity germanium detectors may be changed to remove excess noise from low-temperature calorimeters. Here I will present how said changes can be implemented for noise removal from calorimeters instrumented with neutron transmutation doped (NTD) germanium detectors or transition edge sensors (TES) and demonstrate how this new adaptive algorithm improves the energy resolution of these devices.

Session: Oral O5-5: Devices 2

Schedule: Tuesday 27 July 08:25 - Tuesday 27 July 08:40

Submitted by: Matt Bradford - JPL / Caltech

Improved speed and sensitivity in low-G far-IR TES bolometers

M. Bradford, M. Kenyon, H. Nguyen, L. Foote, R. O'Brient, P. Echternach, H. Hui, D. Audley, J. van der Kuur, G. de Lange

We present improvements in a low thermal conductance (G) silicon nitride (SN) leg-isolated TES bolometer for space-borne far-IR spectroscopy. We have developed a new wet-release fabrication process to reduce the heat capacity of the devices compared to previous devices that were released using a XeF2 dry-etch process and showed excess heat capacity. Using a bias-step measurement technique, we have confirmed significant improvement in the bolometer's speed due to the reduction of the excess heat capacity. The devices also indicate a reduction in G for a given SiN leg geometry of 0.4 um wide by 0.5 um thick by 1 mm long over the previous dry-released devices. Electrical noise equivalent power (NEP) measurements indicate phonon-limited performance with sensitivity below $1\text{x}10^{-19}$ W / sqrt(Hz). Low-background performance is enhanced with a frequency-domain RF readout circuit provided by SRON, and we present multi-channel measurements including noise at low audio frequencies, an aspect required for the envisioned wide-field spectroscopic surveys.

Session: Oral O5-6: Devices 2

Schedule: Tuesday 27 July 08:40 - Tuesday 27 July 08:55

Submitted by: Daikang Yan - NIST, University of Colorado Boulder

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Transition-Edge Sensor Microcalorimeter Optimized for Hard X-ray Applications

Daikang Yan, Tejas Guruswamy, Joel C. Weber, Kelsey M. Morgan, Abigail L. Wessels, Douglas A. Bennett, Christine G. Pappas, John A. Mates, Johnathon D. Gard, Daniel T. Becker, Joseph W. Fowler, Daniel S. Swetz, Daniel R. Schmidt, Joel N. Ullom, Takuma Okumura, Tadaaki Isobe, Toshiyuki Azuma, Shinya Yamada, Shinji Okada, Tadashi Hashimoto, Orlando Quaranta, Antonino Miceli, Lisa M. Gades, Umeshkumar M. Patel, Nancy Paul, Guojie Bian, and Paul Indelicato

A transition-edge sensor (TES) microcalorimeter is a low-temperature detector that operates at the device's superconducting-to-normal transition edge. It offers high resolving power owing to the sharp resistance-temperature response and low operating temperature. For hard X-ray applications, a TES is often integrated with an added absorber, the size and material of which must be carefully designed to achieve the desired energy resolution, dynamic range, quantum efficiency (QE) and collecting area.

In this work, we present a TES microcalorimeter with added absorber optimized for 20-45 keV X-ray measurement. It is intended to measure the x-ray spectrum of highly charged muonic argon atoms, in order to study high-field quantum electrodynamics (QED) effects. The TES sensor is a molybdenum/gold bilayer, and the absorber is an evaporated-gold/electroplated-bismuth bilayer. We use gold to tune the total detector heat capacity, which sets the energy resolution and dynamic range, and add bismuth to increase QE. We show how the absorber bilayer thickness and area are optimized to achieve a resolving power of 2000 and QE of 84% at 20 keV and 20% at 45 keV. We also show that the thick (18 μm) electroplated bismuth layer does not have obvious photon energy loss, which is usually present in evaporated bismuth absorbers and leads to undesired non-Gaussian detector response. We also demonstrate the linearity and energy calibration accuracy of this detector at 44 keV.

Session: Oral O5-7: Devices 2

Schedule: Tuesday 27 July 08:55 - Tuesday 27 July 09:10

Submitted by: Sang Goon Kim - Institute for Basic Science

Light detector development for zero-neutrino double beta decay experiments

Sang Goon Kim [1], K.R. Woo [1,2], J.A. Jeon [1], S.R. Kim [1], D.H. Kwon [1,2], H.J. Lee [1], H.B. Kim [1], M.K. Lee [3], Y.H. Kim [1,2,3]

[1] Center for Underground Physics, Institute for Basic Science (IBS), Daejeon, South Korea
[2] University of Science and Technology (UST), Daejeon, South Korea
[3] Korea Research Institute of Standards and Science (KRISS), Daejeon, South Korea

We report the recent progress on light-detector development applied to a large-scale experiment of the AMoRE project searching for zero-neutrino double beta decay of ^{100}Mo. The AMoRE detector modules measure heat and light signals with MMC sensors from scintillating molybdate crystals at mK temperatures. We performed systematic test experiments with various detector components and measurement conditions such as absorber materials, temperatures and field currents. In particular, we carried out a direct comparison between two light detectors made of Ge and Si wafers. We also present the heat flow mechanism of the detectors and further optimizations for the AMoRE project.

Session: Oral O5-8: Devices 2

Schedule: Tuesday 27 July 09:10 - Tuesday 27 July 09:25

Submitted by: Avirup Roy - University of Wisconsin-Madison

Development of precise light delivery setup for calibration of transition-edge sensors

A. Roy, C. V. Ambarish, H. Dai, C. Howe, F. T. Jaeckel, E. John, S. Liu, D. McCammon, H. Stueber, Z. Wang, T. Yan
University of Wisconsin - Madison
S. R. Bandler [1], J. A. Chervenak [1], M. E. Eckart [1,2], K. Sakai [1], S. J. Smith [1], N. Wakeham [1]
[1] NASA Goddard Space Flight Center
[2] Lawrence Livermore National Laboratory - Livermore
K. M. Morgan [1,2], D. R. Schmidt [1], D. S. Swetz [1], J. Weber [1], J. N. Ullom [1,2]
[1] National Institute of Standards and Technology
[2] University of Colorado - Boulder

We have previously demonstrated that high-resolution X-ray microcalorimeters can be precisely calibrated at low energies and up to $\sim$1 keV with the help of short pulses of UV light generated by a 405 nm laser diode, which produces a comb of lines spaced 3 eV apart. We have used an optical fiber to concentrate most of the light on a single pixel but crosstalk arising from spillover degrades resolution and shifts photon peaks. To largely eliminate crosstalk interference we are developing a system that allows a 50 μm diameter projected image of the fiber end to be precisely scanned over the array. This allows direct measurement of any position-dependence across an absorber, and accurate evaluation of the electrical and thermal crosstalk between adjacent pixels. The geometry of the setup also provides simultaneous illumination of the array with X-ray lines from a standard fluorescent source for comparison.

Here we describe current work in designing this setup and its use in better characterization of high-resolution TES detectors.

Session: Oral O5-9: Devices 2

Schedule: Tuesday 27 July 09:25 - Tuesday 27 July 09:40

Submitted by: Yoshitaka Miura - National Institute of Advanced Industrial Science and Technology

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Development of transition-edge sensor with high counting rate

Yoshitaka Miura, Sachiko Takasu, Kaori Hattori, Daiji Fukuda

National Institute of Advanced Industrial Science and Technology

The photon number-resolving detector (PNRD) with fast response speed and high detection efficiency is required in various applications based on quantum optics. One of PNRDs is a superconducting transition-edge sensor (TES). For such applications, we aim to fabricate a TES with fast response speed.

The higher transition temperature (T_c) of TES leads to fast response speed because the time constant depends on T_c^{-3} in an optical TES. Whereas, a TES with higher T_c leads to degradation of energy resolution. One solution to this degradation is reducing the heat capacity. To realize the TES with a high counting rate, we have designed and fabricated extremely small TES with a 1 µm square size (Fig. 1). To achieve a higher T_c, we have spattered Ti and gold (Au) successively directly on a silicon wafer. The thickness of Ti and Au films are 40 nm and 10 nm, respectively. The 1 µm square size TES is patterned with photolithography and etched with chemical solutions. Nb electrodes are placed with a lift-off method. The Ti/Au-TES was coupled to a single-mode optical fiber with self-alignment method. The performances of the small size TiAu TES are evaluated in a dilution refrigerator. From the current-voltage measurements, the T_c of Ti/Au-TES was 508 mK. From the measurements of photon response, we obtained very fast signals to the incident laser pulses at 1528 nm as shown in Fig. 2. From the fitting result, the decay time constant was 37.4 ns.

Session: Oral O5-10: Devices 2

Schedule: Tuesday 27 July 09:40 - Tuesday 27 July 09:55

Submitted by: Yuta Yagi - The Univ. of Tokyo, ISAS/JAXA

Performance of TES X-Ray Microcalorimeters Designed for 14.4 keV Solar Axion Search

Yuta Yagi [1,3], Ryohei Konno [1,4], Tasuku Hayashi [2], Keita Tanaka [1,3], Noriko Y. Yamasaki [1,3,4], Kazuhisa Mitsuda [5], Rumi Sato [6], Mikiko Saito [7], Takayuki Homma [6,7], Yoshiki Nishida [8], Shohei Mori [8], Naoko Iyomoto [8]

[1] Department of Space Astronomy and Astrophysics, Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), 3-1-1 Yoshinodai, Chuo-ku, Sagamihara-shi, Kanagawa 252-5210 , Japan
[2] Astromaterials Science Research Group (ASRG), Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), 3-1-1 Yoshinodai, Chuo-ku, Sagamihara-shi, Kanagawa 252-5210 , Japan
[3] Department of Physics, School of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
[4] Department of Physics, School of Science, Kitasato University, 1-15-1 Kitasato, Minami-ku, Sagamihara-shi, Kanagawa 252-0373, Japan
[5] National Astronomical Observatory of Japan (NAOJ), 2-21-1 Osawa, Mitaka-shi, Tokyo 181-8588, Japan
[6] Department of Applied Chemistry, Waseda University, Okubo 3-4-1, Shinjuku-ku, Tokyo 169-8555, Japan
[7] Research Organization for Nano & Life Innovation, Waseda University, 513 Waseda-tsurumaki-cho, Shinjuku-ku, Tokyo 162-0041, Japan
[8] Department of Applied Quantum Physics and Nuclear Engineering, Kyushu University, Motooka 744, Nishi-ku, Fukuoka 819-0395, Japan

Axion is a hypothetical elementary particle proposed to solve the strong CP problem in QCD and is one of cold dark-matter candidates. ^{57}Fe nuclei in the solar core interacting with $kT \sim$1.3 keV blackbody photons are through M1 transition to the first 14.4 keV level, and soon de-excite and can emit 14.4 keV monochromatic axions (Moriyama 1995). The monochromatic axion would excite ^{57}Fe nucleus resonantly, and would be converted to a 14.4 keV photon. The rest of energy converts other X-rays and electrons. Moreover, the ^{57}Fe absorbs most of them by itself. Although Namba (2007) and Derbin et al. (2010) searched for 14.4-keV γ-rays from ^{57}Fe foils with a semiconductor detector, the overall efficiency considering the solid angle of the detector was only 1-9%. TES X-ray microcalorimeters can detect self-absorbed thermal energy from axions, and therefore more than 80% of efficiency is expected. We have thus developed dedicated TES arrays with ^{57}Fe axion absorbers for the solar axion search. The spectroscopic performance of a TES could, however, decrease if it works under a magnetic field made by ferromagnetic iron absorbers. To reduce the effect of the magnetization, the iron absorber is set next to the TES with keeping a certain distance and they are connected by a thermal transfer strap. This is our first time producing the device having such structure. We describe the fabrication process and the results of pulse data obtained from irradiation tests using a radioactive source.

Session: Poster P5-1: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Keita Tanaka - ISAS

Challenge to improve the ^{229}Th isomer energy measurement with TES calorimeters

K. Tanaka (ISAS/UT), K. Hirano (ISAS/UT), A.Yamaguchi (Riken), H. Muramatsu (ISAS, present NASA/GSFC), T. Hayashi (ISAS), N. Yuasa (Kyushu), K. Nakamura (JAEA), M. Takimoto (JAEA), H. Haba (Riken), K. Shirasaki (Tohoku), H. Kikunaga (Tohoku), K. Maehata (Kyushu, present Teikyo U.), N Y. Yamasaki (ISAS), K.Mitsuda (ISAS, present NAOJ)

Determination of the isomer energy of ^{229}Th is essential to realize a nuclear clock by a UV laser excitation. Several experiments such as spectroscopy of internal conversion electrons or γ-ray spectroscopy using TES or magnetic calorimeters have been made and the isomer energy seems to converge to around 8 eV. In 2019, we have measured the energy of the 29.2-keV γ-ray with a single-pixel TES and determined the isomer energy to be 8.30±0.92 eV (A. Yamaguchi et al. 2019). We continued our experiments at Tohoku University to reduce the statistical errors and determination of the isomer energy with smaller uncertainty. We optimized a TES design and achieved an improved energy resolution of about 20 eV (H. Muramatsu et al. 2020). By using 3 pixels of the new TES elements with a 5 times stronger 233U source, the new measurements were performed. We are also trying to resolve two emission lines separating by the isomer energy, which were successfully demonstrated with magnetic calorimeters (T. Sikorsky et al. 2020). We will report the results obtained in our new measurement campaigns.

Session: Poster P5-2: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Vivek Singh - University of California Berkeley

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Characterization of bilayer-TES based light detectors for CUPID

Vivek Singh, Clarence Chang, Brian Fujikawa, Roger Huang, Yury G Kolomensky, Marharyta Lisovenko, Valentyn Novosad, Gensheng Wang, Sachinthya L Wagaarachchi BSc, Bradford Welliver, Volodymyr G. Yefremenko, Jianjie Zhang, Mattia Beretta PhD, Erin V Hansen PhD, Kenny Vetter, Chiara Capelli, Enectali Figueroa-Feliciano, Benjamin Ernst Ludwig Schmidt, Valentina Novati, Ran Chen

CUPID is a proposed next-generation ton-scale experiment that will deploy ∼1500 scintillating (Li_2MoO_4) macro-calorimeters to search for neutrinoless double beta decay in ^{100}Mo. It aims to achieve an extremely low radioactive background index of 1E-4 counts / (kev.kg.y) by distinguishing alpha events from signal events in the region of interest. The discrimination is possible by collecting energy information of both the heat and the light channel of the scintillating detector. We are developing a wide-area auxiliary calorimeter – using a low T_c Ir/Pt bi- layer transition edge sensor on a Si wafer – to detect the scintillation light. This work will present the bias characteristic of our TES, preliminary measures of the detector's performance regarding energy and timing resolution, and a thermal model validated with the acquired data for future optimization of the TES detector.

Session: Poster P5-3: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Michael Witthoeft - NASA/GSFC

Correcting energy estimation errors due to finite sampling of transition edge sensor data

M. C. Witthoeft, J. S. Adams, S. R. Bandler, S. Beaumont, J. A. Chervenak, M. E. Eckart, F. M. Finkbeiner, R. L. Kelley, C. A. Kilbourne, A. R. Miniussi, F. S. Porter, K. Sakai, S. J. Smith, N. A. Wakeham, E. J. Wassell

NASA/GSFC

We are developing transition edge sensor (TES) microcalorimeters for future x-ray astronomy instruments such as the X-ray Integral Field Unit (X-IFU) on-board ESA's Athena space telescope. These detectors will be read out using Time-Domain-Multiplexing (TDM). Due to the practical limitations on sampling rate of the readout, the optimally filtered pulse heights of the measured x-ray signals from the TESs can suffer from a nonlinear variation with the exact photon arrival time relative to the sampling points. Both the shape and magnitude of this variation with the arrival time phase also depend on the energy of the photon. In this work, we describe a method to characterize this energy-dependent variation with few parameters, which can then be interpolated over energy to correct event energies across the whole spectrum. We implement our method on measurements taken using a prototype X-IFU kilo-pixel array with $\sim$200 pixels read out using 8-column x 32-row TDM. We use a rotating target source containing 12 fluorescent targets to generate x-ray lines covering the energy range 4 keV (Sc-Kα) to 12 keV (Br-Kα). We show that the interpolation errors between calibration points can be made sufficiently small that they do not adversely impact the measured energy resolution across the full spectral range.

Session: Poster P5-4: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Jingkai Xia - ShanghaiTech University

Data acquisition and analysis for a TES-based spectrometer

Jingkai Xia [1], Shuo Zhang [1], BingJun Wu [2], Yanru Song [1], Jinping Yang [1], Zhi Liu [1]

[1] ShanghaiTech University, Shanghai, 201210, China
[2] Shanghai Institute of Microsystem and Information Technology Chinese Academy of Science, Shanghai 200050, China

X-ray or gamma spectrometers based on superconducting transition edge sensors (TESs) are promising in beamline spectroscopy research for combination relatively good energy resolution and detection efficiency. For Free-Electron Laser facilities under construction in Shanghai, application of TESs-based X-ray spectrometers is proposed. Spectrometer prototypes are currently developed using commercial data acquisition devices. Acquisition software is designed and programmed for multi-pixel data recording in the prototype study. Different data analysis methods are tested and compared to best realize the performance of the prototype. Recently, we have prepared an eleven-channel prototype, in which better than 8eV resolution at 8keV is achieved.

Session: Poster P5-5: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Arnulf Barth - Kirchhoff Institute for Physics, Heidelberg University

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Data Reduction Algorithms for the ECHo Experiment

A. Barth, R. Hammann, M. Griedel, F. Mantegazzini, N. Kovac, L. Gastaldo

Kirchhoff Institute for Physics, Heidelberg University

The goal of the Electron Capture in Ho-163 (ECHo) experiment is the determination of the neutrino mass scale by analyzing the electron capture (EC) spectrum of Ho-163. Metallic magnetic calorimeters operated at low temperatures, in which the Ho-163 has been implanted, have been selected to conduct a high resolution, high statistics, and low background calorimetric measurement of the Ho-163 EC spectrum.

In order to reliably infer the energy of Ho-163 events and discard triggered noise or pile-up events, fast and robust analysis algorithms are required. We present the results obtained with applying on different datasets the newly developed data reduction algorithms based on filters acting on the trigger time of the events and on filters using pulse shape information. In the light of these results, we discuss the present structure for data reduction algorithms to be applied for the analysis of the ECHo-1k high statistics data.

Session: Poster P5-6: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Johannes Staguhn - Johns Hopkins University

Development of a robust, efficient process to produce scalable, superconducting kilopixel Far-IR Detector Arrays

Johannes Staguhn, Johns Hopkins University
Ari Brown, NASA/GSFC
Shannon Duff, NIST Boulder
Gene Hilton, NIST Boulder
Samuel H. Moseley, NASA/GSFC & Quantum Circuits
Karwan Rostem, NASA/GSFC
Elmer Sharp, NASA/GSFC
Edward Wollack, NASA/GSFC

The far-IR band is uniquely suited to study the physical conditions in the interstellar medium and star formation out to the highest redshifts. Robust, high sensitivity detector arrays with up to several 10^4 pixels, large focal plane filling factors, and low cosmic ray cross sections that operate over the entire far-IR regime are required for future FIR missions. The arrays could consist of smaller sub-arrays, in case they are tileable. The Backshort Under Grid (BUG) array architecture which our group has fielded in a number of FIR cameras, including HAWC+ on SOFIA, is a good example for an architecture that is scalable beyond wafer sizes. BUGs provide high filling factors (90% at 1 mm pixel pitch) and are designed to have low Cosmic ray cross sections. However, the production of BUGs with integrated readout multiplexers has many time- and resource consuming process steps.

In order to meet the requirement of robustness and efficiency on the production of future arrays, we have developed a new method to provide the superconducting connection of BUG detectors to the readout multiplexers or readout boards behind the detectors. This approach should allow us to reach the goal to produce reliable, very large detector arrays for future instrumentation.

We will present the main design features, followed by recent results from our laboratory demonstration of the first prototype array.

Session: Poster P5-7: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Xiaolong Xu - National Institute of Metrology, China

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Development of an Optical Ti/Au Transition-Edge Sensor for Single Photon Detection

Xiaolong Xu [1], Mauro Rajteri [2], Jinjin Li [1], Shuo Zhang [3], Carlo Pepe [2,4], Jian Chen [1], Huifang Gao [1], Qi Li [1], Wei Li [1], Xu Li [1], Mingyu Zhang [1], Yanyan Ouyang [1], Xueshen Wang [1]

[1] National Institute of Metrology (NIM), 100029 Beijing, China;
[2] Istituto Nazionale di Ricerca Metrologica (INRiM), 10135 Torino, Italy;
[3] ShanghaiTech University, 201210 Shanghai, China;
[4] Politecnico di Torino, 10129 Torino, Italy

We present the state of art of an optical Ti/Au bilayer superconducting transition-edge sensor (TES), developed and characterized at NIM and INRiM, to detect photons at 1550 nm. The superconducting transition temperature (T_c) of Ti/Au films could be effectively tuned from 162 mK to 72 mK by increase the relative thickness ratio between the Au and Ti layer. We also simulated and fabricated SiO_2-SiN_x antireflection coating on the surface of Ti/Au films to increase photon detection efficiency. The characterized TES device operated at 97 mK with a 20 µm × 20 µm sensitive area. The device was able to reach an energy resolution better than 0.2 eV and discriminate up to 15 incident photons, with an effective time constant around 30 μs.

Session: Poster P5-8: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Wen Zhang - Purple Mountain Observatory, CAS

Development of self-aligned Ti optical transition-edge sensors at 1550 nm

P. Z. Li [1,2,3], Y. Gen [1,2,3], W. Zhang [1,2], J. Q. Zhong [1,2], Z. Wang [1,2], K. M. Zhou [1,2], W. Miao [1,2], Y. Ren [1,2], F. Wu [1,2], K. Zhang [1,2], Q. J. Yao [1,2], and S.C. Shi [1,2]

[1] Purple Mountain Observatory, CAS, Nanjing, 210023,China
[2] Key Laboratory of Radio Astronomy,CAS, Nanjing 210023, China
[3] University of Science and Technology of China, Hefei,230026, China

Presented by Wen Zhang

With high energy resolution and nearly perfect quantum efficiency, superconducting transition edge sensors (TESs) are capable of detecting single photons from ultra-violet (UV), optical to near-infrared (NIR). They are therefore very attractive for applications such as astronomy, quantum information and communications, optical imaging, and quantum metrology. We are developing Ti TES single photon detectors with a self-aligned method to improve the reliability of TES packaging. Self-aligned optical TESs with different active areas are designed and thoroughly investigated. Preliminary results show that although optical TESs after AR coating exhibit two transitions as well as lower critical temperatures, they have a system detection efficiency of higher than 60% and an energy resolution of about 0.6 eV. Detailed design and measurement results will be presented.

Session: Poster P5-9: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Yume Nishinomiya - University of Tokyo

Development of the characterization methods for TES bolometers for CMB measurements

Yume Nishinomiya [1], Akito Kusaka [1,4], Kenji Kiuchi [1], Tomoki Terasaki [1], Johannes Hubmayr [2], Adrian Lee [3,4], Heather McCarrick [5], Aritoki Suzuki [4], Ben Westbrook [3]

[1] University of Tokyo
[2] NIST Quantum Sensors Group
[3] UC Berkeley
[4] Lawrence Berkeley NL
[5] Princeton University

Superconducting Transition Edge Sensor (TES) bolometers are used for ground-based observations of the Cosmic Microwave Background (CMB) polarization. We aim to evaluate the dark thermal performance of TES bolometers in a testbed, such as transition temperature, saturation power, and intrinsic time constant. We measure TES resistance by the 4-wire method with a dilution refrigerator with a bath temperature of around 100 mK. We develop a unique evaluation method in which DC/AC electric power is applied to TES to simulate optical power. Here we report on the demonstration of the method using TES samples.

Session: Poster P5-10: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Tetsuya Tsuruta - Kyushu University

Development of Transition Edge Sensor Microcalorimeter for Several-MeV Gamma Rays

Tetsuya Tsuruta [1], Yukino Hamamura [1], Naoko Iyomoto [1], Yunosuke Nakamura [1], Shoutaro Kawaguchi [1], Tasuku Hayashi [2], Yuta Yagi [2], Noriko Yamasaki [2]

[1] Kyushu University
[2] ISAS/JAXA

We developed a transition edge sensor (TES) microcalorimeter to measure gamma rays up to a few MeV. We report the results of gamma-ray irradiation experiments using two sources (Cs-137 and Co-60) with this TES device, which have a large bismuth absorber (1 mm × 1 mm × 1 mm) and a thick silicon membrane (7 μm). Compared to our previous TES devices, the volume of the silicon substrate was reduced by about half in order to reduce the Compton scattering pulses on the silicon substrate. We fabricated devices with different size of the TES and the membrane to study the thermal conductance of the thermal link. It was found that the thermal conductance between the TES and the heat bath depends only on the perimeter of the TES, not on the distance between the TES and the heat bath, like TES devices for X-rays which have thin silicon-nitride membranes.

Session: Poster P5-11: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Cindy Xue - Argonne National Laboratory

Electroplated Bi RRR measurements for X-ray TES

C. Xue [1], L. Gades [1], C.S. Miller [2], R. R. Divan [2], T. Guruswamy [1], A. Miceli [1], U. Patel [1], O. Quaranta [1]

[1] Detectors Group, X-ray Science Division, Advanced Photon Source, Argonne National Laboratory
[2] Center for Nanoscale Materials, Argonne National Laboratory

Presented by Lisa Gades and Orlando Quaranta

Bismuth (Bi) is commonly used in Transition-Edge Sensors (TESs) for X-rays because of its high stopping power and low heat capacity [1]. Electroplated Bi has seen wider usage than evaporated Bi, due to the absence (or at least very reduced presence) of low-energy tails [2] in the spectra measured by these devices. A typical proxy for thermal properties of a TES absorber at cold temperatures is the residual resistance ratio (RRR). Electroplated Bi is usually grown on top of another metal that acts as seed layer, typically gold (Au), making it challenging to extrapolate the RRR of Bi because the dominant contribution to the electrical conductivity is from the Au. In this work, we present four wire resistance measurement structures that allow us to measure resistance as a function of temperature of electroplated Bi independently of Au. The measured resistivity at room temperature of the electroplated Bi in our test structures matches the resistivity found in literature for bulk Bi, confirming that the Bi in our structures is measured independently of the Au layer. We notice that at low temperatures, Bi seems to change nature from a metal to a semiconductor. We hypothesize that this is due to mechanical stress in the bridges [3] from the differential thermal contraction between Bi and the substrate; we are currently further exploring this phenomenon. Details on the fabrication process will be discussed.

Session: Poster P5-12: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Yanru Song - ShanghaiTech University

Fabrication of Transition edge sensor for X ray spectrometer

Yanru Song, Shuo Zhang, Jingkai Xia, Jinping Yang, Tsu-Chien Weng, Zhi Liu

ShanghaiTech University

As superconducting transition edge sensor (TES) spectrometer with high energy resolution and high absorption efficiency is demanded in a dozen of end-stations at Shanghai HIgh repetitioN rate XFEL and Extreme light facility (SHINE), so we fabricate TES for X ray application. So far, the 16 pixels' TES prototype chip is developed, the preliminary result shows the T_c is 110mK and the energy resolution is 6.1eV@ 1.5KeV. More details will be shown in the poster.

Session: Poster P5-13: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Bo Gao - Shanghai institute of microsystem and information technology, Chinese Academy of Sciences

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Fabrication of transition edge sensors using selective-area ion-implantation technique

D. X. Li [1], Y. Lv [1], H. Huang [1], H. B. Wang [1], S. Zhang [2], J. K. Xia [2], T. G. You1 , F. Ren [3], X. Ou [1], Z. Liu [2], Z. Wang [1], B. Gao [1]

[1] State Key Laboratory of Functional Materials for Informatics, Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences, 865 Changning Road, Shanghai 200050, China.
[2] School of Physical Science and Technology, ShanghaiTech University, 201210, Shanghai, China
[3] School of Physics and Technology, Wuhan University, Wuhan 430072, China

Presented by Bo Gao

In a previous study, we have shown that multi-energy ion-implantation can create a homogeneous Mn dopant distribution in Al films[1]. The doped Al film with low transition temperature and sharp transition edge is a candidate material to fabricate transition edge sensors (TES). We here present a fabrication method of TES using selective-area ion-implantation. The Al films grown by magnetron sputtering were patterned and etched to form sensors together with connecting wires and leads. Small amount of Mn dopants was then implanted into the sensor area using photoresistor as implantation mask. Overhanging gold absorbers were made onto the sensors by electroplating. In the last step of the fabrication, the silicon substrate under the sensor area was removed by silicon deep reactive dry etching process, which leaves a thin silicon nitride membrane to mechanically support the sensors. The characterization of these sensors was performed in millikelvin refrigerators with a radioactive ^{55}Fe X-ray source. The energy resolution measured as the full-width-half-maximum (FWHM) of the Mn kα lines was approximately 7 eV.

1. Y. Lv, H. Huang, T. You, F. Ren, X. Ou, B. Gao and Z. Wang, Journal of Low Temperature Physics 202 (1), 71-82 (2021).

Session: Poster P5-14: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Naoko Iyomoto - Kyushu University

Finite-Element Simulation of Transition-Edge Sensor Microcalorimeters for Gamma rays

Naoko Iyomoto

Kyushu University

We modeled transition-edge-sensor (TES) microcalorimeters for gamma rays using a three-dimensional finite-element method with the software COMSOL Multiphysics. In the simulations, we reproduced the electrothermal feedback by applying a constant-voltage bias to the TESs. Assuming typical electrical and thermal parameters of our gamma-ray TES microcalorimeters, we performed simulations to model a single-pixel TES microcalorimeter. We studied the dependence of the pulse shape on the gamma-ray interaction position in its 1 mm × 1 mm × 1 mm bismuth absorber. Further, we studied the influence of the heat capacity of Stycast epoxy, which connects the TES and the absorber, on the simulated pulse shape of the single-pixel device. In addition, using the same electrical and thermal parameters as those for the single-pixel device, we modeled a position-sensitive TES microcalorimeter (PoST), which consists of a 1 mm × 1 mm × 20 mm bismuth absorber and two TESs.

Session: Poster P5-15: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Takahiro Kikuchi - National Institute of Advanced Industrial Science and Technology

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Gamma-ray Transition Edge Sensor with SiO2/SixNy/SiO2 Membrane for Uniform Property

T. Kikuchi, G. Fujii, R. Hayakawa, R. Smith, F. Hirayama, Y. Sato, S. Kohjiro, M. Ukibe, M. Ohno, A. Sato, H. Yamamori

National Institute of Advanced Industrial Science and Technology

A major problem for achieving uniform characteristics among pixels can be considered as a position dependence of the silicon (Si) etching speed over the wafer where we fabricate self-standing membranes. We employ an $SiO_2/Si_xN_y/SiO_2$ tri-layer membrane where silicon dioxide (SiO_2) has a greater tolerance against the etching plasma than silicon nitride (Si_xN_y) single layer one. The tri-layer wrinkle-free membranes were successfully fabricated with the film stress that showed low tensile, +18 MPa. Thermal conductance of the 6.9-um thick tri-layer membrane was about 1.5 nW/K, i.e., close to 3 nW/K reported for 1-um single one[1]. Typical critical temperature of our Ti/Au TES with the tri-layer membrane is 130 mK. Joule power to keep the TES transition state was measured as a function of membrane size, and we found out that the phonon transport follows intermediate state between the ballistic and diffusive. No membranes were broken by mounting $0.5 \times 0.5 \times 0.5$ mm3 Sn absorbers for the whole 51 pixels under test. Gamma-ray spectroscopy around 93 keV was carried out based on series-biased 5-pixels TES irradiated by a ^{67}Ga photon source. The best energy resolution and fall time among the pixels were 43.1 +/- 1.6 eV and 1 msec, respectively, which were almost as same as conventional TESs with single membrane [1]. Therefore, the tri-layer membrane can be used without any problems for Gamma-ray TESs. A spectroscopy of Np is under the progress. [1] D. A. Bennett, doi/10.1063/1.4754630

Session: Poster P5-16: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Sergey Cherednichenko - Chalmers University of Technology

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High response rate in low kinetic inductance MgB_2 nanowire photon detectors

Sergey Cherednichenko [1], Ilya Charaev [2], Vladimir Drakinskiy [1], Samuel Lara Avila [1], Karl K. Berggren [2]

[1] Department of Microtechnology and Nanoscience, Chalmers University of Technology, Göteborg SE-41296, Sweden
[2] Massachusetts Institute of Technology, 50 Vassar Street, Cambridge, MA 02139

Superconducting nanowire single-photon detectors (SNSPD) have traditionally been made from low-T_c superconducting thin films, such as NbN, Nb, NbTiN, MoSi, WSi, etc. Such materials are very forgiving with respect to deposition parameters (e.g. allowing room temperature depositions), substrates (no epitaxial growth is required), and have a high normal state resistivity (allowing for a high quantum efficiency). However, these materials have a low critical temperature, requiring cooling to at least 4K, and often as low as 1K. Cryogenic coolers of this sort are expensive and bulky. However, they become much lighter should 15-20K-detector- operation be possible. Moreover, the issue of a high kinetic inductance in low-T_c superconductors (100pH/sqr) and a limited electron cooling rate becomes a hard limit for the reset time in large area SNSPDs.

We turn towards magnesium diboride (MgB_2) films since based on the thick film date a much lower kinetic inductance could be obtained if high quality ultra-thin films could have been made. Using Hybrid Physical Chemical Vapor Deposition (HPCVD) we obtain 5nm MgB_2 films with a T_c of 34K. We fabricate nanowires based on such films which show very low kinetic inductance (1-3pH/sqr), single-photon response for both visible and IR light, with a reset time down to 100ps. We study film properties in an attempt to reach a high detection efficiency.

Session: Poster P5-17: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Jodoi Takeshi - The University of Tokyo

Improvement of the photon number resolving detector with superconducting transition edge sensor

Jodoi Takeshi, Tsuyoshi Sakura, Ryan Smith, Yuki Mitsuya, Masashi Ohno, Hiroyuki Takahashi

The University of Tokyo

In the chemistry, there are some applications which measure photons in the mid-infrared wavelength region, which originate from molecular vibrations. To detect photons in the wavelength region, due to their low energies, it is necessary to lower the superconducting transition temperature T_c of a TES in order to achieve better energy resolution. For that reason, we designed and fabricated an Au-Ir bilayer TES, which is expected to have low T_c due to the proximity effect between normal metal (Au) and superconductor (Ir). We designed the Au-Ir bilayer structure by numerical calculation, and fabricated the bilayer TES via photolithography and lift-off techniques. As a result of I-V curve characterization, the superconducting transition temperature T_c was estimated to be about 175 mK. It is possible to control the superconducting transition temperature by changing the ratio of bilayer thickness.

In order to improve the accuracy of alignment between the optical fiber core and the sensitive area of TES, we formed the silicon wafer into a racket-like shape which matches the inner diameter of optical fiber sleeve. This process enhanced the result of energy resolution, because we could avoid indirect heat inflow paths into the TES by reducing photon irradiation to the substrate or electrodes.

Due to inspect the characterization of the bilayer TES, we carried out an experiment by using a pulse laser with the wavelength of 850nm. Consequently, we have developed transition edge sensor (TES) with an energy resolution of 0.65 eV in full-width at half-maximum for a pulse laser with the wavelength of 850 nm.

Session: Poster P5-18: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Stephen Smith - NASA GSFC

Influence of environmental parameters on the performance of transition-edge sensor microcalorimeters

Stephen J. Smith, Joseph S. Adams, Simon R. Bandler, Sophie Beaumont, James A. Chervenak, Fred M. Finkbeiner, Ruslan Hummatov, Richard L. Kelley, Caroline A. Kilbourne, Antoine R. Miniussi, Frederick S. Porter, Kazuhiro Sakai, Nicholas A. Wakeham, Edward J. Wassell, Michael C. Witthoeft

NASA GSFC

The next generation of x-ray space telescope requires kilo-pixel arrays of transition-edge sensors (TESs), with very high spectral resolution over a broad range of energies. A TESs responsivity is strongly affected by variations in its environment, such as the heat-sink temperature, magnetic field and TES bias voltage. Variations in these environmental boundary conditions can cause temporal drift in the gain of the detector and affect both the energy scale and the energy resolution. In this paper we report on the energy gain sensitivity to these important environmental parameters, and in particular, examine how these and other performance metrics vary as a function of applied magnetic field and bias point in the transition. Measurements are presented on $\sim$ 200 pixels in a prototype kilo-pixel array under development for the X-ray Integral Field Unit (X-IFU) onboard ESA's Athena mission. Our results illustrate how the resistive transition shape, parameterized by alpha/beta, is modulated by the applied magnetic field, which in turn modulates the detector responsivity. This is discussed in the context of the applied magnetic field and local self-induced magnetic field (from current in the TES and bias leads) modulating the critical current of the TES. As well as improving our understanding of the gain sensitivities, this may also allow us to use magnetic field to tune the transition shape to improve various aspects of detector performance including resolution and uniformity.

Session: Poster P5-19: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Yuki Mitsuya - The University of Tokyo

Iridium/gold bilayer optical transition edge sensor and optical cavity structure for single-photon detection at telecommunication wavelengths

Yuki Mitsuya [1,2], Takeshi Jodoi [1], Ryan Smith [1], Masashi Ohno [1], Hiroyuki Takahashi [1,2]

[1] The University of Tokyo
[2] AIST-UTokyo Advanced Operando-Measurement Technology Open Innovation Laboratory

Photon number resolution by single photon measurement at telecommunication wavelengths is widely required in many applications, including optical quantum information processing. The transition edge sensor (TES) is one of the ideal single photon detectors; it has an intrinsic photon number resolving capability and a near unity quantum efficiency.

We have demonstrated single photon detection and photon number resolution with iridium TESs so far. To improve the photon number resolution capability, we have recently designed and fabricated an iridium/gold bi-layer optical TES, which has a lower T_c due to the proximity effect between iridium and gold. In this research, we measured telecommunication wavelength (1303 nm) photons using the iridium/gold bi-layer TES. We successfully demonstrated photon number resolution, and the energy resolution was estimated to be 0.65 eV.

In this research, we also designed an optical cavity structure which was optimized for a telecommunication wavelength (1550 nm). We experimentally fabricated an anti-reflection coating on an iridium film, which was sputtered on a silicon wafer. The thickness of iridium was 40 nm. The anti-reflection coating was made of 6 layers of SiO2 and TiO2. The reflectance of the optical cavity structure was smaller than 3 % at 1550 nm. We will proceed to the fabrication of an iridium TES integrated in an optical cavity structure in a near future.

Session: Poster P5-20: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Archana Devasia - NASA Goddard Space Flight Center

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Large-scale metallic magnetic calorimeter arrays for the Lynx X-ray Microcalorimeter

Archana Devasia, Simon R. Bandler, Kevin Ryu, Thomas R. Stevenson, Wonsik Yoon

NASA Goddard Space Flight Center

The Lynx X-ray Microcalorimeter (LXM) is an imaging spectrometer consisting of an array of greater than 100,000 pixels. Metallic magnetic calorimeter (MMC) technology is a leading contender for detectors for the LXM. In this work, we detail the fabrication of a full-size LXM MMC array fabricated using superconducting, multi-layer, buried wiring, with all pixels wired out on a full-size support wafer. We adopt a scheme that facilitates mixing and matching DUV and i-line steppers to stitch the high feature resolution detector array to the large field fanout wiring. In order to improve the coupling of the sensor to the pick-up coil, and thus enhance the energy resolution, we also employ a sandwich geometry to realize the main array of the microcalorimeter. Additionally, we describe the integration of superconducting flux transformers to optimize the performance of the ultra high resolution array. The wiring to each pixel terminates on bump bond pads, which allow future 2D microwave SQUID based multiplexer chips to be indium bump bonded over the buried wiring. We present preliminary results of measured values of inductance and critical currents.

Session: Poster P5-21: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Daniel Unger - Heidelberg University

MMC-based X-ray Detectors for IAXO

Daniel Unger, Andreas Abeln, Daniel Behrend-Uriarte, Daniel Hengstler, Andreas Fleischmann, Christian Enss and Loredana Gastaldo

Heidelberg University

Axion helioscopes search for evidence of axions and axion-like particles (ALPs) produced in the interior of the Sun. Via the generic ALP-photon coupling, a strong magnetic field would convert ALPs into photons which could then be detected by low background and high efficiency X-ray detectors. Having also good energy resolution and low energy threshold detectors would allow to investigated ALP generation mechanisms in the Sun as well as properties of the Sun by studying the X-ray spectrum. We propose to use low temperature metallic magnetic calorimeters (MMCs) for the International Axion Observatory (IAXO). We present the current state of our detector system developed for IAXO containing a two-dimensional 64-pixel MMC array covering an active area of 16 mm^2 with a fill factor of 93 %. We achieve an average energy resolution of 6 eV FWHM allowing for energy thresholds below 100 eV. We compare the background detected over multiple weeks for two different experimental configurations, one of them featuring a low-Z material shield between the metallic cover of the setup and the detector array. The obtained results show that the presence of such a shield reduced the background by 58 % in the energy range from 1 keV to 10 keV. In the future, active and passive shields will be used to reduce the background to 10^{-7} keV^{-1} s^{-1} cm^{-2}. The obtained results highlight that MMC-based arrays are a suitable technology for helioscopes to discover and study ALPs.

Session: Poster P5-22: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Ansgar Lowack - Kirchhoff Institute for Physics, Heidelberg University

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MOCCA, a 4k-pixel molecule camera for the position and energy resolving detection of neutral molecule fragments: First light

Ansgar Lowack, Dennis Schulz, Steffen Allgeier, Christian Enss, Andreas Fleischmann, Lisa Gamer, Loredana Gastaldo, Sebastian Kempf, Oldřich Novotný, Andreas Wolf

Kirchhoff Institute for Physics, Heidelberg University

MOCCA is a 64 x 64-pixel detector based on metallic magnetic calorimeters (MMCs), enabling a spatially- and energy-resolved detection of neutral massive particles with keV kinetic energies on a detector area of 4.5 cm x 4.5 cm with 99.5% filling factor. MOCCA was developed for the investigation of dissociative recombination, a fundamental process in interstellar chemistry, at the Cryogenic Storage Ring CSR at the Max-Planck Institute for Nuclear Physics in Heidelberg. For this purpose, a high detection efficiency for molecule fragments with kinetic energies between 1 and 300 keV, rates up to several hundred hits per second and multi-hit capability are required. We present the detector design, the fabrication of gold-filled through-wafer vias to ensure thermalization over the full detector area and recent measurements showing the full functionality of the detector. Measurements with 6 keV X-ray photons yielded an energy resolution of 88 eV (FWHM). With this, MOCCA meets all the requirements for its use at the CSR. MOCCA is presently the largest and most complex MMC-based detector. As demonstrated in measurements with alpha particles, a MOCCA detector with slightly thicker particle absorbers can also be used as a very large, high-resolution alpha detector.

Session: Poster P5-23: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Ryan Smith - University of Tokyo

Optimized detector design of transition edge sensors for the calorimetry of carbon ion beam

Ryan Smith, Masashi Ohno, Yuki Mitsuya, Hiroyuki Takahashi

University of Tokyo

Carbon ion beam is used in radiotherapy. Today, conventional detectors such as ionization chambers are used in measuring the absorbed dose in human body tissue. However, measurement of absorbed dose using these detectors generates an unignorable amount of error. Improving the measurement method of absorbed dose would lead to a much more precise treatment.

In order to improve the absorbed dose measurement for carbon ion beam, transition edge sensors (TES) with graphite absorbers were designed. In our past research for the calorimetry of carbon ion beam, a TES for gamma-ray detection which is mounted with a tin absorber with the size of about 0.5 mm cube was used. Instead of applying heavy metal absorbers, the use of absorbers made of materials which are similar to human body tissues could realize an evaluation of the absorbed dose in human body with smaller calibration. In addition, simulation results suggests that the use of a larger absorber can reduce a good amount of energy loss which are derived from the variation of the incidence angle and the incident point of carbon ion particles.

Thus, we have fabricated a TES device with a carbon absorber with the size of 0.5 mm cube and 2.0 mm cube. We are currently evaluating the characteristics of our new device by the detection of alpha particles.

Session: Poster P5-24: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Toshio Konno - National Institute of Advanced Industrial Science and Technology

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Photon Detection by Optical Transition Edge Sensor Array

T. Konno, S. Takasu, K. Hattori, and D. Fukuda

National Institute of Advanced Industrial Science and Technology

Transition edge sensors (TES) exhibit high energy resolution for a single optical photon as energy-dispersive detectors. We have applied TESes to photon-counting microscopy for biological imaging [1,2]. Our aim is to develop TES arrays with large effective areas to improve the count-rate.

In this study, we prepared a new TES pixel array device and performed photon detection by voltage-biasing pixels simultaneously. The optical TES array consists of nine pixels, which are fabricated on a dielectric layer of SiO_2. The size of each pixel is 8 µm × 8 µm and the TES film thicknesses of AuTi are 10 nm and 20 nm, respectively. Compared to our previous TES array, in which the pixels were fabricated directly on Silicon wafer, thermal interference of Joule power between each pixel is expected to be small in this device. We measured photon responses to the incident photons at 1550 nm through a multi-mode fiber by biasing the pixels simultaneously. As a result, the time constant of the response signal is ranged from 520 ns to 990 ns, and the energy resolution is obtained to be 0.14 eV to 0.22 eV @ 0.81 eV. We also evaluated the crosstalk performances as shown in Fig. 1, in which the crosstalk energy from the peripheral pixels to the interest pixel are calculated from photon response signals. We found that the crosstalk effect is negligible in this device.

[1] D. Fukuda et al., Jour. Low Temp. Phys., 193, 1228-1235 (2018).
[2] K. Niwa et al., Sci. Rep., 7, 456

Session: Poster P5-25: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Stephen Boyd - University of New Mexico

RF Mode Structure and Damping in Magnetic Microcalorimeter Sensors for Direct-Coupled Readout

S. T. P. Boyd [1] , G.-B. Kim [2], S. Friedrich [2]

[1] University of New Mexico, Albuquerque, NM 87131, USA
[2] Lawrence Livermore National Laboratory, Livermore, CA 94550, USA

Magnetic microcalorimeters (MMCs) are high-resolution particle detectors with a predictable response based on the physics of paramagnetism. To maximize energy resolution, we are exploring designs with MMCs that directly couple to the SQUID by making the sensing coil part of the SQUID loop and thereby maximizing the signal. Direct coupling to the SQUID is expected to require the use of an MMC sensor with a magnetizing coil separate from the sensing coil. This creates a three-layer MMC sensor supporting poorly-damped RF resonances that can interact with the Josephson oscillations of the SQUID. In this report we describe the calculated mode structure for such MMC sensors, results of different approaches to damping the resonances, and implications for the design of direct-coupled MMC detectors.

This work was funded by U.S. Department of Energy, Office of International Nuclear Safeguards NA-241. It was performed under the auspices of the U.S. DOE by LLNL under Contract No. DE-AC52-07NA27344.

Session: Poster P5-26: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Shohei Mori - Kyushu University

Simulation of TES X-Ray Microcalorimeters designed for 14.4 keV Solar Axion Search

Shohei Mori [1], Yoshiki Nishida [1], Naoko Iyomoto [1], Yuta Yagi [2,4], Ryohei Konno [2,5], Tasuku Hayashi [3], Keita Tanaka [2,4], Noriko Y. Yamasaki [2,4,5], Kazuhisa Mitsuda [6], Rumi Sato [7], Mikiko Saito [8], Takayuki Homma [7,8]

[1] Department of Applied Quantum Physics and Nuclear Engineering, Kyushu University, Motooka 744, Nishi-ku, Fukuoka 819-0395, Japan
[2] Department of Space Astronomy and Astrophysics, Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), 3-1-1 Yoshinodai, Chuo-ku, Sagamihara-shi, Kanagawa 252-5210, Japan
[3] Astromaterials Science Research Group (ASRG), Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), 3-1-1 Yoshinodai, Chuo-ku, Sagamihara-shi, Kanagawa 252-5210, Japan
[4] Department of Physics, School of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
[5] Department of Physics, School of Science, Kitasato University, 1-15-1 Kitasato, Minami-ku, Sagamihara-shi, Kanagawa 252-0373, Japan
[6] National Astronomical Observatory of Japan (NAOJ), 2-21-1 Osawa, Mitaka-shi, Tokyo 181-8588, Japan
[7] Department of Applied Chemistry, Waseda University, Okubo 3-4-1, Shinjuku-ku, Tokyo 169-8555, Japan
[8] Research Organization for Nano & Life Innovation, Waseda University, 513 Waseda-tsurumaki-cho, Shinjuku-ku, Tokyo 162-0041, Japan

We attempt to develop detection methods for solar axions using transition-edge-sensor (TES) microcalorimeters. Iron 57 (^{57}Fe) is used as an absorber for detecting solar axions. However, the magnetic field by iron 57 has a negative influence on the TES's superconducting transition. Thus, we electroplated the absorber on the membrane instead of TES and thermally connected the absorber and TES with a gold thermal strap. Some of the heat deposited into the absorber escapes to the heat sink through the membrane before it was detected by the TES. If the heat loss depends on the axion interaction position in the absorber, the position dependence degrades the energy resolution. We studied the dependence of the TES pulse shape on the heat incident position. We used the software called COMSOL Multiphysics using the finite element method for the simulation. We set a heat source in the absorber and estimated the temperature change of the TES. Further, we estimated it when the heat source was in the gold thermal strap and the membrane.

Session: Poster P5-27: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Alexander Kavner - University of Michigan (Ann Arbor)

Systematic Study of Pile-up Effects in Cryogenic Decay Energy Spectroscopy

A. R. L. Kavner [1], S. Friedrich [2], I. Jovanovic [1], S. T. P. Boyd [3], and G.B. Kim [2]

[1] University of Michigan, Ann Arbor, MI 48109, USA
[2] Lawrence Livermore National Laboratory, Livermore, CA 94550, USA
[3] University of New Mexico, Albuquerque, NM 87131, USA

Pile-up is an unavoidable complication for slow cryogenic detectors with relatively large heat capacities, such as metallic magnetic calorimeters (MMCs) and transition edge sensors (TESs) coupled to large Au absorbers for decay energy spectroscopy (DES). We have simulated the spectral response of such cryogenic detectors using Monte-Carlo algorithms to investigate the influence of pile-up on absolute and relative activity measurements. We focus on the impact of non-distinguishable pile-up signals that occur when the rising edges of two events overlap in time and are recorded as a single event. We find that pile-up can distort the measured value of both the absolute and relative activities. This is evident from our case study of a mixed-isotope Pu sample, where beta-emitting Pu-241 influences the Pu-239 / Pu-240 ratio. We will discuss the influence of signal rise time, count rate, signal processing method, and operation temperature on pile-up. These simulation results are compared to decay energy spectra of Am- 241 measured by an MMC. Our results emphasize the systematic dependence of activity and spectral measurements caused by non-distinguishable pile-up.

This work was funded by the LLNL LDRD grant 20-LW-024. It was performed under the auspices of the U.S. DOE by LLNL under Contract No. DE-AC52-07NA27344. LLNL Approval LLNL-ABS-821833

Session: Poster P5-28: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Edward Wassell - NASA Goddard Space Flight Center

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The ATHENA X-IFU detector: Fabrication and Integration of Full-Scale Arrays

J. S. Adams [1,3], S. R. Bandler [1], S. Beaumont [1,3], J. A. Chervenak [1], F. M. Finkbeiner [1,2], J. Y. Ha [1,4], R. L. Kelley [1], C. A. Kilbourne [1], J. N. Mateo [1], A. R. Miniussi [1,3], H. Muramatsu [1], F. S. Porter [1], A. Rani [1,5], K. Sakai [1,3], S. J. Smith [1], N. A Wakeham [1,3], E. J. Wassell [1], S. H. Yoon [1,5]

[1] NASA Goddard Space Flight Center
[2] Hexagon US Federal
[3] University of Maryland BC
[4] Catholic University of America
[5] Science Systems and Applications Inc

Presented by Edward Wassell

We describe the detector array for the X-ray integral field unit (X-IFU) for ATHENA (Advanced Telescope for High Energy Astrophysics) which we are currently prototyping. Starting from the ATHENA specifications for characteristic energy resolution, quantum efficiency, and crosstalk, we discuss the selected design which best matches fabrication capabilities and achieves the needed uniformity and yield to produce detectors. Certain aspects of the fabrication have required additional process development as we moved from 32x32 pixel square arrays to the larger format specified for ATHENA, 3168 pixels on a 90 mm diameter hexagon shaped substrate. We discuss the superconducting transition shapes and uniformity achieved when our transition edge sensor layer is integrated with high density oxides needed for microstripline wiring. We present our latest fabrication efforts to achieve a high quantum efficiency absorber with suitable thickness and filling fraction to capture sufficient X-rays over the 0.5 to 12 keV band. We identify other sources of yield loss and risk and discuss possible mitigations. The large format array will be glued and wirebonded to a flexible wiring component that transmits the signals from the array to bias and amplifier circuits. We present initial characterization of wirebonding for these signal lines as well as methods of heatsinking the array.

Session: Poster P5-29: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Kevin T. Crowley - University of California, Berkeley

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The Simons Observatory: Device Characterization for Detectors in Synchrotron Channels

Kevin T Crowley, Shawn Beckman, Benjamin Westbrook

University of California, Berkeley

The Simons Observatory (SO), currently under construction, is a set of four telescopes and five receivers designed to observe the polarization anisotropies of the cosmic microwave background (CMB) from a high-altitude site in the Atacama Desert of Chile. A portion of the detectors being fabricated for SO focal planes are sensitive to frequencies where galactic synchrotron radiation dominates, with bandpasses centered at 27 and 39 GHz, below the peak of the CMB spectrum. These low-frequency (LF) detectors feature broadband sinuous antennae and extended hemispherical lenslets for their coupling to the SO telescope optics. Transition-edge sensor (TES) devices are used to convert incoming photon power to electrical signals. In the realized SO focal plane, these sensors will be coupled to cryogenic microwave resonators using RF superconducting quantum interference devices (SQUIDs) in the microwave SQUID multiplexing (uMux) scheme. In this proceeding, we briefly describe the current LF detector design, including target TES parameters, before summarizing recent measurements characterizing both prototype devices and samples of full SO detector arrays. These measurements were carried out using commercially available DC SQUIDs operated at 100 mK, the cryogenic platform base temperature used in operation for SO, as well as commercially-produced superconducting-trace printed-circuit boards to minimize residual resistance in the voltage bias provided to the TES.

Session: Poster P5-30: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Jiwan Song - KRISS

The study for improvement on the fabrication processes of MMC (metallic magnetic calorimeter)

Jiwan Song

KRISS

A study has been conducted to improve the MMC fabrication processes to overcome the difficulties in previous processes and performance degradations of its main elements. There are the three main improvements as follows.

1. In the processes of MMC fabrication the effects of mechanical stress on chips were minimized by using only chemical methods (BOE etching etc) without mechanical methods such as ultrasonic cleaning etc. The microscopic cracks that may occur at the Nb meander structure were reduced as much as possible. The critical currents of superconductor in chips over 3 wafer were measured to be more than 150 mA.

2. We found out the optimal conditions where we escape from photo resist(PR) hardening during depositing Ag:168Er sensor material film with 3 um thickness. The deposition rate was able to speed up three times so that the oxygen contamination on Er in film was estimated to reduce.

3. We simultaneously fabricated not only Au thermalization layers on Ag:168Er but also electrical lead bridges between heat switch and Nb line by using electroplating. The lead bridge was became to be a few um so that the heaters were robust to damage in heater burning test.

With applying the improving processes to manufacture MMC, performances of devices are shown more consistent than before. We will present details at each fabrication processes and the spectra of standard alpha source measured in the mK temperature region using new MMC.

Session: Poster P5-31: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Kaori Hattori - AIST

Thermodynamic noise in optical transition-edge sensors

Kaori Hattori, T. Konno, Sachiko Takasu and Daiji Fukuda

AIST

Optical transition edge sensors (TESs) which can resolve an energy of a single optical photon have proven desirable in quantum information and biological imaging. Optical TESs were designed to have a high detection efficiency at a specific wavelength and has achieved nearly 100

To calculate the theoretical noise level, we measured parameters such as the temperature sensitivity and the current sensitivity, extracted from the complex impedance. Figure 1(a) shows the complex impedance of a TES biased at 0.5 Rn and fit to the single-block model. As shown in Fig.1 (b), the measured noise agreed with the sum of the thermal fluctuation noise and Johnson noise calculated from the parameters extracted from the complex impedance. Figure 1(c) shows the fitted noise level at high frequencies (700 kHz) where Johnson noise was dominant. We will present the noise measurements in detail.

Session: Poster P5-32: MMCs, SNSPDs, more TESs

Schedule: Tuesday 27 July 10:05 - Tuesday 27 July 11:30

Submitted by: Hiroyuki Takahashi - The University of Tokyo

Towards very fast high granular TES with parallel biasing and single readout scheme

Hiroyuki Takahashi, Yuki Mitsuya

The University of Tokyo

Pixelated TESs are usually operated in an individual bias and readout scheme. We have proven that the parallel biasing scheme works for the small pixel TES devices, where pixelated TESs are all connected to the same electrode and operate in parallel. In this biasing scheme, the system can be extremely simplified. We have developed a way to identify the pixel through slight change of signal characteristics for each pixel. Now we are trying to apply the scheme to other than imaging. In this context, the identical signal feature means identical response of the pixel and we can group signals and use them in one large detector. Then we can greatly simplify the system but substantially improve the performance with high granularity approach. Apparently, we saw the improvement of the risetime of our pixelated TES if we scale down the pixel size from 100um to 20um. We have demonstrated the simultaneous operation of two rows of 20 pixels (total 40 pixels) with this scheme. Now we are developing an optical TES for quantum computing and the parallel biasing approach can improve the speed, which is important for optical applications. The small heat capacity leads to the large signal amplitude as well. Actually, it is very difficult to operate high granular pixelated detector with individual readout scheme but this scheme can work even for 500nm scale pixels. We plan to fabricate 8 by 8 array of such a small-scale device (total size 4um x 4um) with the parallel biasing scheme.

Session: Oral O6-1: Warm Readout and Supporting Science

Schedule: Wednesday 28 July 07:00 - Wednesday 28 July 07:30

Submitted by: Sonia Buckley - NIST

Superconducting opto-electronic hardware for neuromorphic computing

Sonia Buckley

National Institute of Standards and Technology

The field of neuromorphic computing aims to develop hardware that mimics some of the features of the hardware in the brain, in order to reproduce some of the brain's unique computational abilities. Towards this goal, we have proposed a superconducting opto-electronic neuromorphic hardware platform that aims to realize complex, brain-inspired systems by combining the high degree of parallelism available in the photonic domain with the high efficiency of electronics in the superconducting domain. I will provide a brief overview of the field of neuromorphic computing before discussing the proposed superconducting opto-electronic hardware in particular. I will discuss our progress toward developing the new required components in-house at NIST, including semiconductor LED light sources coupled to integrated waveguides for communication, and superconducting single-photon detectors and superconducting electronics for low-power, energy efficient computation. Finally, I will discuss ideas for future exploration in this area, and where I believe some of the most important questions and opportunities remain.

Session: Oral O6-2: Warm Readout and Supporting Science

Schedule: Wednesday 28 July 07:30 - Wednesday 28 July 07:45

Submitted by: Manuel Gonzalez - Astroparticle and Cosmology laboratory

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Fully differential broadband LNA with active impedance matching for SQUID readout

Manuel Gonzalez, Damien Prêle, Si Chen

Astroparticle and Cosmology laboratory

Low noise amplifiers (LNA) are key elements in most instrument's detector readout chains. In this paper we present the development and characterization of a differential to differential SiGe BiCMOS LNA with active impedance matching for the readout of Superconducting Quantum Interference Devices (SQUIDs). The matching impedance is particularly important when using the LNA over a wide band and it is achieved using the Miller effect by adding a negative feedback loop. This approach avoids the degradation of the noise performance that is generated by simply using a parallel resistor at the LNA input. Furthermore, this impedance matching implementation preserves the signal to noise ratio (SNR) because both, the signal signal and the noise, are divided by a factor of 2 due to the impedance matching and negative feedback loop. This was verified by measuring a lower input voltage noise with the LNA input loaded with a 100 Ω resistor at 77 K compared to a short-circuit.In addition, we present simulations and measurements of the LNA gain, input impedance and input voltage noise. The obtained performances for the LNA show a flat gain of 86 V/V with a cut-off frequency of 26 MHz and an input voltage white noise spectral density level lower than 0.5 nV/$\sqrt{Hz}$ with a corner frequency of 200 Hz. These values are in good agreement with the simulations. Finally, a discussion about the impact of the impedance matching on the SQUID biasing is also presented.

Session: Oral O6-3: Warm Readout and Supporting Science

Schedule: Wednesday 28 July 07:45 - Wednesday 28 July 08:00

Submitted by: Neelay Fruitwala - UC Santa Barbara

End-to-end Deep Learning Pipeline for Microwave Kinetic Inductance Detector (MKID) Resonator Identification and Tuning

Neelay Fruitwala, Alex B. Walter, John I. Bailey III, Rupert Dodkins, Benjamin A. Mazin

UC Santa Barbara

We present the development of a machine learning based pipeline to fully automate the calibration of the frequency comb used to read out optical/IR Microwave Kinetic Inductance Detector (MKID) arrays. This process involves determining the resonant frequency and optimal drive power of every pixel (i.e. resonator) in the array, which is typically done manually. Modern optical/IR MKID arrays, such as DARKNESS (DARK-speckle Near-infrared Energy-resolving Superconducting Spectrophotometer) and MEC (MKID Exoplanet Camera), contain 10-20,000 pixels, making the calibration process extremely time consuming; each 2000 pixel feedline requires 4-6 hours of manual tuning. Here we present a pipeline which uses a single convolutional neural network (CNN) to perform both resonator identification and tuning simultaneously using a sliding-window object detection scheme. We find that our pipeline has performance equal to that of the manual tuning process, and requires just twelve minutes of computational time per feedline.

Session: Oral O6-4: Warm Readout and Supporting Science

Schedule: Wednesday 28 July 08:00 - Wednesday 28 July 08:15

Submitted by: Andrew Beyer - Jet Propulsion Laboratory

Comparing hydrogenated amorphous silicon fabrication techniques for low loss, low noise dielectrics in superconducting detectors

Andrew D. Beyer [1], Fabien Defrance [2], Shibo Shu [2], Debopam Datta [2], Byeong H. Eom [1], Peter Day [1], Jack Sayers [2], Sunil Golwala [2]

[1] Jet Propulsion Laboratory, California Institute of Technology Pasadena, CA, USA.
[2] California Institute of Technology, Pasadena, CA, USA.

We compare our different methods of fabricating hydrogenated amorphous silicon (a-Si:H) for use as a low-loss, low-noise dielectric in kinetic inductance detectors (KIDs) and superconducting microstripline for mm-wave instrumentation. We deposited a-Si:H using plasma-enhanced chemical vapor deposition (PECVD) and inductively coupled plasma (ICP)-PECVD. Our ICP-PECVD films employed a range of recipes using Ar, H_2 and SiH_4 process gasses and varying total pressure, ICP power, and RF substrate power. We also examined a-Si:H from a PECVD tool with SiH4 diluted in Ar and at two different substrate temperatures. We studied the morphology and film properties of the a-Si:H films using Fourier-transform infrared spectroscopy (FTIR), ellipsometry, energy dispersive spectroscopy, and atomic force microscopy. Superconducting resonators using parallel-plate Nb/a-Si:H capacitors were used to measure film performance. Films with larger refractive index n (from ellipsometry, indicating denser films) and smaller FTIR peaks associated with Si-H species (thought to track voids in the films) generally showed lower loss. Our best films demonstrate loss tangent $\leq$ $10-5$ for resonators with RF frequencies at internal fields of 1000 V/m.. We also measured two-level-system fractional frequency noise for a subset of these recipes, obtaining a noise level of ~ 5 x 10^{-19}/Hz at 240 mK, 1 Hz audio frequency, and 850 MHz resonant frequency for one recipe.

Session: Oral O6-5: Warm Readout and Supporting Science

Schedule: Wednesday 28 July 08:25 - Wednesday 28 July 08:40

Submitted by: Jennifer Smith - University of California, Santa Barbara

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Designing the Next Generation UVOIR MKID Readout on RFSoC Devices

Jennifer Smith, J. I. Bailey, III, John Tuthill, Leandro Stefanazzi, Gustavo Cancelo, Ken Treptow, Benjamin A. Mazin

University of California, Santa Barbara

Current readout systems for highly-multiplexed superconducting detector arrays suffer from the complexity associated with disparate analog components, outdated FPGA designs and tool flows, and overall lack of reproducibility. These ailments lead to physically cumbersome and power-intensive systems which are also difficult to maintain, improve, and reuse. We are designing a new Gen3 UVOIR MKID readout system targeting recently developed analog-integrated FPGAs known as RF system-on-a-chip (RFSoC) devices. The new system will decrease the readout volume and weight by 80% and will process 2x the bandwidth with an order of magnitude less power. The FPGA system design eschews custom Hardware Description Language (HDL) and instead leverages Vivado HLS to synthesize more familiar C++ code to HDL leading to enhanced flexibility and adaptability for scientific users without specialized knowledge in FPGA design. The design uses the novel PYNQ system which runs a Jupyter Notebook server on the RFSoC hard-core CPU providing a user-friendly platform to interface with the system using Python and the enhanced capability to create an instrument dashboard using Jupyter Labs. We report on the design and implementation of the current system targeting the ZCU111 evaluation board.

Session: Oral O6-6: Warm Readout and Supporting Science

Schedule: Wednesday 28 July 08:40 - Wednesday 28 July 08:55

Submitted by: David Goldfinger - Harvard University

Thermal Filtering in BICEP Array

David Goldfinger on behalf of the BICEP/Keck Collaboration

Harvard University

Managing the thermal load from infrared radiation is an important aspect of the design of cryogenic receivers. Successive filters that intercept “out-of-band radiation from warmer stages while transmitting in the science band optimize both the cryogenic and scientific performance. To explore the performance of infrared filtering components, we have installed macrobolometers into a BICEP Array receiver undergoing commissioning to directly measure the radiative load from successive thermal stages. We compare these measurements from multiple configurations to predictions obtained from a thermal model that we have developed for this purpose. These results are used to better inform design choices for current stage 3 and future stage 4 instruments.

Session: Oral O6-7: Warm Readout and Supporting Science

Schedule: Wednesday 28 July 08:55 - Wednesday 28 July 09:10

Submitted by: Joel Weber - NIST Boulder

Flexibility in Array Design with Hybrid Additive-Subtractive TES Process

Joel C. Weber, Kelsey M. Morgan, Douglas A. Bennett, Daikang Yan, Abigail L. Wessels, Christine G. Pappas, Galen C. O'Neil, Daniel S. Swetz, Gene C. Hilton, Joel N. Ullom, and Daniel R. Schmidt

National Institute of Standards and Technology

Mature applications of superconducting transition-edge sensor (TES) microcalorimeters demand larger array sizes and hybrid arrays with varied pixel designs. Achieving high performance necessitates a fabrication platform with predictable control of material properties. Superconducting-normal metal bilayers have become the standard approach to fill this demand but are limited in their design flexibility. We have introduced the hybrid additive-subtractive TES (hasTES) process whereby the bilayer films are deposited and patterned independently, enabling novel TES designs, hybrid transition temperature (T_c) arrays, and film-specific deposition methods.

Development of new arrays for beamline experiments has highlighted the flexibility of hasTES. Two recent examples include an array for the Stanford Synchrotron Radiation Lightsource and a wide energy band array for Los Alamos National Lab. For the former, balancing strict resolution, readout speed, and cryostat limits requires exquisite control of T_c and thermal properties. We can fabricate six arrays with six different T_c's on a single wafer run, enabling rapid design-fabrication-test cycles. In the latter, we were tasked with designing an array with low-, mid-, and high-energy pixels spanning from 1 keV – 20 keV. The hasTES compatibility with electroplated Bi absorbers enables each pixel variant to have a unique absorber thickness and T_c to meet highly customized design requirements with straightforward fabrication steps.

Session: Oral O6-8: Warm Readout and Supporting Science

Schedule: Wednesday 28 July 09:10 - Wednesday 28 July 09:25

Submitted by: Carolyn Volpert - University of Maryland & NASA Goddard

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Low Loss Thin Film Al-on-Si Microwave Resonators for Astronomy Applications

Carolyn Volpert, Eric R. Switzer, Emily M. Barrentine, Thomas R. Stevenson, Trevor M. Oxholm, Omid Noroozian, Larry A. Hess, Mona Mirzaei, Jake A. Connors, Aveek Gangopahyay, Alberto D. Bolatto, Giuseppe Cataldo, Edward J. Wollack

University of Maryland & NASA Goddard

As microwave kinetic inductance detectors (MKIDs) grow in popularity for far-IR and sub-mm applications, there is an increasing drive to deliver low loss devices. We present measurements of prototype thin-film Al resonators capable of achieving high Q_i's. The device we exhibit contains 16 coplanar waveguide (CPW) resonators etched into a $\sim$ 25 nm sputter deposited Al layer on a single crystal silicon dielectric, and is not optically coupled. The resonators span the f_0 = 3.5 - 4 GHz range, and include both $\lambda/2$ and $\lambda/4$ resonators. Each resonator is coupled to the feedline using one of three alternating coupling designs. We performed transmission line measurements of the device for a series of excitation powers and base temperatures to model mechanisms of loss. We note loss contributions from two-level system (TLS), microwave-induced pair-breaking, and thermal quasiparticle loss. We observe Q_i's ranging from $\sim 2 \times 10^6$ - 1×10^7 at a base temperature of 73 mK for high to medium read-tone powers. The results of these measurements are actively informing the design of the EXperiment for Cryogenic Large-Aperture Intensity Mapping (EXCLAIM) instrument. EXCLAIM will incorporate six spectrometers, each sensitive to light in the 420-540 GHz range and containing an array of over 300 microstrip resonators of the same thin aluminum material. The Q_i performance demonstrated by these early-stage test devices is already sufficient to meet EXCLAIM's desired sensitivity.

Session: Oral O6-9: Warm Readout and Supporting Science

Schedule: Wednesday 28 July 09:25 - Wednesday 28 July 09:40

Submitted by: Miguel Daal - UC Santa Barbara

Hafnium, Zirconium and Vanadium Superconducting Resonators

Miguel Daal, Greg Coiffard, Nick Zobrist, Ben Mazin

UC Santa Barbara

We share data from our studies to use Hf, Zr, and V as superconducting resonators. Information on Etching, chemical compatibility, deposition, and deposition material quality is included. Film properties such as resistivity, stress, crystal structure, morphology and how they influence resonator quality factor and T_c are also presented.

Session: Oral O6-10: Warm Readout and Supporting Science

Schedule: Wednesday 28 July 09:40 - Wednesday 28 July 09:55

Submitted by: Jason Stevens - University of Colorado Boulder

Measuring the Effects of Background Radiation on Superconducting Devices

Jason R. Stevens [1,2], Raymond Bunker [3] , Ellen Edwards [3] , Jiansong Gao [2] , Ben Loer [3] , Sae Woo Nam [2], John Orrell [3] , Joel Ullom [2], Brent Vandevender [3] , and Michael Vissers [2]

[1] University of Colorado, Boulder
[2] National Institute of Standards and Technology
[3] Pacific Northwest National Laboratory

We live amid a background of ionizing radiation from both terrestrial and cosmic sources. This background radiation affects the operation of superconducting devices including both qubits and sensors. For example, one contibution to qubit decoherence may be excess quasiparticles produced by ionizing background radiation in the environment. Naturally occurring background radiation is also a source of unwanted background events in sensors designed to detect dark matter or perform various rare event searches. Other sensors, such as those for nuclear materials analysis, operate in elevated radiation fields by design. However, the same radiation that interacts with the sensors can also interact with other circuitry, such as superconducting readout elements, producing unwanted effects.

To better understand the impact of background radiation on superconducting devices, we are performing a combination of simulations and laboratory measurements. We are particularly interested in understanding how energy from background radiation can couple to superconducting devices through their underlying substrate. We have run Monte Carlo simulations using the Geant4 toolkit to simulate radiation deposition in a silicon substrate due to both cosmic and terrestrial sources under a variety of circumstances. These simulations include phonon transport using the Condensed Matter Physics (G4CMP) library. Including phonon transport allows us to study how energy deposited in one region of a silicon substra

Session: Poster P6-1: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Carl Reintsema - NIST

A Cryogenic Quality Assurance Test Platform For SQUID-Based Readout Electronics

Carl Reintsema Scott Backhaus, Doug A. Bennett, Edward V. Denison, William B. Doriese, Malcolm Durkin, Johnathon D. Gard, Gene C. Hilton, Vince Kotsubo, Tammy Lucas, Nathan J. Ortiz, Dan R. Schmidt, Robert W. Stevens, Joel N. Ullom

National Institute of Standards and Technology

The x-ray integral field unit (X-IFU), a spectroscopic x-ray imaging instrument aboard the ESA Athena satellite, will utilize 3168-pixels of transition edge sensors read out by time division SQUID multiplexers (TDM). Each version of the X-IFU (development to flight versions) will require up to 24 qualified 2-dimensional SQUID multiplexers and well over 100 qualified devices will be required over the life of the program. NIST is developing measurement techniques and a dedicated cryogenic system for the quality assurance of these components. The system must be able to provide fast turn-around, minimally impactful (no wire bonding), low risk qualification through execution of a full set of dc parametric tests that assure basic functionality and adequate yield of the devices. To meet this challenge, we are designing a system based on a Gifford-McMahon 2-stage mechanical cryocooler that cools a wafer of multiplexers and a cryogenic probe card electrical interface with 400 signal lines to 3K. The cryostat has optical access and limited mechanical translation to allow warm alignment and to assure contact to the device under test after cooling to 3 K. The system is designed to test devices at wafer scale and utilizes a removeable 3 K cartridge that allows for wafer-probe card translation and alignment to reach all die on a wafer. Two of these cartridges will be cycled to meet throughput demands. We report on the unique challenges of this system and the progress made to date.

Session: Poster P6-2: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Yingni Chen - Southwest Jiaotong University

A novel superconducting RF low-pass filter based on low-T_c Ti/TiN artificial transmission line for detector and qubit readout

Y. Chen [1], J. Hu [1], X. Dai [1], Q. He [2], H. Gao [2], P. Ouyang [2], J. Han [2], Y. Wang [1],, a) L. F. Wei [2], M. R. Vissers [3], J. Gao [3]

[1] Quantum Optoelectronics Laboratory, School of Physical Science and Technology, Southwest Jiaotong University, Chengdu, Sichuan 610031, China.
[2] Information Quantum Technology Laboratory, School of Information Science and Technology,Southwest Jiaotong University, Chengdu, Sichuan 610031, China.
[3] National Institute of Standards and Technology, Boulder, CO 80305, USA

Cryogenic detector and qubit readout systems often include RF low pass filters (LPF) at the input/output paths to protect the sensitive devices from stray radiations traveling down the coaxial lines. For this application, a popular solution is to use custom-made copper powder filters, which are LPFs with injection of copper powder loaded epoxy. They are very effective in attenuating high frequency (THz and far infrared) radiations but often introduce a few dB undesired insertion loss at the readout band < 10 GHz. Here we describe a novel LPF design concept based on low-T_c (500 mK) Ti/TiN superconducting artificial (lumped-element) transmission lines. We carefully design the unit inductance L and unit capacitance C so that the cut-off frequency $f_c = 1/(\pi\sqrt{LC}) \approx 25$ GHz and the characteristic impedance $Z_0 = \sqrt{L/C} \approx 50$ Ohm. Above the gap frequency (~ 45 GHz), the transmission line behaves like a lossy line made of normal metal which naturally attenuates all the high-frequency radiations. In addition, we use radiation-absorbing material (ecosorb) placed away from the transmission line to suppress the box resonance modes and parasitic propagation mode while not affecting the low frequency transmission. A detailed design and EM simulation using realistic material parameters will be discussed. Our novel LPF design offers the advantages of close-to-zero insertion loss at < 10 GHz, precise and sharp frequency cut-off, compact size, easy fabrication and integration with other superconducting circuits

Session: Poster P6-3: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Tasuku Hayashi - ISAS/JAXA

A quantitative study in STEM-EDS with a broadband TES X-ray microcalorimeter toward astromaterials analysis

Tasuku Hayashi [1], Takaaki Noguchi [2], Yuta Yagi [1], Keita Tanaka [1], Noriko Y. Yamasaki [1], Kazuhisa Mitsuda [3], Keisuke Maehata [4], Toru Hara [5]

[1] ISAS/JAXA
[2] Kyoto Univ.
[3] NAOJ
[4] Teikyo Univ.
[5] NIMS

Studies of astromaterials, including sample-return missions such as HAYABUSA2 and OSIRIS-REX, provide valuable insights into the formation and the evolution of the solar system. Astromaterials are composed of both organic and inorganic materials. Therefore, various kinds and amounts of elements can be found in them. To analyze such astromaterials on a sub-micrometer scale, one of the most useful tools is Energy-dispersive X-ray spectroscopy (EDS) in conjunction with a scanning transmission electron microscope (STEM). We studied an analysis method of concentration determination of astromaterials with a transition edge sensor (TES) X-ray microcalorimeter. We developed a 64-pixel TES X-ray microcalorimeter array with two different-thickness absorbers in the same device for the broadband X-ray, which had an energy resolution of about 7 eV (FWHM) at the energy band from B K_α (=183 eV) to Cu K_α (=8 keV).

In order to implement the quantitative analysis without damaging the sample in the TES-EDS system, we established an analytical quantitative procedure. We intended to find the relative concentration of elements in the X-ray energy spectra and estimate the intensities of the characteristic emission lines of those elements. For this conversion, we adopted the Cliff-Lorimer method, also known as the k-factor method, which is widely used for material analysis (Cliff and Lorimer, 1975). During this study, we optimized an estimation method of the k-factor in the TES-EDS system.

Session: Poster P6-4: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Jiao Ding - Department of Astronomy, Tsinghua University

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A μK-level Temperature Stability Control Method for TES Energy Resolution Test

J. Ding [1], Y. R. Wang [1], H. Jin [1,2,3], C. Z. Li [1], J.J. Liu [1] , W. Cui [1], S. F. Wang [1], Y.L. Chen [1] , F. J. Li [1], Y.J. Liang [1], G. L. Wang [1], R. Huang [1] , Y. N. Zhang [1] , Y. Zhou [1], J. Shen [2,3] and W. Dai [2,3]

[1] Department of Astronomy, Tsinghua University
[2] University of Chinese Academy of Sciences, Beijing 100049, China
[3] Technical Institute of Physics and Chemistry, Beijing 100190, China

Hot Universe Baryon Surveyor (HUBS) will focus on the major scientific issue of missing" baryons by developing high-resolution X-ray imaging satellite to detect large-scale fiber-like structures in the universe and the distribution of matter around galaxies. It is believed that the missing baryons exist in the halos of galaxies or in the large-scale filamentary structures. Since the expected radiation is in the soft X-ray band ($<\sim$ 1 keV) and is very weak, HUBS will use an X-ray microcalorimeter based on transition-edge sensors (TES) array and an adiabatic demagnetization refrigerator (ADR) is employed to reach the detector working temperature ($<$100 mK). TESs are thermal detectors based on superconducting films which detect the energy of a single X-ray photon as a temperature rise. By biasing the superconducting film within the normal state to the superconductive state region, it can be used as a highly sensitive thermometer with its steep resistance-temperature relationship in the transition region. Therefore temperature fluctuation of TES stage will influence its measurement on the photon's energy, which requires a very stable temperature regulation on TES stage. In order to have such a stable temperature regulation, we developed a method of close cycle control. Based on this method we are able to reduce the temperature fluctuation of the detector stage down to μK level at about 100mK. This temperature stability could meet our requirements for detector resolution test.

Session: Poster P6-5: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Masatoshi Tsuji - National Institute of Technology, Kagawa College

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Assessment of the RFI by the X-band antenna in LiteBIRD using a 3D electromagnetic field simulator

M. Tsuji [a], M. Tsujimoto [b], Y. Sekimoto [b], T. Dotani [b], M. Shiraishi [a]

[a] National Institute of Technology, Kagawa College, 355 Chokushi-cho, Takamatsu, Kagawa 761-8058, Japan
[b] Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science, 3-1-1 Yoshino-dai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan

LiteBIRD is a planned spacecraft aiming to detect the large-scale anisotropy of the linear polarization of the cosmic microwave background expected from the theory of inflation. It will be launched into the second Lagrangian point of the Sun-Earth system, from which it communicates with the ground stations using the X-band (8.4 GHz). This is considered a potential source of the radio frequency interference (RFI) upon the transition-edge sensor bolometers placed at the focal plane of LiteBIRD. It is mandatory to assess the level of RFI and optimize the design early in the project, which we performed using an electromagnetic field simulator based on the finite-difference time-domain solver. We constructed a 3D model of the entire spacecraft, radiated a power from the position of the X-band antenna, and assessed the electric field strength at the bolometer positions.

First, we evaluated the level of RFI for the different surface materials used in the spacecraft main body. A larger attenuation was obtained for Al and CFRP with respect to PEC by 1.5 dB and 10.5 dB, respectively. Second, we evaluated the frequency dependence of the RFI. The attenuation slope was -10 dB/oct. The electric field intensity at 8.4 GHz was estimated to be -116.8 dBV/m at the bolometer position. Finally, we evaluated the RFI level for several proposed designs of the thermal shields against the Sun and the solar panels. An additional attenuation of 17-31 dB was obtained for the optimum designs.

Session: Poster P6-6: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Cyndia Yu - Stanford University

Bandwidth and Aliasing in the Microwave SQUID Multiplexer

Cyndia Yu (Stanford)
Edward Young (Stanford)
Zeeshan Ahmed (SLAC)
J. Mitch D'Ewart (SLAC)
Josef Frisch (SLAC)
Shawn Henderson (SLAC)
Jake Connors (NIST)
Bradley Dober (NIST)
Hannes Hubmayr (NIST)
J. A. B Mates (NIST)

The microwave SQUID multiplexer (umux) has found application across a wide range of experiments, including particle physics, astronomy, and spectroscopy. The large multiplexing factor coupled with recent availability in microwave components and warm electronics readout systems make it an attractive candidate for systems requiring large cryogenic detector counts. Since the multiplexer is considered for both bolometric and calorimetric applications across several orders of magnitude of signal frequencies, understanding the bandwidth of the device is key to designing appropriately matched detectors. We show that the bandwidth of the multiplexer can be extended beyond the bandwidth of the microwave resonance; however, technical challenges often limit operational bandwidth to the resonance linewidth. For a given signal frequency range, we discuss how aliasing and noise considerations set the optimal operation frequency, particularly for high-bandwidth systems. We present simulations and measurements of umux devices coupled with SLAC Microresonator RF (SMuRF) tone-tracking electronics and discuss the implications for future experimental design.

Session: Poster P6-7: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Kana Sakaguri - University of Tokyo

Broadband multi-layer Anti-reflection coatings with mullite and duroid used for half wave plate and alumina filter for CMB polarimetry

Kana Sakaguri, Masaya Hasegawa, Yuki Sakurai, Charles Hill, Akito Kusaka

University of Tokyo

For the precise measurement of cosmic microwave background (CMB) signals, anti-reflection (AR) coating is important to maximize the number of photons reaching the detectors. Sapphire and alumina used for half-wave plates and infrared filters have a high refractive index of about 3.1, making AR coatings particularly critical for these materials.

We develop broadband AR coatings on half-meter-scale optics for ground-based CMB experiments with 90/150 GHz and 220/280 GHz dichroic detectors that cover 30% fractional bandwidth. To realize such broad frequency coverage, we develop multi-layer coatings with an average reflectivity of less than 1%. There are two challenges regarding AR coatings for CMB observations. First, it is difficult to apply the coating on 50 cm-diameter sapphire or alumina with a uniformity of tens of microns. Second, the AR coatings operate at 50 K to limit thermal radiation on the cryogenic detectors, creating challenges associated with differential thermal contraction. We use mullite, a ceramic material, for the first layer and duroid, a composite material, for the second layer. These materials are selected both for their refractive index and coefficient of thermal expansion. We discuss the production and the optical performance evaluation of our AR coatings.

Session: Poster P6-8: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Hiroshi Matsuo - National Astronomical Observatory of Japan

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Cryogenic Readout Electronics for SIS Photon Detectors

Hiroshi Matsuo [1,2], Hajime Ezawa [1,2], Ryohei Noji [3], Kazuyuki Iwata [4]

[1] National Astronomical Observatory of Japan
[2] The Graduate University for Advanced Studies, SOKENDAI
[3] University of Tsukuba
[4] Toho University

Intensity interferometry can be an innovative technology for aperture synthesis imaging in terahertz frequencies when fast photon counting detectors are introduced. We named this method Photon Counting Terahertz Interferometry, which utilizes the fast photon counting detectors to measure the delay time accurately to obtain complex visibility only from intensity measurements. For this purpose, we work on SIS photon detectors with low leakage current operational at less than 0.8 K. Fast response with bandwidth larger than a few GHz can be obtained either by photon assisted tunneling or pair breaking processes.

For fast readout electronics of SIS photon detectors, we have chosen Junction-pHEMTs (JpHEMTs) to make source followers operational at 0.8 K for impedance transformation. Cryogenic performance of JpHEMTs with different gate sizes was measured at operational temperature between 300 K and 0.8 K. Their I-V characteristics are almost the same below 77 K and gate leakages are less than 100 fA owing to the junction gate structures. However, when the drain voltages are larger than 2 V, kink structure in I-V characteristics appear which cause large gate leakages as large as 100 pA, which should be avoided. To achieve photon counting capability, gate capacitance of less than 10 fF is required, which is under evaluation. In the presentation, we would like to show some early results on cryogenic performance of JpHEMT source followers at 0.8 K to readout SIS photon detectors.

Session: Poster P6-9: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Mayu Tominaga - the University of Tokyo, JAXA

Design of the On-board Data Compression of the Bolometer Data for LiteBIRD

Mayu Tominaga (the University of Tokyo/JAXA), Masahiro Tsujimoto (JAXA)
on behalf of LiteBIRD Joint Study Group

LiteBIRD is a space-born experiment dedicated for detecting a large-scale B-mode anisotropy of the linear polarization of the Cosmic Microwave Background (CMB) predicted by the theory of inflation. It is planned to be launched in the late 2020s to the second Lagrangean point of the Sun-Earth system and map the sky in 15 frequency bands. In comparison to Planck HFI, which is the preceding low-temperature bolometer for CMB observations, the number of detector has increased by two orders. The data rate is 19 Hz from each detector. The bandpass to the ground is limited to 10 Mbps with the X-band for a few hours per day. These require the data to be compressed by more than 50%. This depends on how much information entropy is contained in the real data. We thus evaluated this by simulating the time-ordered data of the polarization sensitive bolometers. The foreground emission, detector noise, cosmic ray glitches, leakages from the CMB total power to the polarization, etc are simulated. We developed an algorithm combining fitting and lossless encoding, and demonstrated that the required compression rate can be achieved in all frequency bands. We describe the details of the evaluation and propose an algorithm that can be employed in the on-board digital electronics of LiteBIRD.

Session: Poster P6-10: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Tammy Lucas - National Institute of Standards and Technology

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Development of Hybridization Processes for Superconducting Sensors and Readout Circuitry

Tammy Lucas, Gene Hilton, Dan Schmidt, Mike Vissers, John Biesecker, Shannon Duff, Joel Ullom

National Institute of Standards and Technology

As instruments based on superconducting sensors and readout circuitry become larger and more complex, traditional two-dimensional packaging architectures become impractical. Three-dimensional hybridization processes offer advantages in increasing interconnect density, ease in connecting dissimilar devices, and isolation between distinct device functions. Yield improvements may be enabled by hybridization of structures that are difficult to integrate on the same wafer. Even when fully integrated fabrication is possible, production efficiency may be increased with hybridization.

We will present our flip-chip die bonding processes with electrical and mechanical interconnects formed from indium bumps on a titanium nitride under bump metallization layer (UBM). Titanium nitride is reactively sputtered onto wiring pads for electrical interconnects or as designed elsewhere for mechanical interconnect enhancement. Indium is thermally evaporated onto titanium nitride at the desired thickness for bump bonding. Patterning for both titanium nitride and indium is accomplished by liftoff techniques. Additionally, we will present electrical and mechanical results from hybridized devices constructed by our fabrication process. While our test results illustrate the promise of three-dimensional hybridization applied to a wide range of superconducting sensor applications, we will also highlight some of the expected challenges.

Session: Poster P6-11: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Kyohei Yamada - The university of Tokyo

Development of inductively coupled position and temperature sensors for cryogenic rotating half wave plate

Kyohei Yamada, Yuki Sakurai, Akito Kusaka

The University of Tokyo

In the precision polarimetry of the Cosmic Microwave Background (CMB), it is important to modulate the CMB polarization while also minimizing photon noise due to thermal emission. The modern CMB experiments employ cryogenic sapphire half-wave plate (HWP) rotating at 2 Hz on a superconducting magnetic levitating bearing. For measuring the 3 dimensional position and the temperature of the rotor, we designed an inductively coupled cryogenic LC sensor which has a resonance peak when driven around 100 kHz. This low resonance frequency has the advantage of being less susceptible to the stray impedance and the environmental noise, and does not affect the readout electronics. This sensor is useful to identify the cause of systematic noise synchronized with the rotation of the HWP on the detectors for the CMB measurement. This sensor works as an eddy current position sensor and at the same time it works as a temperature sensor by resonant coupling with the resonator connected to the thermometer on the rotor. We will report the development status and the performance as the position and the temperature sensor in the actual equipment.

Session: Poster P6-12: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Junya Suzuki - Kyoto University

Development of low-cost readout electronics for resonator-based multiplexing detector arrays

Junya Suzuki, Shunsuke Honda, Yoshinori Sueno, Osamu Tajima

Kyoto University

Microwave multiplexing has gained popularity for superconducting detector readout. This is because the multiplexing reduces the complexity of wiring and heat transfer via the wires. Kinetic Inductance Detectors (KIDs) can be read with microwave multiplexing by nature, and used as a solution to a large format array for mm/THz astronomical observation.

We developed low-cost multiplexing readout electronics for superconducting resonator arrays combining commercially available analog and digital boards. The system consists of a digital-analog converter board with 1 GHz sampling capability and a digital board equipped with a Xilinx Kintex Ultrascale FPGA. The use of consumer products helps to reduce costs and to enhance availability.

The firmware can handle 512 readout channels within a 1 GHz bandwidth. The output waveform is stored in the DDR4 memory and is streamed by a DMA core. The input is Fourier-transformed by quad FFT cores, followed by a frequency bin selector to reduce the data amount before being sent over Gigabit Ethernet.

In this poster, we will describe the readout system and show the results of performance tests. The firmware for FPGA on the digital board will be presented in detail. The performance of the system, including the noise figure, will be presented and discussed. We applied the system to a KIDs array readout, and the result will also be shown.

Session: Poster P6-13: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Jozsef Imrek - NIST

Direct RF Readout of SQUID Multiplexed Transition-Edge Sensors Using Xilinx RFSoC

Jozsef Imrek [1,2], Daniel Becker [1,2], Douglas A. Bennett [2], John Gard [1,2], Carl D. Reintsema [2], Abigail Wessels [1,2], Joel Ullom [1,2]

[1] University of Colorado
[2] National Institute for Standards and Technology

There is pressing demand for arrays of TES and MMC microcalorimeters with ever-increasing numbers of pixels. System complexity and per pixel readout cost are a concern for such multi-kilopixel cryogenic detector setups.

One attractive scheme to read out a high number of cryogenic pixels is microwave SQUID (frequency division) multiplexing with heterodyne RF readout.

Typically an FPGA drives a set of high speed DACs, generating readout tones in baseband, which are moved to the sensors' readout frequency using single-sideband upmixing, passed through the readout resonators, moved back to baseband using downmixing, digitized with high speed ADCs, and processed in the FPGA. DAC outputs and ADC inputs are filtered, to remove signal components above their Nyquist frequencies.

However it is also possible to keep only the usually unwanted higher harmonics in the DAC outputs, and to use ADCs in undersampling mode, operating both in their higher Nyquist zones. This allows readout tone transmission and reception directly at the sensors' frequency, in direct RF mode, without IF electronics, reducing system complexity and cost.

Recent advances in DAC and ADC technology (higher sampling rates, IC packages with more analog bandwidth, mix-mode DAC output, built-in up/downconverters) have made it practical to use direct RF mode with our sensor arrays.

We present our first successful attempt at reading out SQUID multiplexed TES sensors in direct RF mode, using Xilinx's RFSoC FPGA family.

Session: Poster P6-14: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Gabriel Spahn - University of Minnesota Twin Cities

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Epoxy IR Filters for Superconducting Resonators

Gabriel Spahn, Noah Kurinsky, Daniel Bowring, Matt Hollister, Akash Dixit, Osmond Wen

University of Minnesota Twin Cities

Microwave Kinetic Inductance Detectors (MKIDs) are superconducting microresonators that are most commonly used for microwave detection in astronomy. They have potential for use as phonon detectors in cryogenic dark matter searches, but their implementation faces a number of technical challenges. Among these issues is the potential for higher-temperature infrared photons to reach the superconducting substrate and consequently degrade the quality factor of the MKID's resonance. This thesis details the design and construction of epoxy-based filters meant to mitigate this effect, and finds that their installation in the readout system for an Al MKID increased its quality factor by up to 10% across a range of operating temperatures.

Session: Poster P6-15: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Naoko Iyomoto - Kyushu University

Gamma-Ray Position-Sensitive Transition-Edge-Sensor Microcalorimeters With a Bismuth Absorber

Naoko Iyomoto

Kyushu University

We are developing position-sensitive transition-edge-sensor microcalorimeters (PoSTs) to detect gamma rays with energies up to a few MeV. We have fabricated a PoST device consisting of a 1 mm × 1 mm × 20 mm bismuth absorber and two transition-edge sensors (TESs). We irradiated the PoST device with gamma rays using a Cs-137 source and compared the pulse heights of the output signals from the two TESs to determine the gamma-ray-interaction position in the absorber. We modeled the PoST device by assuming that the continuous absorber can be represented as a series of seven segments and six thermal links between the segments. By numerically solving two electrical differential equations of the two TESs and nine thermal differential equations of the two TESs and seven absorber segments, we simulated the pulse shapes of the signals from each of the seven segments. The shape of the actual and simulated pulses were in good agreement.

Session: Poster P6-16: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Elizabeth Mae Scott - National Institute of Standards and Technology

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Large-Area TKIDs for a New Generation of Neutron Beta Decay Experiments

E. M. Scott, H. Pieter Mumm, Shannon F. Hoogerheide, Colin Heikes, M. Scott Dewey, Jeff Nico, Jiansong Gao, Michael R. Vissers, Joel Ullom

National Institute of Standards and Technology

Neutron beta decay, the process by which a free neutron decays into a proton, electron and antineutrino, is the simplest example of the semi-leptonic weak interaction. Experimentally, it is a powerful way to search for physics beyond the Standard Model. A new detector paradigm for charged particle detection could potentially open up orders of magnitude improvement in sensitivity. The majority of beta decay experiments have traditionally used semiconductor detectors. Investigating low temperature detectors (sub-1K) could inspire a new generation of neutron beta decay experiments. These detectors, including Transition Edge Sensors (TES) and Microwave Kinetic Inductance Detectors (MKID), have been used in X-ray and gamma spectroscopy as well as dark matter searches and have been shown to have photon energy resolutions on the order of tens of eV or better. They can be multiplexed to create large area detectors with energy resolutions keV, which would revolutionize the next generation of neutron beta decay experiments. This poster covers the development of a robust design and testing program for optimizing thermal kinetic inductance detectors (TKIDs) for charged particle detection in neutron beta decay experiments. Initial prototype design and characterization will also be presented.

Session: Poster P6-17: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: John Hood - Vanderbilt University

Low loss microstrip materials with MKIDs for microwave applications

J. Hood [1,2], S. Meyer [2], C. Chang [2,3], P. Barry [3], T. Cecil [3], A. Bender [3], A. Tang [2], E. Shirokoff [2], Z. Pan [3], J.Li [3]

[1] Vanderbilt University, Nashville, TN 37235 USA
[2] University of Chicago, Chicago, IL 60637 USA
[3] Argonne National Laboratory, Argonne, IL 60439 USA

Future measurements of the millimeter-wavelength sky require a low-loss superconducting microstrip coupling the antenna to detectors, typically made from niobium and silicon-nitride. We propose a simple device for characterizing these low-loss microstrips at 150 GHz. In our device we illuminate an antenna with a thermal source and compare the measured power at 150 GHz transmitted down microstrips of different lengths. The power measurement is made using Microwave Kinetic Inductance Detectors (MKIDs) fabricated directly onto the microstrip dielectric, and comparing the measured response provides a direct measurement of the microstrip loss. Our proposed structure provides a simple device (4 layers and a DRIE etch) for characterizing the dielectric loss of various microstrip materials and substrates. We present initial results using these devices.

Session: Poster P6-18: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Fabien Defrance - Caltech

Low noise hydrogenated amorphous silicon for superconducting resonators

Fabien Defrance, Shibo Shu, Andrew D. Beyer, Byeong H. Eom, Peter Day, Jack Sayers, Sunil Golwala

Caltech

As described by the standard tunneling model (STM), two-level-systems (TLS) occurring inside amorphous materials at low temperatures are a major source of noise and loss for superconducting resonators like those used in kinetic inductance detectors and superconducting qubits. Resonators incorporating crystalline dielectrics like silicon or sapphire exhibit low TLS noise and loss, but they can be incorporated only in planar geometries (like interdigitated capacitors). Multi-layer capacitor geometries, such as parallel-plate capacitors, would vastly enhance design possibilities. We have developed hydrogenated amorphous silicon (a-Si:H) films that have low loss, approaching that of crystalline dielectrics. We report on noise measurements of niobium superconducting resonators incorporating parallel-plate capacitors with these a-Si:H films, finding noise performance that is comparable to that observed in superconducting resonators with planar capacitors on crystalline dielectrics.

Session: Poster P6-19: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Kyung-Rae Woo - Institute for Basic Science, KOREA

Low-temperature scintillation characteristics of Li2MoO4 and CaMoO4 crystals measured in AMoRE-I

Kyung-Rae Woo, Hye-Lim Kim, Yong-Chang Lee, Han-Beom Kim, Do-Hyung Kwon, Ho-Seong Lim, Yong-Hamb Kim

Institute for Basic Science, KOREA

The advanced Mo-based rare-process experiment (AMoRE) is an underground cryogenic particle detection experiment searching for neutrinoless double beta($0\nu\beta\beta$) decay of ^{100}Mo. The first phase experiment AMoRE-I uses thirteen $^{40}Ca^{100}MoO_4$ (CMO) and five $Li_2{}^{100}MoO_4$ (LMO) scintillating crystals composed of enriched ^{100}Mo isotopes as the target materials for simultaneous detection for phonon and scintillation signals with metallic magnetic calorimeter (MMC) readouts at mK temperatures at Yangyang underground laboratory. We investigated the scintillation dynamics of the two types of the crystals based on the pulse shape analysis of the light signals. The analysis obtained very distinct decay time constants of the scintillation processes for the types of molybdate crystals. We also present the correlation between the light signals and the corresponding phonon signals that show pulse shape differences for particle identification.

Session: Poster P6-20: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Tatsuya Takekoshi - Kitami Institute of Technology

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Material properties of a low contraction and resistivity silicon-aluminum alloy for cryogenic detectors

Tatsuya Takekoshi (Kitami Institute of Technology), Kianhong Lee, Kah Wuy Chin, Shinsuke Uno, Shuhei Inoue (University of Tokyo), Toyo Naganuma (UEC Tokyo), Yuka Niwa (Tokyo Institute of Technology), Kazuyuki Fujita, Akira Kouchi (Hokkaido University), Shunichi Nakatsubo (JAXA/ISAS), Satoru Mima (RIKEN), and Tai Oshima (NAOJ)

Large format arrays of superconducting detectors such as MKIDs and TESs are being developed to enhance the survey speed of the astrophysical telescopes. These detectors are often built on silicon wafers which are fixed on or sandwiched in between the aluminum components. The large difference in thermal contraction between silicon and aluminum can cause alignment error and thermal stress damaging the device when cooled to cryogenic temperature. Thus, recent mm/submm polarimetry experiments (e.g., CLASS, AdvACT) have introduced silicon-aluminum (SiAl) alloy, Sandvik Osprey CE7, for the feedhorn arrays as a low thermal expansion ($\sim$1/3 of aluminum) and non-magnetic material.

Here we report the cryogenic properties of alternative SiAl alloy, Japan Fine Ceramics SA001, which has similar composition (72wt%Si) and material properties at room temperature to CE7. The thermal contraction of SA001 immersed in liquid nitrogen is ΔL(293K-77K)/L=1.2E-4, which is equivalent to CE7 and $\sim$1/3 of aluminum. The measured superconducting transition temperature of SA001 is 1.18 K in good agreement with that of aluminum and CE7. On the other hand, the residual resistivity of SA001 is 0.06 $\mu\Omega$m and considerably lower than 0.5 $\mu\Omega$m for CE7. As a result, relatively high thermal conductivity is expected, thus making SA001 a good candidate for cryogenic detector applications. We will also present the demonstrated fabrication of the conical feedhorn array as an example of the machinability of SA001.

Session: Poster P6-21: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Hideyuki Tatsuno - Tokyo Metropolitan University

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Measurement of thermal crosstalk from charged particles absorbed in the Si substrate of a microcalorimeter array

H. Tatsuno [1], D.A. Bennett [2], W.B. Doriese [2], M.S. Durkin [2], J.W. Fowler [2], J.D. Gard [2], T. Hashimoto [3], R. Hayakawa [1], T. Hayashi [4], G.C. Hilton [2], Y. Ichinohe [5], H. Noda [6], G.C. O'Neil [2], S. Okada [7], T. Okumura [8], C.D. Reintsema [2], D.R. Schmidt [2], H. Suda [1], D.S. Swetz [2], J.N. Ullom [2], S. Yamada [5], (the HEATES Collaboration)

[1] Department of Physics, Tokyo Metropolitan University, Tokyo 192-0397, Japan
[2] National Institute of Standards and Technology, Boulder, CO 80305, USA
[3] Japan Atomic Energy Agency (JAEA), Tokai 319-1184, Japan
[4] Department of High Energy Astrophysics, Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), Kanagawa 229-8510, Japan
[5] Department of Physics, Rikkyo University, Tokyo 171-8501, Japan
[6] Department of Earth and Space Science, Osaka University, Osaka 560-0043, Japan
[7] Engineering Science Laboratory, Chubu University, Kasugai, Aichi 487-8501, Japan
[8] Atomic, Molecular and Optical Physics Laboratory, RIKEN, Wako 351-0198, Japan

Transition-edge-sensor (TES) microcalorimeters are increasingly used in high-resolution X-ray spectroscopy at accelerator beamlines and are in development for satellite missions. In these applications, understanding of the influences of high-energy charged particles (in- cluding cosmic rays) is critical.

Through experiments at charged particle beamlines, we have found that the charged par- ticle events cause thermal events throughout the Si substrate of the TES array, which leads to thermal-crosstalk events. Although the magnitude of each event is small, the resulting distortion of the signal-current pulse leads to a systematic shift in measured x-ray energies. Therefore, identification of charged particle events and mitigation of the resulting thermal- crosstalk effects are necessary for high-precision X-ray spectroscopy in a charged-particle environment.

We present experimental data showing charged-particle-induced thermal crosstalk in a 240-pixel TES array. Heat diffusion from a charged-particle impact is measurable in every TES pixel in the array. The diffusion and attenuation of thermal crosstalk pulses in the Si substrate are compared to a model.

Session: Poster P6-22: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Sora Kim - Institute for Basic Science

Metal film deposition on molybdate crystals

Sora Kim

Institute for Basic Science

We developed reliable and efficient methods for metal film deposition on the surface of various molybdate crystals for the AMoRE neutrinoless double beta decay ($0\nu\beta\beta$) project. AMoRE utilizes molybdate crystals as the main target material to search for $0\nu\beta\beta$ of ^{100}Mo based on heat-light detection with MMC readouts. In the heat measurement channel, a phonon collector film deposited on a crystal surface serves as a heat transfer mediator between the absorber crystal and an MMC sensor. We found the surface condition is crucial to evaporate reliable phonon collector films on some molybdate crystals having hygroscopic properties such as Li_2MoO_4.We report a batch of surface treatments required for the evaporation process together with the atmospheric conditions required for handling and long-term storage. We also discuss the performance of the phonon signals appearing in the AMoRE detectors with phonon collector films on the molybdate crystals as the results of the successful metal deposition.

Session: Poster P6-23: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Samantha Stever - Okayama University

Modelling signal oscillations arising from electrothermal coupling and stray capacitance in semiconducting bolometer impulse response

Samantha Stever

Okayama University

Electrothermal coupling in semiconductor bolometers is known to create nonlinearities in transient detector response, particularly when such detectors are biased outside of their ideal regions (i.e. past the turnover point in their IV curves). This effect is further compounded in the case where a stray capacitance in the bias circuit is present, for example in long cryogenic cabling. We present a physical model of the influence of such electrothermal coupling and stray capacitance in a composite NTD germanium bolometer, in which previous experimental data at high V_{bias} resulted in oscillations of the impulse response of the detector to irradiation by alpha particles. The model reproduces the transient oscillations seen in the experimental data, depending both on electrothermal coupling and stray capacitance.

Session: Poster P6-24: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Connor Bray - Colorado School of Mines

Monte-Carlo Simulations of Superconducting Tunnel Junction Quantum Sensors for the BeEST Experiment

Connor Bray, Stephan Friedrich, Kyle Leach

The BeEST experiment uses Superconducting Tunnel Junction (STJ) quantum sensors to search for sterile neutrinos in the electron capture decay of Be-7. We are developing Monte-Carlo simulations to understand electron escape after the Be-7 decay and to distinguish between instrument artifacts and possible sterile neutrino signals. The goal of the simulation is to model the spatial trajectory of quasiparticles, phonons and the Li-7 daughter nucleus in the sensor. We will show preliminary results of the energy relaxation and the dependence of electron escape on the Be-7 implantation depth.

Session: Poster P6-25: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Cole Brookhouse - University of Illinois Urbana-Champaign

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Noise analysis in electromagnetically induced transparency in nitrogen-vacancy diamond

C. Brookhouse, D. H. Beck

University of Illinois Urbana-Champaign

The preponderance of matter over antimatter in the observable universe suggests the violation of charge-parity symmetry in subatomic particles. One such symmetry-breaking quantity is the neutron electric dipole moment (nEDM), the existence of which has yet to be experimentally verified. The nEDM can be determined by the Larmor precession of a neutron in electric and magnetic fields. Modern experiments use slow, "ultracold", neutrons to increase the measurement sensitivity and decrease the effects of field inhomogeneities. Measurements at low temperature require a sensor that properly functions in cryogenic environments.

With this poster, we present our work so far in reaching the optimal sensitivity of nitrogen-vacancy (NV) diamond sensors. The NV center is a nanoscale defect in diamond that possesses a suitable electronic structure to measure static electric and magnetic fields. These defects can be probed with optical fields using methods like electromagnetically induced transparency, i.e., without the unwanted fields inherent to magnetic resonance techniques that might interfere with the nEDM measurement. Additionally, NV centers maintain their sensitivity at low temperatures, making them excellent candidates for use as nEDM sensors. The optimal sensitivity of a single NV center is on the order of 10^{-10} T/$\sqrt{Hz}$ for magnetic fields and 10^{-1} V/cm/$\sqrt{Hz}$ for electric fields. We present studies of technical noise sources which need to be eliminated to reach these sensitivities.

Session: Poster P6-26: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Hajime Ezawa - National Astronomical Observatory of Japan

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Properties of SIS Devices for Terahertz Photon Detection

Hajime Ezawa[1,2], Hiroshi Matsuo[1,2], Masahiro Ukibe[3], Go Fujii[3], Shigetomo Shiki[3], Ayako Niwa[4,1]

[1] National Astronomical Observatory of Japan, Mitaka, Tokyo, Japan
[2] The Graduate University for Advanced Studies, SOKENDAI, Mitaka, Tokyo, Japan
[3] National Institute of Advanced Industrial Science and Technology, Tsukuba, Ibaraki, Japan
[4] University of Tsukuba, Tsukuba, Ibaraki, Japan

Fast photon detectors sensitive to submillimeter or terahertz region may have various applications including those for astronomy and astrophysics. Fast photon detection will improve the signal-to-noise ratio by resolving each photon arrival, or high-precision measurements may be realized by introducing photon statistics. Among various detection technologies, we focused on SIS junctions (or STJs) as fast detectors. Recently we have developed an antenna coupled SIS detector designed for center frequency of 500 GHz. The detector exhibited the low leakage current of 1-2 pA at cryogenic temperature of $T \leq 0.8$ K, while differences from the designed values were observed with the optical performances. Based on the results, we have revised the detector design. The antenna and the waveguide were redesigned to improve the optical efficiency. The design of the PCTJ (parallel connected twin junction) and the choke-filter were integrated to realize the desired optical performance and small detector capacitance for fast readouts. The detector was fabricated in the CRAVITY facility at AIST, and the detector properties are being evaluated at NAOJ. The optical efficiency was measured by irradiating the detector with a black-body source, and the frequency response was evaluated with a Fourier-transform spectrometer, which are showing encouraging results. The design and properties of the developed SIS detector, as well as the detection system will be discussed in the presentation.

Session: Poster P6-27: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Aritoki Suzuki - Lawrence Berkley National Laboratory

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Recent developments of commercially fabricated horn antenna-coupled Transition Edge Sensor bolometer detectors for next generation Cosmic Microwave Background polarimetry experiments

Aritoki Suzuki, Elijah Kane, Adrian T. Lee, Tiffany Liu, Christopher Raum, Mario Renzullo, Patrick Truitt, John Vivalda, Benjamin Westbrook, Daniel Yohannes

Lawrence Berkley National Laboratory

We report on the development of commercially fabricated horn antenna-coupled Transition Edge Sensor (TES) bolometer arrays for Cosmic Microwave Background (CMB) polarimetry experiments with the superconductor electronics fabrication facility at Seeqc Inc. The orders of magnitude increase in detector count for next generation CMB experiments, such as CMB-S4, require a new approach in detector wafer production to increase fabrication throughput.

Previously, we have reported on successful fabrication of sinuous antenna-coupled detector arrays on 150 mm diameter wafers. In this conference, we report on our successful fabrication of orthomode transducer (OMT) coupled horn detector array fabrication on 150 mm wafers. The OMT coupled horn detector array is the baseline detector technology for CMB-S4.

We have also developed a design to achieve TES sensors with two different superconducting temperatures (T_c) without changing the fabrication process. We modified T_c using a superconducting proximity effect between Nb and AlMn alloy. Such dual-T_c TES sensors are useful when same the detectors are required to operate under different incoming power.

We will discuss the motivation, design considerations, fabrication processes, test results, and how industrial detector fabrication could be a path to fabricate hundreds of detector wafers for future CMB polarimetry experiments and other experiments that require TES sensors and superconducting RF circuits.

Session: Poster P6-28: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Jozsef Imrek - NIST

Scalable FPGA Design for Frequency Division Multiplexed Microwave Readout

Jozsef Imrek [1,2], Daniel Becker [1,2], Douglas A. Bennett [2], John Gard [1,2], Carl D. Reintsema [2], Abigail Wessels [1,2], Joel Ullom [1,2]

[1] University of Colorado
[2] National Institute for Standards and Technology

Microcalorimeters based on transition-edge sensors have been shown to be suitable for a wide range of applications, and to be scalable to high pixel counts using microwave SQUID (frequency division) multiplexing with heterodyne RF readout.

Applications have different requirements for per channel bandwidth, channel count per RF line, and number of RF lines; and there are many suitable FPGA boards, which can differ in their FPGA families, number of ADC/DAC channels, and analog bandwidths. As a result, there is a need for a scalable FPGA design that can support many hardware / readout specification combinations.

We present such a design, which generates and processes SQUID readout tones in baseband, suitable for heterodyne readout when coupled with Intermediate Frequency electronics.

The design's DSP chain consists of waveform tables, channelizer (PFBFFT, bin selection, fine DDC), flux ramp demodulation, and further IP blocks for data transfer. Output at multiple taps are formed into data packets with a custom header, the packets are multiplexed, and transferred over a memory mapped interface (PCIe or AXI), or as UPD/IP packets over 1G or 10G Ethernet.

The IP blocks are written in VHDL, configurable via generics, and packaged as IP-XACT cores. Descriptors embedded in each block allow for run-time discovery of blocks, their version, and their generics.

The FPGA design is hardware-proven, tested by measuring sensor noise levels, and energy spectra from a radioactive source.

Session: Poster P6-29: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Hirotaka Suda - Tokyo Metropolitan University

Spatial map of X-ray emission spectra using a 240-pixel X-ray TES array at the SPring-8 synchrotron X-ray light source

H. Suda [1], R. Hayakawa [1,6], H. Tatsuno [1], Y. Ishisaki [1], S. Yamada [2,1], Y. Ichinohe [2], T. Hashimoto [3], Y. Takahashi [4], T. Itai [4], T. Uruga [5], O. Sekizawa [5], K. Nitta [5], H. Suga [5], S. Kohjiro [6], T. Nakamura [7], T. Azuma [8], T. Okumura [8], S. Okada [9], J. W. Fowler [10], D. S. Swetz [10], D. A. Bennett [10], M. Durkin [10], G.C. O'Neil [10], J. N. Ullom [10], W. B. Doriese [10], C. D. Reintsema [10], J. D. Gard [10], H. Noda [11], T. Hayashi [12], Y. Imai [13,6], T. Kashiwabara [14], T. Yomogida [15], and the HEATES collaboration

[1] Department of Physics, Tokyo Metropolitan University, Minami-Osawa 1-1, Hachioji, Tokyo, 192-0397,
[2] Department of Physics, Rikkyo University, Tokyo 171-8501, Japan
[3] Advanced Science Research Center (ASRC), Japan Atomic Energy Agency, Tokai, Ibaraki 319-1184, Japan
[4] Department of Earth and Planetary Sciences, Graduate School of Science, The University of Tokyo, Bunkyo-Ku, Tokyo 113-0033, Japan [5] Japan Synchrotron Radiation Research Institute,Sayo, Hyogo, 679-5198, Japan
[6] Device Technology Research Institute, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki 305-8568, Japan
[7] Division of Earth and Planetary Materials Science, Graduate School of Science, Tohoku University, Aoba, Sendai, Miyagi, 980-8578 Japan
[8] Atomic, Molecular and Optical Physics Laboratory, RIKEN, Wako351-0198, Japan
[9] Engineering Science Laboratory, Chubu University, Kasugai, Aichi 487-8501, Japan
[10] Quantum Sensors Group, National Institute of Standards and Technology (NIST), Boulder, Colorado 80305, USA
[11] Department of Earth and Space Science, Osaka University, Osaka 560-0043, Japan,
[12] Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), Kanagawa 252-5210, Japan
[13] Department of Physics, Saitama University, Saitama-shi, Saitama 338-8570, Japan
[14] Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka, Kanagawa, 237-0061, Japan
[15] Nuclear Science and Engineering Center , Japan Atomic Energy Agency , 2-4 Shirakata , Tokai , Ibaraki 319-1195 , Japan

In preparation for spatially resolved composition measurements of extraterrestrial materials, we installed a Transition Edge Sensor (TES) spectrometer system at the SPring-8 beamline BL37XU in February 2020. By integrating the TES system with a Kirkpatrick-Baez (KB) mirror, we succeeded in obtaining two-dimensional spatial maps of the X-ray emission spectrum from several natural samples. The spectrometer is a 240-pixel TES system made by the U.S. National Institute of Standards and Technology. At the environment of BL37XU, more than 200 pixels operated simultaneously with a coadded energy resolution of about 5 eV (FWHM) at 6 keV. The X-ray beam is focused to a spot size of about 5 um using the KB mirror. As a demonstration, we measured fluorescence K-lines from Fe, Cr, Ni, and Cu, and L-lines of heavy elements while scanning the sample stage to obtain a composition map of a 30 um x 30 um region. The duration for one scan is a few tens of seconds, which results in low counting statistics. However, even with a limited number of counts, several peaks which cannot be resolved with a spectrometer such as a SDD are present above the background in the TES spectrum. We successfully obtained the spatial distribution of both light and heavy elements, suggesting that TES analysis will be a suitable tool for non-destructive composition measurements of asteroid materials obtained from a sample-return mission.

Session: Poster P6-30: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Harold Pinckney - University of Massachusetts Amherst

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The Thermal Conductivity of Sapphire Ball Based Detector Clamps

Harold Pinckney, Gassan Yacteen, Scott Hertel, Alessandro Serafin

University of Massachusetts Amherst

Point contact sapphire ball clamping is a method used to hold low temperature detectors. This method takes advantage of the low surface area between the detector and clamp to provide strong clamping with low thermal conductivity. While this clamp method is increasingly common, the thermal conductivity across this interface has not been well documented. In this poster we present a study of the thermal conductivity of such clamps. The clamps in this study are based on 3.18 mm diameter sapphire balls held in place by bronze springs. We performed this measurement between 200 and 600 mK, and the conductivity was found to have power law scaling as expected from phonon heat transfer.

Session: Poster P6-31: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Feiming Li - Purple Mountain Observatory, Chinese Academy of Sciences

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Thermal Conductance of a Titanium Hot-Electron Bolometer with Different Microbridge Thicknesses

Feiming Li [1,2,3], Wei Miao [1,3], Hao Gao [1,2,3], Zheng Wang [1,3], Kangmin Zhou [1,3], Jiaqiang Zhong [1,3], Yuan Ren [1,3] , Wen Zhang [1,3], Shengcai Shi [1,3]

[1] Purple Mountain Observatory, CAS, Nanjing 210033, China
[2] University of Science and Technology of China, Hefei 230026, China
[3] Key Lab of Radio Astronomy, CAS, Nanjing 210033, China

Hot-electron bolometers (HEBs) with Johnson noise thermometry are a kind of terahertz detectors of high sensitivity and wide dynamic range. As is well known, their sensitivity is linearly proportional to the bolometer's thermal conductance. In this paper, we focus on the experimental study of the thermal conductance of a titanium HEB with different microbridge thicknesses ranging from 15 to 59 nm. It has been found that the electron-phonon thermal conductance of the HEB takes a temperature power law of Tn, and that the thinner the titanium microbridge is, the larger the index n is. Different n indices might be attributed to electron scattering on the surface boundaries of the thin titanium microbridge. In addition, we observed that the thermal radiation from the low-noise amplifier for Johnson noise readout may increase the electron temperature to some extent, giving an excessive thermal conductance.

Session: Poster P6-32: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Kyung-Rae Woo - Institute for Basic Science, KOREA

Two stage temperature control system using an MMC readout for a long-term data taking

Kyung-Rae Woo, Hye-Lim Kim, Yong-Chang Lee, Han-Beom Kim, Do-Hyung Kwon, Ho-Seong Lim, Yong-Hamb Kim

Institute for Basic Science, KOREA

We developed a two-stage temperature control system for a long-term stable measurement using a dilution refrigerator. The first stage control was made with a normal PID system using an AC bridge with a RuOx thermometer to measure the temperature of the mixing chamber plate. The second stage control was obtained with a metallic magnetic calorimeter (MMC) that is configured to be sensitive to the temperature of a detector tower, the main experiment. While the first stage of the control system regulates the temperature of the MC plate in a few tens of uK, the additional system with an MMC maintains the temperature better than a few uK stability. We report the principle and applications of this method to long term data taking of the AMoRE experiments.

Session: Poster P6-33: Readout, Other Devices, Supporting Science 2

Schedule: Wednesday 28 July 10:05 - Wednesday 28 July 11:30

Submitted by: Stephan Friedrich - Lawrence Livermore National Laboratory

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Uniformity of Superconducting Tunnel Junction Detector Arrays

Stephan Friedrich, Geon-Bo Kim, Owen Drury, James Drake, Andrew Marino, Connor Bray, Spencer Fretwell, Kyle G. Leach, Francisco Ponce, Jack Harris, William K. Warburton, J. Ad Hall, Robin Cantor

The small dimensions of superconducting tunnel junction (STJ) radiation detectors have led to the development of STJ arrays to increase detection efficiency and statistical accuracy. We have used a pulsed UV laser to examine the uniformity of the response for different pixels in Ta-based STJ arrays. To separate the contributions of the detector and the readout electronics, we have also injected the pulses from an arbitrary waveform generator simultaneously into the different channels of the array's amplifier chain. We discuss the magnitude and the sources of detector non-uniformity and approaches to reduce it.

Session: Oral O7A-1: Rare Events 2

Schedule: Thursday 29 July 07:00 - Thursday 29 July 07:30

Submitted by: Loredana Gastaldo - Kirchhoff Institute for Physics, Heidelberg University

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Neutrino mass measurements using cryogenic detectors

Loredana Gastaldo

Kirchhoff Institute for Physics, Heidelberg University

The determination of the absolute mass scale of neutrinos is one of the most important challenges in Particle Physics. The shape of the endpoint region of $\beta-$decay and electron capture (EC) spectra depends on the phase space factor, which, in turn, is function of the neutrino mass eigenstates. High energy resolution and high statistics measurements of $\beta-$ and EC spectra are therefore considered a model-independent way for the determination of the neutrino mass scale. Since almost four decades, low temperature microcalorimeters are used for the measurement of low energy $\beta-$ and EC spectra. The first efforts were focused on the development of large arrays for the measurement of the ^{187}Re $\beta-$spectrum. In the last ten years, the attention moved to EC of ^{163}Ho. This choice was mainly motivated by the very good performance which could be achieved with low temperature microcalorimeters enclosing ^{163}Ho with respect to microcalorimeters with absorber containing ^{187}Re. I will present the development of low temperature microcalorimeters for the measurement of the finite neutrino mass and motivate the step from ^{187}Re to ^{163}Ho. In particular, I will discuss the possibility to reach sub-eV sensitivity on the effective electron neutrino mass with ^{163}Ho thanks to the multiplexing of large microcalorimeter arrays. In conclusion, I will give an overview on other nuclides which have been proposed as good candidates, motivated by the excellent performance of low temperature microcalorimeters.

Session: Oral O7A-2: Rare Events 2

Schedule: Thursday 29 July 07:30 - Thursday 29 July 07:45

Submitted by: Markus Griedel - Kirchhoff Institute for Physics, Heidelberg University

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From ECHo-1k to ECHo-100k: Optimisation of high-resolution metallic magnetic calorimeters with embedded Ho-163 for the determination of the electron neutrino mass

Markus Griedel, F. Mantegazzini, A. Barth, R. Hammann, D. Hengstler, W. Holzmann, N. Kovac, C. Velte, T. Wickenhäuser, A. Fleischmann, C. Enss, L. Gastaldo, H. Dorrer, T. Kieck, N. Kneip, C. Duellmann, K. Wendt

Kirchhoff Institute for Physics, Heidelberg University

Presented by Markus Griedel and Federica Mantegazzini

The ECHo experiment aims to determine the effective electron neutrino mass by analysing the end-point of the Ho-163 electron capture spectrum. High energy resolution detectors with a well-tailored detector response are the essential ingredients for the success of the ECHo experiment. The metallic magnetic calorimeter array prototype enclosing Ho-163 fabricated for the first experimental phase, ECHo-1k, has been fully characterised, in terms of detector response, energy resolution and Ho-163 activity per detector pixel. An average energy resolution of 5.5 eV FWHM has been achieved and a high-statistics measurement with more than 10^8 electron capture events has been performed with two ECHo-1k detectors operated in parallel. The optimisation studies performed based on the results obtained with the ECHo-1k detectors have paved the way towards a new detector design for the next experimental phase, ECHo-100k. The ECHo-100k chip features an optimised single pixel design to improve the detector performances as well as an upgraded on-chip thermalisation layout and read-out flexibility. The newly fabricated ECHo-100k detectors have been fully characterised at room temperature, at 4 K and at millikelvin temperature. The obtained results show that the ECHo-100k array achieved the expected performance with an average energy resolution of 3.5 eV FWHM, fulfilling the requirements for the ECHo-100k experiment.

Session: Oral O7A-3: Rare Events 2

Schedule: Thursday 29 July 07:45 - Thursday 29 July 08:00

Submitted by: Kyle Leach - Colorado School of Mines

The BeEST Experiment: Searching for Sterile Neutrinos in 7Be Decay with STJs

K. Leach, C. Bray, R. Cantor, J. Dilling, S. Fretwell, S. Friedrich, J. A. Hall, G.B. Kim, A. Lennarz, V. Lordi, P. Machule, D. McKeen, X. Mougeot, F. Ponce, C. Ruiz, A. Samanta, W. K. Warburton

The search for sterile neutrinos is among the brightest possibilities in our quest for understanding the microscopic nature of dark matter in our universe. Sterile neutrinos - unlike the active neutrinos in the Standard Model (SM) - do not interact with normal matter as they move through space, and their existence is best probed via momentum conservation with SM particles in radioactive decay. One way to observe these momentum recoil effects experimentally is through high-precision measurements of electron-capture (EC) nuclear decay, where the final state only contains the neutrino and a recoiling atom. This approach is a powerful method for new physics searches searches since it relies only on the existence of a heavy neutrino admixture to the active neutrinos - a generic feature of neutrino mass mechanisms - and not on the model-dependent details of their interactions. The BeEST experiment precisely measures the eV-scale radiation that follows the decay of ^{7}Be ions implanted into sensitive superconducting tunnel junction (STJ) quantum sensors. In this talk we will report the first results in our experimental program which already set limits on the existence of these particles in the 100 – 860 keV mass range that are up to an order of magnitude more stringent that all previous measurements.

Session: Oral O7A-4: Rare Events 2

Schedule: Thursday 29 July 08:00 - Thursday 29 July 08:15

Submitted by: Junsong Lin - Univeristy of California Berkeley

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HeRALD - a superfluid He-4 detector with transition edge sensor readout for light dark matter

Junsong Lin on behalf of the SPICE/HeRALD collaboration

Univeristy of California Berkeley

HeRALD - the Helium Roton Apparatus for Light Dark matter, uses calorimeters read out by transition edge sensors to detect signals in superfluid He-4 from sub-GeV dark matter interaction. Operated at milli-Kelvin temperature, the scintillation, triplet excitation and quasi-particle excitation from particle interaction in superfluid He-4 are all detected by calorimeters covering the active volume. The phonon/roton excitation can liberate helium atoms from the liquid/vacuum interface in a process called quantum evaporation. Those helium atoms are then absorbed by the top calorimeter suspended above the superfluid, leading to signal amplification. The low signal threshold enabled by calorimeters operated at milli-Kelvin temperature, the signal amplification from quantum evaporation, and the good kinematic matching between He-4 nuclei and sub-GeV dark matter is a powerful combination for light dark matter detection. I will discuss some recent development in stopping the superfluid helium film from covering the calorimeter surface, which is critical to the performance of the calorimeters. I will also discuss recent results on measuring the scintillation light yield of superfluid He-4 at 1.75 K with cryogenic photomultiplier tubes.

Session: Oral O7A-5: Rare Events 2

Schedule: Thursday 29 July 08:25 - Thursday 29 July 08:40

Submitted by: Rupak Mahapatra - Texas A&M University

MINER Reactor Neutrino Experiment for CENNS and ALP Searches

Rupak Mahapatra on behalf of the MINER Collaboration

Texas A&M University

The Mitchell Institute Neutrino Experiment at Reactor (MINER) experiment at the Nuclear Science Center at Texas A&M University is searching for coherent elastic neutrino-nucleus scattering within close proximity (2-5 meters) of a 1 MW TRIGA nuclear reactor core using phonon mediated low threshold solid state detectors . Given the Standard Model cross section of the scattering process and the proposed experimental proximity to the reactor, as many as 5 to 20 events/kg/day are expected. In this talk we will present an overview of the experiment, the science projections, along with a variety of very low-threshold, low-background detector technologies that are currently deployed in the MINER setup. The MINER experiment also has a new experimental direction for ALP probes via their production by the intense gamma ray flux available from the reactor through Primakoff-like or Compton-like channels. The existing low-threshold detectors in close proximity to the core will have visibility to ALP decays and inverse Primakoff and Compton scattering, providing world-leading sensitivity to the ALP-photon and ALP-electron couplings.

Session: Oral O7A-6: Rare Events 2

Schedule: Thursday 29 July 08:40 - Thursday 29 July 08:55

Submitted by: Caleb Fink - University of California Berkeley

Design and First Results of a Gram-Scale Low-Surface-Coverage Athermal-Phonon Detector for Polar Crystal Dark Matter Searches

Caleb Fink

University of California Berkeley

In the push towards sub-eV energy thresholds needed for direct detection of sub-MeV/c^2 dark matter (DM) with polar crystals, Transition-Edge Sensors (TESs) have been used for their energy variance scaling relation $\sigma_E^2 \propto VT_c^3$ with a focus on both low TES volume (V) and low superconducting transition temperature (T_c) devices. However, a baseline energy variance that scales as $\sigma_E^2 \propto VT_c^6$ can be achieved by using QETs (Quasiparticle-trap-assisted Electrothermal feedback Transition-edge sensors) and decreasing the amount of phonon absorbing surfaces ("low-coverage") to match the athermal phonon collection bandwidth to the QET sensor bandwidth.

The SPICE collaboration is taking advantage of this improved scaling relation in its detector design principles to achieve the required low energy thresholds. In this talk, I will introduce the light DM direct detection goals of the SPICE collaboration, the designs of prototype low-coverage, low-T_c polar crystal detectors optimized for bandwidth matching, and the first results from these devices.

Session: Oral O7A-7: Rare Events 2

Schedule: Thursday 29 July 08:55 - Thursday 29 July 09:10

Submitted by: Han beom Kim - Institute for Basic Science

Status and performance of the AMoRE-I experiment for neutrinoless double beta decay

H.B. Kim, On behalf of AMoRE Collaboration

Institute for Basic Science, Daejeon, Republic of Korea

The Advanced Mo-based Rare process Experiment (AMoRE) is an international collaboration project to search for neutrinoless double beta decay ($0\nu\beta\beta$) of ^{100}Mo with enriched Molybdenum-based crystals in cryogenic bolometric experiments to investigate the beyond-SM characteristics of the neutrino. AMoRE-I, the upgraded phase following the successfully finished AMoRE-pilot, utilizes thirteen $^{48\mathrm{depleted}}Ca^{100}MoO_4$ and five $Li_2{}^{100}MoO_4$ with a total mass of 6.2 kg as scintillating bolometers and has been running in the dilution refrigerator system located at Yangyang underground laboratory since August, 2020. In order to achieve its science goals, AMoRE aims at operation in zero-background condition to maximize the detection sensitivity for this extremely rare event. The simultaneous measurement of phonon and photon signals at each bolometer based on the metallic magnetic calorimeter (MMC) read-outs is performed at few tens mK temperatures to distinguish α backgrounds from β/γ events. We detail the AMoRE-I detector concept and status and provide the results from the first physics datasets.

Session: Oral O7A-8: Rare Events 2

Schedule: Thursday 29 July 09:10 - Thursday 29 July 09:25

Submitted by: SeungCheon Kim - Institute for Basic Science

Test measurements of an MMC-based 510-g lithium molybdate crystal detector for AMoRE-II experiment

SeungCheon Kim on behalf of the AMoRE-II experiment

Institute for Basic Science, Korea

The AMoRE collaboration is developing its phase-II experiment which aims to probe neutrinoless double beta decay from about 100 kg of ^{100}Mo isotope. The ^{100}Mo isotope will mainly be contained in lithium molybdate crystals instrumented with metallic magnetic calorimeter (MMC), which will detect the phonon excitations from the neutrinoless double beta decay in the crystals with an energy resolution (FWHM) of around 10 keV at 10 $\sim$ 20 mK. For scaling up the overall detector mass, individual detector modules with larger mass will help to reduce the number of detector channels and allow a few practical advantages associated with crystal growings, detector preparation and the operation of the experiment. To this end, we carried out an experiment with a 6 cm (diameter) x 6 cm (height) cylindrical lithium molybdate crystal of 516-g mass, which is 73% heavier than 5 cm (D) x 5 cm (H) crystals used in the present AMoRE-I setup. Further increase beyond 6 cm x 6 cm results in a higher rate of pile-up events from two neutrino double beta decay in the energy region of interest, and therefore unacceptable loss of sensitivity. We present the performance of the larger crystal detector such as an energy resolution, event selection capability and timing resolution.

Session: Oral O7A-9: Rare Events 2

Schedule: Thursday 29 July 09:25 - Thursday 29 July 09:40

Submitted by: Shumpei Kotaka - Kyoto University

Dark-photon Observation System for Unexplored Radio Range - DOSUE-RR

S. Kotaka [1], S. Adachi [2], Y. Sueno [1], J. Suzuki [1], T. Sumida [1], O. Tajima [1], S. Honda [3]

[1] Kyoto.U
[2] Kavli IPMU
[3] IAC

Existence of the dark matter is no doubt because of various astronomical observations, such as the gravitational lens effect of galaxies. Revealing its properties is an important subject for both cosmology and particle physics, in particular its mass and interactions except for gravity. The “dark-photon” is one of the candidates of dark matter. It has very small coupling with the electromagnetic field, and it converts to photon (a propagator of the electromagnetic field) at the surface of the metal plate (a boundary of the electromagnetic field). The frequency of photon signal indicates the mass of the dark-photon, i.e. $h/\nu = mc^2$. We have developed an experiment to search for this dark matter candidate in millimeter wave range. Our system is named DOSUE-RR (Dark-photon Observation System for Unexplored Radio Range) since most of our target range has not been explored yet. We currently build our initial system for the 20 - 30 GHz range which corresponds to 80 - 120 μeV mass range for the dark-photon. We will achieve the high sensitivity using the cryogenically cooled receiver system. We also mitigate external noises coming into the receiver (i.e. thermal radiations from the outside) using a cryogenically cooled optical path as well as the radio absorber on its surface. We will present our concepts, forecasts, and the status of our development: simulation study for minimizing the thermal radiation noise, results of cool down tests of our system.

Session: Oral O7A-10: Rare Events 2

Schedule: Thursday 29 July 09:40 - Thursday 29 July 09:55

Submitted by: YongChang Lee - IBS(Institute of Basic Science), Korea

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A new method of neutrino studies from tritium beta decay spectrum in LiF crystals

YongChang Lee, SunKee Kim, YongHamb Kim, SangGoon Kim, JinA Jeon, HyeLim Kim, Sora Kim, Hye-Jin Lee, KyungRae Woo, DoHyung Kwon, HanBum Kim, HoSeong Lim

IBS(Institute of Basic Science), Korea

We developed a simple new detection method for beta decay spectrum of ^{3}H. This research is motivated to investigate the presence of sterile neutrinos in keV scale, one of strong dark matter candidates. When a pure LiF crystal is employed in a neutron flux, an appropriate amount of ^{3}H can be embedded in the crystal from ^{6}Li(n,^{3}H)^{4}He reaction. The beta decay spectrum can be accurately measured with an MMC sensor attached to the LiF crystal. We carried out a feasibility study with a LiF crystal in 1x1x1 cm^3 with about 20 Bq ^{3}H activity. We present the physics result from 30 hour measurement of the ^{3}H activity in an ADR including the methods to find energy calibration and trigger efficiency. Moreover, an expected sensitivity to search for the heavy neutrino is discussed for one year measurement of a small size experiment.

Session: Oral O7B-1: Astrophysics and Cosmology

Schedule: Thursday 29 July 07:00 - Thursday 29 July 07:30

Submitted by: Masashi Hazumi - Institute of Particle and Nuclear Studies (IPNS), High Energy Accelerator Research Organization (KEK)

Cosmology with Low-Temperature Detectors

Masashi Hazumi

Institute of Particle and Nuclear Studies (IPNS),
High Energy Accelerator Research Organization (KEK)

Low-temperature detectors (LTDs) have played pivotal roles in establishing the concordance model of cosmology, the ΛCDM. We still have two reasons in cosmology to continue innovating LTDs for much higher performance. First, the ΛCDM has no firm particle physics behind it. There are five outstanding issues in cosmology beyond the standard model of particle physics, i.e., inflation, matter-antimatter asymmetry, neutrino properties, dark matter, and dark energy. In particular, the accelerating expansions of our universe at the beginning (inflation) and late times (dark energy) are the most bizarre phenomena. We need to improve cosmological observations significantly to connect cosmology and particle physics, which imposes more stringent requirements on LTDs than ever. Second, some recent observations are incompatible with the ΛCDM. Examples include the Hubble tension, which might suggest time dependence of dark energy. To scrutinize the problem, we again need LTDs with much higher performance than the present. In this talk, I review current and next-generation LTD systems in experimental cosmology. A particular emphasis is on the cosmic microwave background (CMB) polarization, which will be the key to understanding inflation, dark energy, neutrino properties, and the Hubble tension. Next-generation CMB telescopes on the ground, balloons, and in space are summarized and compared. I also discuss how to optimize the system performance taking instrumental systematics into account.

Session: Oral O7B-2: Astrophysics and Cosmology

Schedule: Thursday 29 July 07:30 - Thursday 29 July 07:45

Submitted by: Cody Duell - Cornell University

Characterization of the first light 280 GHz kinetic inductance detector array for the CCAT-prime project

Cody Duell on behalf of the CCAT-prime Collaboration

Cornell University

The Fred Young Submillimeter Telescope (FYST) is a 6 m aperture high-throughput telescope for the CCAT-prime project, which aims to measure the Cosmic Microwave Background (CMB) polarization and foregrounds, Sunyaev-Zel'dovish galaxy clusters, and the [CII] line intensity from the Epoch of Reionization. FYST will make both broadband and spectroscopic measurements in the mm to sub-mm regime with Microwave Kinetic Inductance Detectors (MKIDs) fabricated on 150-mm silicon wafers. One of the first light instruments for FYST will include a polarization-sensitive broadband 280 GHz MKID array with $\sim$3400 sensors coupled to feedhorns. We present here the lab characterization of the dark and optical properties of the 280 GHz MKID array.

Session: Oral O7B-3: Astrophysics and Cosmology

Schedule: Thursday 29 July 07:45 - Thursday 29 July 08:00

Submitted by: Matteo D'Andrea - INAF/IAPS Roma

ATHENA X-IFU Demonstration Model: First joint test between the main TES array and the Cryogenic Anti-Coincidence (CryoAC) detector system

Matteo D'Andrea (INAF/IAPS, previously at SRON), Kevin Ravensberg (SRON),
Andrea Argan, Daniele Brienza, Simone Lotti, Claudio Macculi, Gabriele Minervini, Luigi Piro (INAF/IAPSRoma)
Guido Torrioli (CNR/IFN Roma)
Lorenzo Ferrari Barusso, Flavio Gatti, Giovanni Gallucci, Manuela Rigano (University of Genova)
Hiroki Akamatsu, Johannes Dercksen, Luciano Gottardi, Roland den Hartog, Jan-Willem den Herder, Ruud Hogeveen, Brian Jackson, Alec McCalden, Simon Rosman, Emanuele Taralli, Davide Vaccaro, Martin de Wit (SRON)
James Chervenak, Stephen Smith, Nicholas Wakeham (NASA/GSFC)

Athena is an L-class X-ray observatory (launch by ESA in 2030s). The X-ray Integral Field Unit (X-IFU) is its cryogenic spectrometer, able to perform simultaneously imaging and high-energy resolution spectroscopy (2.5 eV @ 7 keV). The core of the instrument is an array of ∼3000 TES microcalorimeters.

The TES array is not able to distinguish between target X-ray photons and background particles that deposit energy in the detector band, seriously limiting the instrument sensitivity. For this reason, the Focal Plane Assembly (FPA) design implements several techniques to reduce the background expected in the spacecraft orbit by a factor ∼50. Most of the reduction is achieved thanks to the Cryogenic Anti-Coincidence detector system (CryoAC). It is a second detector hosted in the FPA, placed 1 mm behind the TES array. While target X-ray photons are absorbed in the TES array, cosmic and secondary particles deposit energy in both detectors, producing a coincidence signal that can be used to veto these events. Ensuring mechanical, thermal and electromagnetic compatibility between TES array and CryoAC is a challenge in the FPA development.

Here we present the first joint test of the TES array and CryoAC detector systems in the FPA Demonstration Model. We show that it is possible to operate properly together both detectors, and we provide a preliminary demonstration of the anti-coincidence capability of the system, achieved by the simultaneous detection of cosmic muons.

Session: Oral O7B-4: Astrophysics and Cosmology

Schedule: Thursday 29 July 08:00 - Thursday 29 July 08:15

Submitted by: Fabian Kislat - University of New Hampshire

ASCENT - A Superconducting Energetic X-ray Telescope Using A Gamma-ray Transition Edge Sensor Array For Astrophysics On A Suborbital Platform

Fabian Kislat [1] for the ASCENT Team: Daniel Becker [2], Douglas Bennett [3], Joseph Fowler [3], Chris Fryer [4], Johnathon Gard [2], Ephraim Gau [5], Danielle Gurgew [6], Keon Harmon [7], Takayuki Hayashi [6], Scott Heatwole [7], Gene Hilton [3], Md Arman Hossen [5], Henric Krawczynski [5], R. James Lanzi [7], John A. B. Mates [3], Mark McConnell [1], Johanna Nagy [5], Takashi Okajima [6], Toshiki Sato [6], Daniel Schmidt [3], Yang Soong [6], Sean Spooner [1], Daniel Swetz [3], Keisuke Tamura [6], Joel Ullom [3], Joel Weber [2], Amanda Wester [1], Patrick Young [8]

[1] University of New Hampshire, Durham, NH 03825
[2] University of Colorado, Boulder, CO 80309
[3] National Institute of Standards and Technology, Boulder, CO 80309
[4] Los Alamos National Laboratory, Los Alamos, NM 87545
[6] NASA Goddard Space Flight Center, Greenbelt, MD 20771
[7] NASA Wallops Flight Facility, Wallops Island, VA 23337
[8] Arizona State University, Tempe, AZ 85281

Spectroscopy of X-ray and gamma-ray lines is one of the most powerful tools of high-energy astrophysics. Gamma-ray emission originating from decays of Ti-44, for example, allows us to study ejecta in supernova remnants in great detail and provides some of the strongest constraints on the explosion mechanism. In this paper we give an overview of the scientific potential and technical challenges of a high-energy X-ray (10-80keV) imaging telescope using an array of transition-edge sensor (TES) microcalorimeter detectors that achieves a spectral resolution far exceeding that provided by semiconductor detectors.

We introduce ASCENT (A SuperConducting ENergetic x-ray Telescope), a proposed balloon-borne high-energy X-ray imaging and spectroscopy telescope. The use of TES detectors for astrophysics on a pointed balloon platform poses a unique set of challenges due to power and mass constraints. Furthermore, the requirements on the focal plane instrument in a telescope like ASCENT differ from those on laboratory instrumentation. For example, due to the low expected photon rates from astrophysical sources of interest, both per-detector quantum efficiency and high focal-plane fill factor are of paramount importance.

In this paper, we present the ASCENT mission concept and our approach to addressing the challenges outlined above, and we close with an outlook to possible future developments, in particular towards an improved spatial resolution for a potential future space telescope.

Session: Oral O7B-5: Astrophysics and Cosmology

Schedule: Thursday 29 July 08:25 - Thursday 29 July 08:40

Submitted by: Kosuke Sato - Saitama University

Super DIOS mission for exploring dark baryon

K. Sato (Saitama Univ.), T. Ohashi, Y. Ishisaki, Y. Ezoe, Y. FUjita (TMU), N. Y. Yamasaki, M. Ishida, Y. Maeda (ISAS/JAXA), K. Mitsuda (NAOJ), I. Mitsuishi, Y. Tawara (Nagoya Univ.), R. Fujimoto (Kanazawa Univ.), T. G. Tsuru (Kyoto Univ.), N. Ota (Nara women's Univ.), K. Osato (IAP, Sorbonne Univ.), D. Nagai (Yale Univ.), K. Yoshikawa (Tsukuba Univ.), N. Kawai (Tokyo institute of Technology), K. Matsushita (TUS), S. Yamada, U. Ichinohe (Rikkyo Univ.), Y. Uchida (Hiroshima Univ.), Y. Nakashima (AIST/PTB)

We are studying an improved DIOS (Diffuse Intergalactic Oxygen Surveyor) program, Super DIOS, for a launch year after 2030. The aim of Super DIOS is an X-ray exploration of dark baryon from cluster outskirt to warm-hot intergalactic medium along the Cosmic web and also the circumgalactic medium. Our scientific review team has been accepted for establishing the Research Group in ISAS/JAXA since 2020. This mission will perform wide field X-ray spectroscopy with FOV of about 30-60 arcmin, energy resolution of a few eV with TES microcalorimeter, and angular resolution of about $\sim$15 arcseconds. The mission will be developed under international collaboration with Japan, US, and Europe. We will report the expected science and the design and development of the instrumentation for the Super DIOS.

Session: Oral O7B-6: Astrophysics and Cosmology

Schedule: Thursday 29 July 08:40 - Thursday 29 July 08:55

Submitted by: Sarah Steiger - University of California, Santa Barbara

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Discovery of a Low Mass Stellar Companion to HIP 109427 Using Stochastic Speckle Discrimination with The MKID Exoplanet Camera

Sarah Steiger, Thayne Currie, Timothy D. Brandt, Olivier Guyon, Masayuki Kuzuhara, Jeffrey Chilcote, Tyler D. Groff, Julien Lozi, Alexander B. Walter, Neelay Fruitwala, John I. Bailey, III, Nicholas Zobrist, Noah Swimmer, Isabel Lipartito, Jennifer Pearl Smith, Clint Bockstiegel, Seth R. Meeker, Gregoire Coiffard, Rupert Dodkins, Paul Szypryt, Kristina K. Davis, Miguel Daal, Bruce Bumble, Sebastien Vievard, Ananya Sahoo, Vincent Deo, Nemanja Jovanovic, Frantz Martinache, Greg Doppmann, Motohide Tamura, N. Jeremy Kasdin, Benjamin A. Mazin

University of California, Santa Barbara

The MKID Exoplanet Camera (MEC) is a recently commissioned y-J band integral field unit for exoplanet direct imaging located behind the Subaru Coronagraphic Extreme Adaptive Optics System (SCExAO) at the Subaru telescope on Maunakea. Enabled by its 20,000-pixel MKID array, MEC can determine the arrival time (to within a microsecond) and energy (R $\sim$ 5) for each photon in an image, giving it a unique advantage over other traditional astronomical cameras. One of the main challenges of direct imaging is in the removal of diffracted light from the host star which manifests as time variable "speckles" in an image that can easily masquerade as faint companions. Fortunately, the statistical properties of these speckles have been studied at length, and the probability density function (PDF) that describes their intensity has been derived analytically. Using the microsecond timing resolution of MEC, we can directly probe this PDF to distinguish between speckles and true companions using a post-processing technique called Stochastic Speckle Discrimination (SSD). SSD is especially effective at small inner working angles where other post-processing techniques suffer/where low-mass companions are likely to hide. Using this technique, we report the joint SCExAO/MEC and CHARIS discovery of a low-mass stellar companion to the nearby A star HIP 109427 where MEC resolves this target at a comparable signal to noise to CHARIS, but without the use of any PSF subtraction techniques.

Session: Oral O7B-7: Astrophysics and Cosmology

Schedule: Thursday 29 July 08:55 - Thursday 29 July 09:10

Submitted by: Reinier Janssen - Jet Propulsion Laboratory

Design and performance of kinetic inductance detector arrays for the Terahertz Intensity Mapper balloon mission

R. M. J. Janssen [1,2], R. Nie [3], B. Bumble [1], L.-J. Liu [2], J. Redford [2], J. Fu [3] S. Hailey- Dunsheath [2], C. M. Bradford [1,2], J. P. Filippini [3], and the TIM consortium [4]

[1] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA
[2] California Institute of Technology, Pasadena, CA 91125 USA
[3] University of Illinois at Urbana-Champaign, Urbana, IL 61801 USA
[4] http://obscos.astro.illinois.edu/tim/

TIM, the Terahertz Intensity Mapper, is a NASA far-IR balloon mission designed to perform [CII] intensity mapping of the peak of cosmic star formation. To achieve this, TIM has two longslit (1 degree slitlength) grating spectrometers covering the 240-317 um and 317-420 um wavelength bands, respectively, at R$\sim$250. Each of the spectrometer arms is serviced by a focal plane of $\sim$4000 pixels. In turn, each focal plane contains four quadrants of $\sim$1000 hex-packed, horn-coupled kinetic inductance detectors (KIDs) on a single microstrip readout line. Each individual lumped-element KID is a resonator made from a 20 nm thick aluminum film, designed to achieve photon noise limited performance at 100 fW of loading at a 250 mK operation temperature. The inductor is optimized to achieve a 80% absorption efficiency in both polarizations across the entire band. The inductor is coupled to an interdigitated capacitor with a different number of tines for each of 16 KIDs in the lithographic 'unit cell'. This unit cell is stepped around the wafer with 60 instances, varying the length of the capacitor tine for each instance to vary the frequency of all 16 resonators by a constant factor. The full ensemble thus has 16 frequency sub-bands of $\sim$60 resonances within the 0.5 – 1.0 GHz readout band, allowing readout using either a ROACH2 or RFSoC. In this presentation, we will discuss the array design and performance predicted by simulations performed in HFSS and Sonnet and present initial measurements.

Session: Oral O7B-8: Astrophysics and Cosmology

Schedule: Thursday 29 July 09:10 - Thursday 29 July 09:25

Submitted by: Adrian Sinclair - Arizona State University

In Flight-Performance of the BLAST-TNG Kinetic Inductance Detector Arrays and Readout Electronics

Adrian Sinclair, Gabriele Coppi, Peter A.R. Ade, Peter C. Ashton, Jason E. Austermann, Erin G. Cox, Mark J. Devlin, Bradley J. Dober, Valentina Fanfani, Laura M. Fissel, Nicholas Galitzki, Jiansong Gao, Samuel Gordon, Christopher E. Groppi, Gene C. Hilton, Johannes Hubmayr, Jeffrey Klein, Dale Li, Nathan P. Lourie, Ian Lowe, Hamdi Mani, Philip Mauskopf, Christopher McKenney, Federico Nati, Giles Novak, Giampaolo Pisano, L. Javier Romualdez, Juan D. Soler, Carole Tucker, Joel Ullom, Michael Vissers, Caleb Wheeler, Paul A. Williams

The Balloon-borne Large Aperture Submillimeter Telescope - The Next Generation (BLAST-TNG) is a 2.5 meter telescope with three focal plane arrays containing more than 3000 polarization sensitive kinetic inductance detectors observing at 250, 350 and 500 um. BLAST-TNG flew in Antarctica on January 6th 2020 for approximately 14 hours. During the shortened flight the telescope performed various calibration tasks including, sky-dips, calibration lamp pulsing, and mapping of a bright submm astrophysical source. From these calibrators we have extracted best estimates on in-flight performance and sensitivity. We compare these with pre-flight measurements and theoretical estimates. This work demonstrates the viability of kinetic inductance detectors for far-infrared telescopes operating in the near space environment.

Session: Oral O7B-9: Astrophysics and Cosmology

Schedule: Thursday 29 July 09:25 - Thursday 29 July 09:40

Submitted by: Akio Taniguchi - Nagoya University

DESHIMA 2.0: Development of a science-grade integrated superconducting spectrometer for astronomical observations

Akio Taniguchi, Kenichi Karatsu, Yoichi Tamura, Tatsuya Takekoshi, Tom J. L. C. Bakx, Tai Oshima, Juan Bueno, Bruno Buijtendorp, Yasunori Fujii, Kazuyuki Fujita, Robert Huiting, Tsuyoshi Ishida, Shun Ishii, Ryohei Kawabe, Kotaro Kohno, Akira Kouchi, Nuria Llombart, Jun Maekawa, Vignesh Murugesan, Shunichi Nakatsubo, Alejandro Pascual Laguna, David J. Thoen, Paul P. van der Werf, Stephen J. C. Yates, Shahab Dabironezare, Sebastian Hähnle, Jochem J. A. Baselmans, Matthijs Gouwerok, Matus Rybak, Keiichi Matsuda, Stefanie Brackenhoff, Anne-Kee Doing, Hiroki Akamatsu, Tetsu Kitayama, Akira Endo

The integrated superconducting spectrometer (ISS) offers ultra-wideband, integral-field spectrometers for (sub) millimeter wave astronomy, in particular, for uncovering dust-obscured cosmic star formation and galaxy evolution over cosmic time. Here we present the development of DESHIMA 2.0, a science-grade ultra-wideband ISS ready for deep spectroscopy of high-redshift galaxies.

DESHIMA 2.0 is designed to observe the 220-440 GHz band in a single shot, corresponding to a redshift range of z=3.3-7.6 for the ionized carbon ([CII] 158 μm) emission. The first-light experiment of DESHIMA 1.0, using a 322-377 GHz configuration, has shown an excellent agreement between the performance derived from on-sky measurements, lab measurements, and the design (Endo et al. 2019a, 2019b). We plan the commissioning and science observations of DESHIMA 2.0 to be installed on the ASTE 10-m telescope in 2022.

Ongoing upgrades for the octave-bandwidth full system include the wideband 350-channel chip design, thin-film technology development, the wideband quasioptical system, and laboratory characterization. We also develop the on-sky calibration strategy (Takekoshi et al. 2020), and efficient observing techniques including the mechanical fast sky-position chopper and the sky-noise removal software based on a novel data-scientific approach. In the presentation, we will show the recent status of the upgrade and plans for astronomical science observations.

Session: Oral O7B-10: Astrophysics and Cosmology

Schedule: Thursday 29 July 09:40 - Thursday 29 July 09:55

Submitted by: Kirit Karkare - University of Chicago/Fermilab

SPT-SLIM: The South Pole Telescope Summertime Line Intensity Mapper

Kirit Karkare, A. Anderson, P. S. Barry, B. Benson, T. Cecil, C. Chang, M. Dobbs, G. K. Keating, D. P. Marrone, J. Montgomery, Z. Pan, G. Robson, M. Rouble, E. Shirokoff

University of Chicago/Fermilab

We present an overview of the South Pole Telescope Summertime Line Intensity Mapper (SPT-SLIM), a pathfinder experiment that will demonstrate the use of mm-wave on-chip spectrometers for line intensity mapping (LIM). The focal plane will consist of 18 dual-polarization R=300 filter-bank spectrometers covering 120-180 GHz, coupled to aluminum kinetic inductance detectors (KIDs). A compact cryostat will hold the focal plane at 100 mK and enable observations without removing the SPT-3G receiver. SPT-SLIM will be deployed to the 10-m South Pole Telescope for observations during the 2022-23 Austral summer. We discuss the overall instrument design, expected detector performance and sensitivity to the LIM signal from CO at z$\sim$1-3, and projected constraints on cold molecular gas during the peak of cosmic star formation. The technology and observational techniques demonstrated by SPT-SLIM will enable next-generation LIM experiments that will constrain cosmology beyond the redshift reach of galaxy surveys.

Session: Poster P7-1: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Karthik Ramanathan - Caltech

A broadband search for hidden photon dark matter using a cryogenic reflecting dish and kinetic inductance parametric amplifiers

Karthik Ramanathan[1], Ritoban Basu Thakur [1,2], Nikita Klimovich [1,2]

[1] California Institute of Technology, Pasadena, CA 91125, USA
[2] Jet Propulsion Laboratory (NASA), Pasadena, CA 91109, USA

Travelling-wave kinetic inductance parametric amplifiers (TKIPs/KIPAs) are cryogenic quantum-noise limited devices with 20 dB gain over an octave or more of bandwidth, making them well suited for microwave domain astronomical measurements. We propose and discuss progress in an experiment coupling a 4-20 GHz KIPA to a dish and antenna system to search for hidden photon (HP) dark matter candidates. A cryogenically cooled reflector focuses HPs onto a sinuous antenna, which is then amplified by KIPAs. The broadband nature of the reflector experiment neatly couples to the broadband amplification provided by KIPAs and should allow a first probing of the HP kinetic mixing parameter epsilon down to $\sim 10^{-12}$ for the majority of HP masses between 15-80 ueV. We discuss future avenues to improve the sensitivity of the experiment, along with the ability to probe axion couplings by introducing a magnetic field around the chamber.

Session: Poster P7-2: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Hyelim Kim - Institute for Basic Science

A study for $PbMoO_4$ phonon-scintillation detection with MMC read outs for neutrinoless double beta decay

H.L. Kim [a] , J.H. So [a], Y.H. Kim [a] , H.J. Kim [b], S. Nagorny [c,d], V.N. Shlegel [e,f]

[a] Center for Underground Physics, Institute for Basic Science, Daejeon 34047, Republic of Korea
[b] Department of Physics, Kyungpook National University, Daegu 41566, Republic of Korea
[c] Department of Physics, Engineering Physics and Astronomy, Queen's Universwity, Kingston ON, K7L 3N6, Canada
[d] Arthur b. McDonald Canadian Astroparticle Physics Research Institute, Kingston, ON, K7L 3N6, Canada
[e] Nikolaev Institute of Inorganic Fheistry, 630090 Novosibirsk, Russia
[f] Novosibirsk State Tech University, 20 Karl Marx Prospect, 630092 Novosibirsk, Russia

The AMoRE (Advance Molybdenum based Rare process Experiment) is an international project searching for the neutrinoless double beta decay ($0\nu\beta\beta$) of ^{100}Mo using low-temperature calorimetric detection for heat and light signals based on metallic magnetic calorimeter (MMC) readouts. Li_2MoO_4 crystals have been considered as main target crystals for the second phase of the AMoRE project, which is aiming to use 100-kg of ^{100}Mo isotope, due to its relatively easy crystal growth process and low internal background. However, the hygroscopicity of the Li_2MoO_4 requires careful processes in cleaning, storages, setup, and dehumidification of the laboratory. $PbMoO_4$ crystals have a negligible hygroscopic property and high scintillation efficiency, which have usually led the high particle discrimination power in phonon channel via Pulse-Shape Analysis, as well as via the light/heat ratio variation. The feasibility of the $PbMoO_4$ crystals as a promising candidate for the AMoRE-II will be present together with the detector performance via MMC readout. The aspect of the controllability of the internal background using archeological Pb will also be discussed in detail.

Session: Poster P7-3: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Shigetomo Shiki - National Institute of Advanced Industrial Science and Technology

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A study of timing jitter of superconducting tunnel junction x-ray detector

S Shiki, G Fujii, M Ukibe

National Institute of Advanced Industrial Science and Technology

High-speed, high-energy resolution X-ray detectors always bring about a progress of material analysis. In fact, our superconducting tunnel junction (STJ) detector array, which exhibited a high energy resolution and a high sensitivity, simultaneously (G. Fujii et al, X-ray spectrometry 46, 325 (2017)), realize an mapping analysis of trace light elements in several matrices by a SEM-EDX system. However, in the case of a soft material, such as carbon compounds, damage of the sample and distortion of the image due to the charge-up are still problems. The problems can be avoided by taking advantage of the high speed of the STJ detector to increase the scanning speed. In our case, the rise time of the STJ detector is about 10 to 15 microseconds at the output of the charge-sensitive amplifier in the previous study. The rise time suggests that the jitter can be less than 1 microsecond. However, the jitter value has not been previously measured, therefore we studied jitter of an STJ detector to estimate the upper limit of scanning rate. Jitter was measured as the distribution of a time difference between the X-ray pulse and the X-ray response of the STJ detector. An Nb-STJ with 100 um square was placed at 0.3 K. The responses of the STJ were recorded using a charge-sensitive amplifier and a 200MHz digitizer. The timestamps of X-ray events were measured using zero cross time of a digital constant fraction discriminator. The jitter of STJ was less than 200 ns for 277 eV (Carbon K line).

Session: Poster P7-4: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Aashrita Mangu - University of California, Berkeley

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An Improved Sinuous Antenna Design for Next-Generation Cosmic Microwave Background Surveys

Aashrita Mangu, Aritoki Suzuki, Adrian T. Lee, Benjamin Westbrook, Shawn Beckman, Christopher Raum, Bhoomija Prasad

University of California, Berkeley

Next-generation Cosmic Microwave Background (CMB) experiments aim to house large arrays of antenna-coupled transition-edge sensors (TESs) with spectral band centers ranging from 20 to 600 GHz to increase raw sensitivity by an order of magnitude compared to present-day observations. Mapping faint CMB polarization anisotropies across a large range of frequency channels and angular scales requires high-gain, low-noise pixels to capture the sky. Consequently, several CMB instruments have successfully deployed lenslet-coupled sinuous antenna TES bolometer arrays.

We plan to expand the antenna-level bandwidth, improve optical throughput, and reduce systematic uncertainties to increase overall sensitivity in future CMB polarization surveys. Here we describe these developments in the sinuous antenna design, more specifically the scale factor τ in the sinuous antenna, antenna-to-microstripline coupling, and antenna backshort designs to minimize frequency-dependent polarization angle rotation and maximize gain. We then merge theory and simulation with ongoing fabrication and testing of synchrotron emission monitor pixels with bands centered on 30 and 40 GHz. We also extend this technology to current simulation work in CMB monitor pixels with bands centered on 90, 150, and 220 GHz for next-generation CMB instrumentation.

Session: Poster P7-5: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Yuto Ichinohe - Rikkyo University

Application of deep learning to the waveform processing of transition-edge sensor calorimeters

Yuto Ichinohe [1], Shinya Yamada [1], Ryota Hayakawa [2], Shinji Okada [3], Tadashi Hashimoto [4], Hideyuki Tatsuno [2], Hirotaka Suda [2], Takuma Okumura [5]

[1] Rikkyo University, Tokyo 171-8501, Japan
[2] Kokyo Metropolitan University, Tokyo 192-0397, Japan
[3] Chubu University, Kasugai 487-8501, Japan
[4] Japan Atomic Energy Agency (JAEA), Tokai 319-1184, Japan
[5] Atomic, Molecular and Optical Physics Laboratory, RIKEN, Wako 351-0198, Japan

Transition-edge sensor (TES) calorimeters are the key instrument in the next generation high-resolution X-ray spectroscopy. Traditionally, optimal filtering is applied to the raw waveforms obtained by TES calorimeters in order to achieve their extreme energy resolutions. Although optimal filtering is a mathematically-grounded, solid method in the ideal situations, it has several shortcomings; it is actually not optimal in certain conditions such as large-signal regimes where the linear approximation of the transition edge breaks; it requires offline analysis of dumped waveforms, which could be the bottleneck in processing the large amount of data obtained by e.g. TES arrays with more than 10,000 pixels.

On the growing demand of another method that is robust even in such real-world situations, we propose a new, deep learning-based technique on the TES waveform analysis. We designed the network to predict the X-ray energy from the raw waveform, and demonstrated its capability using the experimental TES calorimeter data. We show that, with a simple multilayer perceptron architecture, it is possible to predict the true X-ray energy with the energy resolution of $\sim$5 eV @ 5.9 keV, which is comparable to that derived by the optimal filtering method. We will present the details of the new method and discuss the results with future prospects.

Session: Poster P7-6: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Shubham Verma - Texas A&M University

Athermal phonon mediated large-mass Sapphire detectors for Dark Matter and CEvNS searches.

Shubham Verma

Texas A&M University

Low mass nuclear recoil dark matter (NRDM) and coherent elastic neutrino nucleus scattering (CEvNS) searches confront similar challenges in choosing ultra low threshold and large-mass detectors. Although single-electron resolution Ionization mediated detectors such as those developed by CDMS (HVeV) or SENSEI (Skipper CCD) can reach these low thresholds, the sensitivity of ionization base signal hinges on the fundamental nuclear recoil threshold for single electron excitation i.e. a challenging measurement that is yet to be performed. This unknown nuclear recoil "quenching factor" at low energies won't be a limiting factor in phonon-only detectors since no quenching is expected for phonon signals. Due to their excellent athermal phonon lifetime, sapphire crystals are the material of choice for phonon mediated detection. We will present our recent progress on large mass ($\sim$200 g) sapphire detectors with an unprecedented detection threshold. We will demonstrate our methods to use information in the transient of phonon signals to identify nuclear recoil (signal) from electron recoil (majority of backgrounds).

Session: Poster P7-7: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Yoshinori Sueno - Kyoto University

Characterization of two-level-system noise for microwave kinetic inductance detector made with niobium film on silicone substrate

Yoshinori Sueno [A], Chiko Otani [B], Shugo Oguri [C], Hiroki Kutsuma [D], Junya Suzuki [A], Osamu Tajima [A], Shunsuke Honda [E], Satoru Mima [F]

[A] Department of Physics, Graduate School of Science, Kyoto University Kitashirakawa-oiwakecho, Kyoto, Kyoto, 606-8502, Japan
[B] Terahertz Sensing and Imaging Research Team, RIKEN 519-1399 Aramaki-Aoba, Aoba-ku, Sendai, 980-0845, Miyagi, Japan
[C] Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA) 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, JAPAN
[D] RIKEN Center for Quantum Computing (RQC), RIKEN
2-1 Hirosawa, Wako, Saitama, 351-0198, Japan
[E] Instituto de Astrofisica de Canarias Calle Vía Láctea, s/n, 38205 San Cristóbal de La Laguna, Santa Cruz de Tenerife, Spain
[F] Superconductive ICT Device Laboratory, Kobe Frontier Research Center, Advanced ICT Research Institute, National Institute of Information and Communications Technology 588-2, Iwaoka, Nishi-ku, Kobe, Hyogo, 651-2492, Japan

Microwave kinetic inductance detectors (MKIDs) have a big potential for scalability because of their multiplex readout technique. Therefore, it has been popular in the field of astronomy. For expanding application areas, it is important to understand a MKIDs specific noise: two-level system (TLS) noise.

The two-level system consists of the ground and an excited state at the surface of the substrate. The origin of the TLS noise is electrical fluctuation among these two states. Therefore, the TLS noise depends on the intensity of the electric field due to the readout microwaves. The intensity of electric field at the surface of the substrate can be controlled by changing the geometry of a coplanar waveguide (CPW) of the MKIDs; the wider CPW geometry is, the smaller electrical intensity is.

We characterize these properties for MKIDs made with niobium film on the silicone substrate. There was no quantitative evaluation for this combination before. We compare two CPW designs: “narrow” geometry MKIDs and “wide” geometry MKIDs. The width of the center-strip film and the gap width from the ground film for the “narrow” (“wide”) MKIDs are 3 um (5 um) and 4 um (24 um), respectively. We measured correlations between the noise power and the power of readout microwaves, and their frequency dependence, and conclude that the TLS noise is mitigated as expected. In this presentation, we will present details of this study including discussions based on the simulation for the MKIDs.

Session: Poster P7-8: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Makoto Nagai - National Astronomical Observatory of Japan

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Configuration of Probe Tones for MKID Readout with Frequency Sweeping Scheme

M. Nagai, Y. Murayama, T. Nitta, R. Suzuki, R. Hikawa, H. Miyazawa, R. Noji, H. Kiuchi, Y. Sekimoto, H. Matsuo, W. Shan, M. Naruse, T. Noguchi, N. Kuno, A. Monfardini, J. Macias-Perez, J. Goupy, M. Calvo, A. Catalano

National Astronomical Observatory of Japan

We are developing detector arrays using microwave kinetic inductance detectors (MKIDs) for astronomical observations in the 100-GHz band and a readout system for MKID arrays with frequency sweeping scheme. Probe tones in this scheme are generated and acquired by a frequency sweep probe (FSP) which is a digital fast Fourier transformation spectrometer (FFTS) while the probe tones are converted and modulated by an intermediate frequency (IF) section. Since the tone frequencies at the FSP become different from those at the MKID resonators, an appropriate method to configure the probe tones is essential for the scheme. We considered a general IF section which is a cascade of up/down converter pairs and found that its characteristics can be described with the base band, the target band, the sign of probe tone order, and the sign of frequency sweep direction. The correspondence between the target resonance frequency and the base tone frequency can be written with these properties. We implemented an algorithm to make a list of tone frequencies from a list of resonance frequencies given. Using this configuring method, we assembled IF sections for an antenna-coupled MKID array and for a LEKID array and set up a prototype FSP. The resonance frequencies of the antenna-coupled MKIDs and the LEKIDs are at 4.6–5.1 GHz and 0.6–1.0 GHz, respectively, and their spectra were obtained successfully. The method enables us to configure the readout system for both types of arrays.

Session: Poster P7-9: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Tomoki Terasaki - the University of Tokyo

Development of Al/Nb hybrid Lumped-Element Kinetic Inductance Detectors for infrared photon detection

Tomoki Terasaki, Kenji Kiuchi, Shugo Oguri, Shunsuke Honda, Yume Nishinomiya, Akito Kusaka

The University of Tokyo

Dark matter particles with masses below one GeV have received increasing attention. In order to detect photons produced from interactions between DM and target material directly, we are developing Lumped Element Inductance Detectors (LEKIDs) sensitive to an infrared single photon and suitable for high integration.

In this talk, we describe the design of hybrid LEKIDs with aluminum (T_c=1.3 K) as sensitive inductive parts and niobium (T_c=9 K) as capacitive parts and fabrication using a commercial-class external foundry. We also report measurement results of the hybrid LEKIDs at around 100 mK temperature.

Session: Poster P7-10: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Hirokazu Ishino - Okayama University

Development of an electron neutrino detector system using superconducting detectors and the surface microstructure forming technique

Hirokazu Ishino, Hirotake Yamamori, Ryota Takaku, Tomotake Matumura

Okayama University

Solar electron neutrinos are generated at the core of the sun as a result of the hydrogen nuclear fusion. In 1976, Raghavan pointed out that the electron neutrinos could be detected using Indium 115 which exist with a natural abundance of 96% in metal. The advantage using that is that we can identify the electron neutrino reactions unambiguously by detecting delayed coincidence of two gamma rays produced by excited Zinc-115. In order to detect 100 solar pp neutrinos in one year, we need an Indium target mass of one ton. We develop a new detector system using superconducting technology for measurements of the solar neutrino observation. We propose a detector system consisting of an indium neutrino target and superconducting detectors that measure the energy deposited in the target. On the target surface we form a cone array micro-structure using a laser ablation technique. The cones are connected to the superconducting detectors through Indium bumps that measure the number of athermal and thermal phonons generated in the target. We employ kinetic inductance detectors (KID) as the superconducting detectors that enables us to have multiple simultaneous readout in the frequency domain as the first step. In this report, we present the status of the development of the newly designed KID that have the capability of having connection to the target cones. We also present the development status of the Indium cone.

Session: Poster P7-11: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Ryota Takaku - The University of Tokyo

Evaluation of instrumental polarization of a 200 mm diameter achromatic HWP with anti-reflective structures and impact on TES non-linearity

Ryota Takaku

The University of Tokyo

The main goal of cosmic microwave background (CMB) experiments is to measure the B-mode polarization to evaluate the cosmic inflation theory. For the accurate measurement, future CMB polarization experiments require broadband, high throughput, cryogenic temperatures and low-systematics telescopes. The modulation using a rotating half-wave plate can suppress the effect of 1/f noise and mitigates differential systematic uncertainties. In order to satisfy the broadband requirement, we are developing sub-wavelength structures (SWS) as a broadband anti-reflection (AR) by ultra-short pulsed laser machining on a Pancharatnam achromatic half-wave plate (AHWP). We have measured the modulation efficiency at cryogenic temperature for a 50 mm diameter sapphire AHWP with SWS AR. In this paper we report on the demonstration of a large size HWP for the next generation telescopes to measure the CMB polarization. We report on the fabrication of SWS on a 200 mm diameter sapphire plate, as well as the optical performance of the assembled AHWP with SWS on both sides including transmittance, reflectance and modulation efficiency using a vector network analyzer (VNA). We also evaluate the instrumental polarization of the AHWP, which is the conversion of un-polarized to polarized light, as a potential source of non-linearity in the low-temperature detector response.

Session: Poster P7-12: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Gensheng Wang - Argonne National Lab

Light dark matter detection with hydrogen-rich crystals and low-T_c TES detectors

Gensheng Wang, C. L. Chang, M. Lisovenko, V. Novosad, V. G. Yefremenko, J. Zhang

Argonne National Lab

Direct detection of nuclear scatterings of sub-GeV dark matter particles favors low-Z nuclei. Hydrogen nucleus, which has a single proton, provides the best kinematic match. The characteristic nuclear recoil energy is boosted by a factor of a few tens from those for larger nuclei used in traditional WIMP searches. Furthermore, hydrogen is also optimal for detecting spin-dependent nuclear scatterings of sub-GeV dark matter, where large parameter space still remains unconstrained yet in direct detection. In this presentation, we first introduce several hydrogen-rich crystals, which emit two classes of signals under kinetic excitations. One class of the signals is infrared photons, which are from the molecular excitations of fundamental vibrational modes and at several characteristic wavelengths. Another is acoustic phonons and optical phonons that decay into acoustic phonons. We then discuss the potential sensitivities of low-T_c TES detectors for reading out the infrared photons and acoustic phonons. Utilization of both hydrogen-rich crystals and sensitive low-T_c TES detectors allows to probe orders of magnitude of unexplored light dark matter parameter space.

Session: Poster P7-13: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Johannes Hubmayr - NIST

LiteBIRD High Frequency Detectors: Design and Status

Johannes Hubmayr for the LiteBIRD collaboration

NIST

LiteBIRD is a JAXA-led satellite mission scheduled for launch in the late 2020s, which will make precision measurements of the polarization of the cosmic microwave background (CMB) on large angular scales. The instrument will image in 15 frequency bands distributed between three separate telescopes: the low frequency telescope (LFT, 40-140 GHz), mid-frequency telescope (MFT, 100-195 GHz), and high-frequency telescope (HFT, 195-402 GHz). Here we describe the design and development status of the HFT detectors, which are transition-edge-sensor (TES) bolometers coupled to feedhorns and orthomode transducers (OMTs). We have designed and fabricated two types of dichroic detectors, which together span the frequency range 150 - 400 GHz, and thus represent the highest frequencies implemented for this detector type to date. We present the design and show measurements of optical efficiency, passbands, and polarization response.

Session: Poster P7-14: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Ryuta Imamura - Ehime University

Mechanical cryocooler noise observed in the ground testing of the Resolve X-ray microcalorimeter instrument onboard XRISM

Ryuta Imamura, Hisamitsu Awaki, Masahiro Tsujimoto, Shinya Yamada, on behalf of the Resolve collaboration

Ehime University

Low-temperature detectors often use mechanical coolers to achieve sub-K operating temperature. Vibration by the cryocoolers causes noise terms in the detectors sensitive to microphonics, which is a general and inherent issue to such detectors. We investigated this using the ground test data obtained with the Resolve instrument onboard the XRISM satellite to be launched in a few years. Resolve is a cryogenic X-ray microcalorimeter spectrometer with an energy resolution of 7 eV (FWHM) at 6 keV. From the ambient temperature to 4 K, five mechanical cryocoolers are used: four two-stage Stirling (2ST) coolers driven nominally at 15 Hz and a Joule-Thomson (JT) cooler at 52 Hz. In 2019, we operated the flight-model instrument for two weeks, in which we also obtained accelerometer data inside the cryostat at a low temperature stage (He tank) and outside at the room temperature. The detector and accelerometer data were obtained at slightly different JT drive frequencies, which produced a unique data set to investigate how the vibration of the cryocoolers propagates to the detector. In detector noise spectra, we clearly observed harmonics of both 2ST and JT cryocoolers. More interestingly, we also observed low (10 Hz) frequency beats between the 4th JT and 14th 2ST harmonics and the 7th JT and the 24th 2ST harmonics. We present an interpretation of these results.

Session: Poster P7-15: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Shunsuke Adachi - Kavli Institute for the Physics and Mathematics of the Universe (WPI), The University of Tokyo

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Millimeter-wave absorber using 3-D printed mold for cryogenic application

S. Adachi [1], T. Otsuka [2], M. Hattori [3], Y. Sakurai [1], O. Tajima [2]

[1] Kavli Institute for The Physics and Mathematics of The Universe (WPI), The University of Tokyo, Kashiwa, Chiba 277-8583, Japan
[2] Department of Physics, Kyoto University, Kitashirakawa-Oiwakecho, Sakyo-ku, Kyoto 606-8502,Japan
[3] Astronomical Institute, Graduate School of Science, Tohoku University, 6-3, Aramaki Aza-Aoba, Aoba-ku, Sendai 980-8578, Japan

Radio absorptive material (RAM) is an indispensable element for high-sensitive radio detection. Radio sensors are maintained at a low-temperature condition for the minimization of their intrinsic noise. Therefore, the RAM requires to be used in the cryogenic condition to mitigate the external thermal radiation noises. We previously established a production method of RAM using 3D-printed mold1. An absorptive material (Stycast-2850FT) is filled into the 3D-printed mold for shaping periodical pyramids on the surface of the RAM. We demonstrated its application in the cryogenic condition. The ability to choose the material is an important advantage of this production method. In this work, we survey the best material for the millimeter waves (20–200 GHz). We measured optical performances at the liquid nitrogen temperature for various samples, e.g. stainless steel powders, carbon blacks, carbon fibers, and carbon nanotube, each of them mixed into the Stycast-2850FT. We found that a mixture of chopped carbon fiber and the Stycast-2850FT has the best absorptive performance. The RAM using this mixture sample is estimated to achieve $\lesssim 1\%$ reflectance in the frequency range described above (Fig. 1).

Session: Poster P7-16: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Jin-A Jeon - Institute for Basic Science/Center for Underground Physics

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MMC-based low-threshold silicon detector using Neganov-Luke (NL) phonon amplification

J.A. Jeon [1], H.L. Kim [1], S.R. Kim [1], S.G. Kim [1], Y.H. Kim [1,2], D.H. Kwon [1,2], Y.C. Lee [1], K.R. Woo [1,2], D.H. Kwon [1,2]

[1] Center for Underground Physics, Institute for Basic Science (IBS), Daejeon, South Korea
[2] University of Science and Technology (UST), Daejeon, South Korea

We developed an MMC-based low-threshold silicon detector using Neganov-Luke (NL) phonon amplification. It is a unique detector composed of a small silicon wafer with 1/2-inch diameter and 1 mm thickness. A vertical electric field can be applied through the wafer by non-contact electrodes on both sides. An MMC sensor was employed to sensitively measure the temperature increase originating from a particle absorption and Luke phonons associated phonon amplification. Systematic measurements were carried out with various bias voltages up to 160 V without changing the baseline noise of the signals. We present the results of the amplification from 6 keV x-ray absorption on the absorber. In addition, we discuss the responses from visible photons toward the sensitivity for single electron-hole pairs.

Session: Poster P7-17: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Takashi Hasebe - Kavli Institute for the Physics and Mathematics of the Universe

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Modeling of Sensitivity of LiteBIRD

Takashi Hasebe on behalf of the LiteBIRD Collaboration

Kavli Institute for the Physics and Mathematics of the Universe

LiteBIRD is an ISAS/JAXA second large class satellite mission to observe the polarization of cosmic microwave background (CMB) radiation, which aims at testing the hypothesis of the inflationary universe. LiteBIRD observes the sky through three telescopes that illuminate their focal planes populated by transition-edge-sensor (TES) bolometers.

We present the estimation of the sensitivity of LiteBIRD. One of the key inputs to this estimation is the optical loadings, estimated using the assumed optical properties of the optical elements in the telescopes.

The beam spillovers at the optical elements were calculated by using an optical simulation. A bolometer thermal noise and readout noise are also accounted for the total detector noise. Using the given statistical sensitivity over 15 bands, the uncertainty of the tensor-to-scalar ratio is estimated as $\sigma_r = 0.6 \times 10^{-4}$ with the presence of the foreground emissions, and it achieves the mission requirement.

Session: Poster P7-18: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Tommaso Ghigna - Kavli IPMU - The University of Tokyo

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Modelling TES non-linearity induced by a rotating HWP in a CMB polarimeter

Tommaso Ghigna, Tomotake Matsumura, Yuki Sakurai, Ryota Takaku, Kunimoto Komatsu, Shinya Sugiyama, Yurika Hoshino, Nobuhiko Katayama

Kavli IPMU - The University of Tokyo

Most upcoming CMB experiments are planning to deploy thousands to a few hundred thousands of TES bolometers in order to drastically increase sensitivity and unveil the B-mode signal. Differential systematic effects and 1/f noise are two big challenges that need to be overcome in order to achieve this result. Rotating Half-Wave Plates have become increasingly more popular as a solution to mitigate both effects, especially for those experiments that are targeting the largest angular scales. However, there are other effects that appear when a rotating HWP is being employed. In this paper we focus on HWP synchronous signals, which are due to intensity to polarization leakages induced by a rotating cryogenic multi-layer sapphire HWP employed as the first optical element of the telescope system. We use LiteBIRD LFT as a case study and we focus primarily on the interaction between these spurious signals and the TES bolometers to determine whether this signal can contaminate the bolometer response. We present the results of simulations under a few different TES model assumptions and spurious signal amplitudes to find what leakage level can be tolerated in order to minimize non-linearity effects in the bolometer response.

Session: Poster P7-19: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Francisco Ponce - PNNL

Observation of Long-Lived UV Induced Fluorescence from Environmental Materials Using the HVeV detector as developed for SuperCDMS

Francisco Ponce, Paul Brink, Blas Cabrera, Matthew Cherry, Chris Stanford, Richard Partridge, Betty Young

We describe recent experiments using a SuperCDMS HVeV single-charge sensitive detector exposed to ultraviolet (270 – 280 nm) and monochromatic visible (650 nm) photons using a dual fiber optic system installed in a small dilution refrigerator at Stanford. We observed a long-lived (2.35 ± 0.05 ms) population of fluorescence background events after UV exposure but not after VIS exposure. This fluorescence is likely due to scattered UV photons absorbed elsewhere in the system. We discuss the possibility of using such UV induced fluorescence to characterize the multisite induced fluorescence backgrounds from muons and cosmic rays in above-ground experiments.

Session: Poster P7-20: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Joanna Perido - University of Colorado Boulder

Parallel-Plate Capacitor TiN Kinetic Inductance Detectors for Infrared Astronomy

Joanna Perido, Peter Day, Jason Glenn, Andrew Beyer

The Balloon Experiment for Galactic INfrared Science (BEGINS) is a concept for a sub-orbital observatory that will characterize dust in the vicinity of high-mass stars. It requires detectors with NEPs on the order of 10^{-15} to 10^{-16} W $Hz^{-1/2}$ from 25-400 microns, respectively. The mission's sensitivity requirements can be met by utilizing arrays of 2,500 lens-coupled, lumped-element kinetic inductance detectors (KIDs) operating at 200 mK. Each KID will consist of a lithographically patterned titanium nitride (TiN) parallel strip absorbing inductive section and parallel plate capacitor deposited on a Silicon (Si) substrate. The parallel plate capacitor geometry allows for reduction of the pixel spacing and keeps the KID resonant frequencies in the range of a few hundred MHz. The relatively low operating frequency enhances the dynamic range of the detectors ensuring that the background loading requirement is met. Incident radiation is focused onto the KID using a Fresnel zone plate lens deposited on the opposite side of the silicon substrate. We present details of the design and initial characterization measurements for a 25 micron band array, the shortest wavelength band of the BEGINS instrument.

Session: Poster P7-21: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Karthik Ramanathan - Caltech

Performance of a multi-KID phonon-mediated particle detector

K. Ramanathan, T. Aralis, R. Basu Thakur, B. Bumble, Y.-Y. Chang, O. Wen, S. R. Golwala

Caltech

Phonon-mediated particle detectors employing Kinetic Inductance Detectors (KIDs) on silicon substrates have demonstrated both $\mathcal{O}(10)$ eV energy resolution and mm position resolution, making them strong candidates for instrumenting next generation rare-event search experiments, such as an upgrade to the SuperCDMS SNOLAB experiment. Such an architecture would enable phonon-based nuclear-recoil discrimination to lower energies than possible with architectures relying on ionization measurement, making it possible to extend nuclear recoil searches to 1 GeV dark matter mass and below. Here we present the performance of an 80-aluminium KID array on a 1 mm-thick Si wafer, based on a symmetric coplanar strip design, with devices operating at $\sim$3 GHz. In particular, we report on the performance and energy resolution of a select subset of 8 KIDs across 7 readout powers, using the unique approach of pulsing neighboring KIDs to generate signals in target KIDs. We compare the resolution expected from first principles for individual KIDs to the measured values, which vary from $\sim$5-70 eV for energy absorbed in a single KID. Finally, we outline plans to achieve sub-eV resolution in the next generation of devices.

Session: Poster P7-22: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Osmond Wen - California Institute of Technology

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Performance of a phonon-mediated detector using KIDs optimized for sub-GeV dark matter

Osmond Wen, T. Aralis, R. Basu Thakur, B. Bumble, Y.-Y. Chang, K. Ramanathan, S. R. Golwala

California Institute of Technology

Detection of sub-GeV dark matter candidates require sub-eV detector thresholds on deposited energy. We provide an update on a gram-scale phonon-mediated KID-based device that was designed for a dark matter search in this mass range at the Northwestern Experimental Underground Site. Currently, the device is demonstrating 6 eV resolution on the energy absorbed by the resonator. With some important assumptions, this translates to 20 eV resolution on energy deposited in the substrate. We show that TLS noise dominates this energy resolution estimate. After modifying the design to mitigate TLS noise, we project 5 eV resolution on energy deposited in the substrate (1.5 eV on energy absorbed by the resonator) for an amplifier white noise dominated device. Finally, we present a clear path forward to sub-eV thresholds, which includes installation of a quantum-limited superconducting parametric amplifier and adjustments to the material makeup of our resonators.

Session: Poster P7-23: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Md Arman Hossen - Washington University in St. Louis

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Plans for the Test of a NIST Microcalorimeter Array for Hard X-ray and γ-ray Astronomy on a Stratospheric Balloon Flight

Md Arman Hossen, Scott Backhaus, Daniel Becker, Douglas Bennett, Ephraim Gau, Johanna Nagy, Fabian Kislat, Vincent Kotsubo, Henric Krawczynski, Takashi Okajima, Nathan Ortiz, Ryan Snodgrass, Daniel Swetz, Joel Ullom

The quantum sensor group at the NIST has developed microwave multiplexed microcalorimeter arrays for the detection of hard X-rays and γ-rays (Bennett et al. 2012, Mates et al. 2017). The arrays are made of approximately 250 tin or bismuth absorbers that are read-out with arrays of Transition Edge Sensors (TES). Each TES is coupled via a SQUID to a microwave resonator, and a single microwave line is used to sample the response of the resonators of all pixels. Used with 1.4 x 1.4 x 0.38 mm 3 tin absorbers, the detector arrays achieve an energy resolution of 55 eV FWHM at 97 keV. Due to high energy resolutions, the detectors have the potential to revolutionize hard X-ray and γ-ray astronomy like studies of the relativistically broadened iron fluorescent lines from mass accreting stellar mass and supermassive black holes, measurements of the resonant cyclotron scattering features in the energy spectra of neutron stars, and etc. We report here on the performance of a 34-pixels prototype detector with a collimated 50 µm diameter 20-50 keV X-ray beam as well as a 152 Eu source. We will also describe a planned stratospheric balloon flight which will be the first time to use a novel mini-dilution refrigerator from the company Chase Cryogenics and the 34-pixels prototype detector in a space environment. We will conclude with a brief description of future applications of these technologies for balloon-borne hard X-ray and γ-ray observatories.

Session: Poster P7-24: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Marion Dierickx - Harvard University

Plastic Laminate Antireflective Coatings for Millimeter-wave Optics in BICEP Array

Marion Dierickx

Harvard University

The BICEP/Keck series of experiments target the Cosmic Microwave Background at degree-scale resolution from the South Pole. Over the next few years, the “Stage-3” BICEP Array (BA) telescope will improve the program’s frequency coverage and sensitivity to primordial B-mode polarization by an order of magnitude. The first receiver in the array, BA1, began observing at 30/40 GHz in early 2020. The next two receivers, BA2 and BA3, are currently being assembled and will map the southern sky at 150 GHz and 95 GHz, respectively. Common to all BA receivers is a refractive, on-axis, cryogenic optical design that focuses microwave radiation onto a focal plane populated with antenna-coupled bolometers. High-performance antireflective coatings up to 760 mm in aperture are needed for each element in the optical chain, and must withstand repeated thermal cycles down to 4 K. Here we present the design and fabrication of the 30/40 GHz anti-reflection coatings for the recently deployed BA1 receiver, then discuss laboratory measurements of their reflectance. We review the lamination method for these single- and dual-layer plastic coatings with indices matched to various polyethylene, nylon and alumina optics. We also describe ongoing efforts to optimize coatings for the next BA cryostats, which may inform technological choices for future Small-Aperture Telescopes of the CMB “Stage 4” experiment.

Session: Poster P7-25: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Shinya Sugiyama - Saitama University

Potential extra noise from a continuously rotating HWP using superconducting magnetic bearing for CMB polarimetry

Shinya Sugiyama, Kosuke Sato, Kunimoto Komatsu, Makoto Tashiro, Nobuhiko Katayama, Satoru Katsuda, Tomasso Ghigna, Tomotake Matsumura, Yuki Sakurai, Yukikatsu Terada, Yurika Hoshino, Ryota Takaku

Saitama University

The measurement of the CMB primordial B-modes at degree angular scales requires an unprecedented control of systematic errors including the 1/f noise. Any systematic effects that appear at the large angular scale directly impact the measurement of the primordial B-mode. A standard method to overcome this challenge is to modulate the polarization signal using a continuously rotating half-wave plate (HWP). While, on the one hand, the HWP mitigates systematic effects, on the other hand it may add additional systematic effects including 1/f-like features. We study the potential source of systematic effects including 1/f noise when the HWP is rotated using a superconducting magnetic bearing (SMB). The SMB employs a permanent magnet and superconductor. Any imperfection of the cryogenically cooled encoder, or the vibrations of the rotor due to the nature of the levitating bearing system can introduce additional disturbance to the low temperature detector system. We present our prototype polarization modulator unit as a demonstrator for the LiteBIRD low-frequency telescope. We evaluate the dynamical performance of the rotational mechanism and forecast the potential impact on the low-temperature detector system.

Session: Poster P7-26: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Nicole Farias - UC Berkeley

Simulated performance of laser-diced metamaterial anti-reflection coatings

Nicole Farias, Shawn Beckman, Adrian Lee

UC Berkeley

LiteBIRD is a satellite that will probe the B-mode polarization and inflation from the Cosmic Microwave Background (CMB). To couple radiation to the detector array, LiteBIRD Low-Frequency and Mid-Frequency Telescopes will use silicon lenslets, small hemispherical lenses mounted on the focal plane. One drawback of silicon optical components is their high reflectivity, which requires that the lenslets be coated with anti-reflection (AR) layers. Metamaterial coatings have been used as AR layers in CMB lenses due to the zero differential in the coefficient of thermal expansion between the lens and its coating. These layers are typically machined using dicing blades. However, this approach cannot be used for lenslets due to their size and curvature. An alternative is to ablate silicon on its surface using laser machining to create the metamaterial layer. To validate the feasibility of this method, an ANSYS HFSS simulation was developed. The model calculated the metamaterial performance of two different geometries in 3 frequency bands: 40-78, 68-140 and 100-195 GHz. The goal of the simulation was to optimize transmission in all bands while meeting laser machinability constraints and optical requirements: all features had to be smaller than a tenth of the incoming wavelength to prevent diffraction effects. Results show that an AR metamaterial coating made under these conditions is feasible, and the baseline of fabrication parameters are provided.

Session: Poster P7-27: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Mingxuan Xue - University of Science and Technology of China

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Study of $PbWO_4$ Crystal for a Coherent Elastic Neutrino-Nucleus Scattering Experiment at Taishan Nuclear Power Plant

Mingxuan Xue, Luxin Zhang, Liang Han

University of Science and Technology of China

The first observation of Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) by COHERENT Experiment using accelerator neutrinos, may provide opportunities for abundant scientific and technology applications. To study the CEvNS process precisely, a project using China Taishan Nuclear Power Plant as reactor neutrino source and cryogenic bolometer technology with lead tungstate ($PbWO_4$) as detector candidate is proposed. At an experimental site located about 30 meters away from one of 4.6 GWth Taishan reactor cores, a flux of $6.73 \mathrm{x} 10^{16}$ v/m^2/s with energy below 10 MeV can be realized. The specific heat of $PbWO_4$ was measured for the first time from 1 K down to 400 mK, and the results were found consistent with Debye prediction. The phonon-only response of PbWO4 crystal to energy deposit at low temperature may offer high sensitivity to the small nucleus recoil CEvNS signal. A configuration of 1 gram $PbWO_4$ cube as a detector unit working at $\mathscr{O}(10)$ mK temperature, with phonon sensor technology sensitive to nucleus recoil energy as small as $\mathscr{O}(10)$ eV is hypothesized as the ideal experiment benchmark. Assuming that the 100 dru background spectrum is flat, a signal rate of more than 200 reactor neutrino coherent scattering events can be expected per day 1 kilogram $PbWO_4$ detector against 20 background counts in optimized signal region.

Session: Poster P7-28: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Jingjing Hu - Southwest Jiaotong University

Study of quasi-particle dynamics using the optical pulse response of a superconducting resonator

J. Hu [1], Q. He [2], F. Yu [2], Y. Chen [1], M. Dai [2], H. Guan [1], P. Ouyang [2], J. Han [2], C. Liu [1], X. Dai [1], Z. Mai, 1 X. Liu [1], M. Zhang [1], L. F. Wei [2],, a) M. R. Vissers [3], J. Gao [3], and Y. Wang [1]

[1] Quantum Optoelectronics Laboratory, School of Physical Science and Technology, Southwest Jiaotong University, Chengdu, Sichuan 610031, China.
[2] Information Quantum Technology Laboratory, School of Information Science and Technology,Southwest Jiaotong University, Chengdu, Sichuan 610031, China.
[3] National Institute of Standards and Technology, Boulder, CO 80305, USA

We study the optical pulse response of a superconducting half-wavelength coplanar waveguide (CPW) resonator. We apply a short optical pulse to the center strip of the CPW resonator, where the current distribution shows antinodes or nodes for different resonance modes, and measure their frequency responses. We develop a time-dependent variable inductance circuit model which successfully simulate the optical pulse response of the resonator. By fitting this model to experimental data, we extract the temporal kinetic inductance variations, which directly reflects the quasi-particle relaxation with time and diffusion in space. We also retrieve the spatial size of the quasi-particle distribution and the quasi-particle diffusion constant. Our study is very useful for the design of photon-counting kinetic inductance detectors and the method developed in this work provides an useful way to study the quasi-particle dynamics in superconductor.

Session: Poster P7-29: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Tyler Reynolds - SuperCDMS

SuperCDMS IMPACT: Measuring the sub-keV Ionization Yield in Cryogenic Solid-State Detectors

Tyler Reynolds on behalf of the SuperCDMS Collaboration

The SuperCDMS collaboration uses cryogenic silicon and germanium detectors to directly search for dark matter. Nonbaryonic dark matter in the mass range of 1-10 GeV/c^2 that interacts primarily through nuclear recoils will deposit less than one keV of energy in detectors. These energy depositions will produce phonons and electron-hole pairs. The number of electron-hole pairs produced per unit energy, called the ionization yield, is a central quantity for reconstructing the recoil energy and properly modeling the dark matter signal. However, it has not been well-characterized for sub-keV nuclear recoils. IMPACT (Ionization Measurement with Phonons At Cryogenic Temperatures) is a neutron scattering measurement that aims to measure the ionization yield in cryogenic Si down to 100 eV recoil energies. This talk will describe the first data taking campaign at the Triangle Universities Nuclear Laboratory using a Si detector and the results obtained from the data. This measurement will be relevant not only to SuperCDMS, but also to other experiments such as SENSEI.

Session: Poster P7-30: Rare Events, Astrophysics and Cosmology, Instruments, more MKIDs

Schedule: Thursday 29 July 10:05 - Thursday 29 July 11:30

Submitted by: Masato Naruse - Saitama University

Superconducting resonators with niobium airbridge inductors for high-energy particle detection

Masato Naruse, Yuki Waga, Tohru Taino, Hiroaki Myoren

Saitama University

We have been developing the lumped element kinetic inductance detectors (LeKID) for high-energy particles, such as gamma-rays, alpha particles, and even dark matter. We often choose low-T_c material such as aluminum or titanium nitride since better energy resolution requires a long quasiparticle lifetime. Devices fabricated the low-T_c, however, need to be operated at low temperature and need expensive cryostat.

To reduce the cooling cost we selected niobium (Nb) whose critical temperature is approximately 8 K. The Nb-based LeKIDs can have a reasonably high quality factor of more than 50k at 1 K, but the estimated quasiparticle lifetime in the Nb film was 1 ns that is approximately 5 orders of magnitude shorter than that in an Al film.

We propose the introduction of an airbridge structure to the inductor part of the LeKID to compensate for the degradation of the energy resolution due to the short lifetime. We made the airbridge of Nb which is the same material as the remaining part of the sensor. The thickness of the airbridge was 500 nm and 5 times thicker than the other part. The length of the bridge varied from 10-50 um. We found that the internal quality factor of the device with the airbridge was approximate 20k and comparable with the normal LeKID at 1 K.

Now we are evaluating performances against the alpha particles.

Session: Oral O8-1: Devices 3

Schedule: Friday 30 July 07:00 - Friday 30 July 07:30

Submitted by: Lixing You - Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences (SIMIT, CAS)

Superconducting nanowire single photon detectors for quantum information

Lixing You

Shanghai Institute of Microsystem and Information Technology,
Chinese Academy of Sciences (SIMIT, CAS)

Since the first experimental demonstration, superconducting nanowire single photon detectors (SNSPD) have grown to be one of the key devices for the development of quantum information in the past 20 years. Detection efficiency (DE) is the most important parameter for a single photon detector. For NbN SNSPD, how to optimize the absorption efficiency (ABS) and intrinsic detection efficiency (IDE) simultaneously is challenging for reaching the near-unity DE. We developed two methods to overcome the balance mechanism of ABS and IDE. One is the He ion irradiation to optimize the IDE without sacrificing ABS; the other is the double layer NbN ultrathin films to optimize the ABS without sacrificing IDE. We were able to produce NbN SNSPDs with the record system DE of 98% at 1.5 μm wavelength. The developed SNSPDs with high system DE have been applied into various quantum information experiments, including optical quantum computation, quantum key distribution etc, which advanced the quantum information processing. In this talk, we will present the latest results of SNSPDs with high system DE and the applications in quantum information.

Session: Oral O8-2: Devices 3

Schedule: Friday 30 July 07:30 - Friday 30 July 07:45

Submitted by: Loredana Parlato - Università di Napoli Federico II

Investigation of fluctuations in superconducting molybdenum silicide nanostrips for single photon detectors

L. Parlato [1,2], D. Salvoni [3,2], M. Ejrnaes [4], F. Mattioli [5], A. Gaggero [5], F. Martini [5], D. Massarotti [6,2], D. Montemurro [1], R. Satariano [1], F. Chianese [1,2], F. Tafuri [1], R. Cristiano [4], G.P. Pepe [1,2]

[1] Dipartimento di Fisica, Università degli Studi di Napoli Federico II, I-80125 Napoli, Italy
[2] CNR-SPIN, Institute of Superconductors, Innovative Materials and Devices, Napoli, I-80126 Napoli, Italy
[3] Dipartimento di Ingegneria Chimica, dei Materiali delle Produzioni Industriali, Università degli Studi di Napoli Federico II, I-80125 Napoli, Italy
[4] CNR-SPIN Institute of Superconductors, Innovative Materials and Devices, Pozzuoli, I-80078 Pozzuoli, Italy
[5] CNR, Institute for Photonics and Nanotechnologies, Rome, Italy
[6] Dipartimento di Ingegneria Elettrica e delle Tecnologie dell'Informazione, Università degli Studi di Napoli Federico II, I-80125 Napoli, Italy

Recent developments in Superconducting Nanostrip Single-Photon Detector (SNSPD) technology have enabled single photon detection at much longer wavelengths extending into the mid-infrared. The performances of SNSPDs depend on materials properties, design, fabrication process, and measurement conditions. Another important feature of SNSPDs is their low DCR, that increases close to the critical current where the detection efficiency is higher. In such a region DCR is dominated by a spontaneous resistive-state formation, i.e. an intrinsic decoherent phenomenon occurring in thin film superconducting nanostrips. In this work we have investigated the effects of fluctuations in MoSi nanomeanders, covered with a very thin layer of Al, that was previously demonstrated to work as single photon detector at λ = 1550 nm. We have measured the switching current distributions from the superconducting to resistive regime in a wide interval of temperatures, from 6 K down to 0.007 K and investigated the role played by vortices. The experimental dependence of the fluctuation rates on the bias current, temperature and width of the strip are presented and discussed in the framework of the theoretical models based on the vortices. The results will be compared with that obtained by MoSi microbridge of different widths. Our results may be of interest for the understanding of the detector's operation mode and for the choice of the materials toward the detection at longer mid-infrared wavelengths.

Session: Oral O8-3: Devices 3

Schedule: Friday 30 July 07:45 - Friday 30 July 08:00

Submitted by: Ilya Charaev - Massachusetts Institute of Technology

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Single-photon detection in superconducting MgB_2 micro-wires operating up to 20 K

Ilya Charaev [1], Sergey Cherednichenko [2], Kate Reidy [1], Vladimir Drakinskiy [2], Yang Yu [3], Samuel Lara Avila [2], Joachim Dahl Thomsen [1], Boris Korzh [4], Karl K. Berggren [1]

[1] Massachusetts Institute of Technology, 50 Vassar Street, Cambridge, MA 02139
[2] Department of Microtechnology and Nanoscience, Chalmers University of Technology, Göteborg SE-41296, Sweden
[3] Raith America, Inc., 300 Jordan Road, Troy, NY 12180
[4] Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA,

The superconducting nanowire single-photon detector (SNSPD) is a key technique for deep-space optical communications, quantum key distribution, high-time-resolution lidars, etc. Based on low-critical-temperature superconductors such as WSi, MoSi, or NbN, detectors show single-photon sensitivity in a broad range and recorded metrics: a 98% of detection efficiency [1], a sub-3 ps timing jitter [2], and a low dark count rate [3]. However, a low operating temperature (4 K) of low-T_c SNSPDs requires expensive and complex cryogenics, which has been hindering the large-scale adoption of these detectors.

Recent progress with ultra-thin films of magnesium diboride (MgB_2) has made possible single-photon detection in MgB_2 nanowires [4] at both visible and IR (1550nm) wavelengths, demonstrating a very low reset time ($\sim$130ps). We make use of a high critical temperature in thin films ($\sim$37 K) and a critical current density approaching the pair breaking current in order to extend the MgB_2 SNSPD operation to both higher temperatures and larger detection areas.

Based on a recently proposed concept of single-photon detection in microscale-wide wires [5], we developed superconducting MgB_2 detectors that show single-photon sensitivity at the telecom wavelength in the temperature range from 3.7 up to 20 K. We systematically studied superconducting and transport properties along with optical response of meander-shaped detectors with widths ranging from 1 to 5 μm.

[1] Dileep V and et al, "Superconducting nanowire single-photon detectors with 98% system detection efficiency at 1550 nm," Optica 7, 1649-1653 (2020).
[2] Korzh, B., Zhao, QY., Allmaras, J.P. et al. Demonstration of sub-3 ps temporal resolution with a superconducting nanowire single-photon detector. Nat. Photonics 14, 250–255 (2020).
[3] Yonit Hochberg, Ilya Charaev, Sae-Woo Nam, Varun Verma, Marco Colangelo, and Karl K. Berggren, "Detecting Sub-GeV Dark Matter with Superconducting Nanowires", Phys. Rev. Lett. 123, 151802 (2019).
[4] Sergey Cherednichenko et al 2021 Supercond. Sci. Technol. 34 044001.
[5] D. Yu. Vodolazov, Single-Photon Detection by a Dirty Current-Carrying Superconducting Strip Based on the Kinetic-Equation Approach, Phys. Rev. Applied 7, 034014 (2017).

Session: Oral O8-4: Devices 3

Schedule: Friday 30 July 08:00 - Friday 30 July 08:15

Submitted by: Alessandro Monfardini - CNRS Grenoble

The CONCERTO wide field-of-view millimeter-wave spectrometer at APEX

Alessandro Monfardini

CNRS Grenoble

We describe the development of a large field-of-view (20 arc-min) instrument, named CONCERTO (for CarbON CII line in post-rEionisation and ReionisaTiOn epoch), operating in the range 120-310 GHz from the APEX 12-m telescope (5100 m above sea level). CONCERTO is a low-resolution (R = 100) imaging-spectrometer based on the lumped element kinetic inductance detectors (LEKID) technology. Spectra are obtained using a fast (4 Hz) Fourier transform spectrometer (FTS), coupled to a dilution cryostat with a base temperature of 0.1K. Two kilo-pixel arrays of LEKID are mounted inside the cryostat that also contains the cold optics and the front-end electronics. We explain the technological choices leading to the instrumental concept, together with the design and fabrication of the instrument during the period 2019-20. We report the laboratory characterization of the instrument. We will describe the installation at APEX coming in April, 2021. If available (observing time will be limited due to current lockdowns in Chile), we will provide a preliminary estimate of the sensitivity achieved on Sky.

Session: Oral O8-5: Devices 3

Schedule: Friday 30 July 08:15 - Friday 30 July 08:30

Submitted by: Tony Zhou - RLE, MIT

Ultrawide MoSi SNSPD detectors

Ilya Charaev, Tony X. Zhou, Xiaofu Zhang, Andreas Schilling, Karl K. Berggren

RLE, MIT

Presented by Tony Zhou

Superconducting nanowire single-photon detector (SNSPD) has become an important technology for detecting mid-infrared photons. We report single photon detection events in ultra wide microwires based on the 2 nm MoSi thin films. The wire widths span up to 60 μm and single photon sensitivity is achieved in 780 nm and 1550 nm wavelength [1]. The result also extends the hot-spot formation length into the tens of micrometers, a surprising observation. Our results pave the way for simple, scalable, optical lithography to fabricate SNSPD. Wafer scale superconducting thin films-based single photon detectors may even be within reach. Such a large detector area may enhance signal sensitivity by orders of magnitude in a dark matter search scheme [2].

[1] X. Zhang, I. Charaev, H. Liu, T. X. Zhou, D. Zhu, K. K. Berggren, and A. Schilling, Physical Properties of Amorphous Molybdenum Silicide Films for Single Photon Detectors, ArXiv:2104.06905 [Cond-Mat] (2021).
[2] Y. Hochberg, I. Charaev, S.-W. Nam, V. Verma, M. Colangelo, and K. K. Berggren, Detecting Sub-GeV Dark Matter with Superconducting Nanowires, Phys. Rev. Lett. 123, 151802 (2019).

Session: Oral O8-6: Devices 3

Schedule: Friday 30 July 08:40 - Friday 30 July 08:55

Submitted by: Pierre Echternach - Jet Propulsion Laboratory

Single Photon Detection in a Large array of Quantum Capacitance Detectors

P. M. Echternach, S. Van Berkel, A.D. Beyer, G. Chattopadhyay and C.M. Bradford
Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA, USA
R. Stephenson A. Sinclair
Arizona State University, Tempe, AZ, USA

The Quantum Capacitance Detector (QCD) is a new high-sensitivity direct detector under development for low background applications such as far-infrared spectroscopy from a cold space telescope. The QCD has demonstrated an optically-measured noise equivalent power of 2×10^{-20} W Hz$^{-1/2}$ at 1.5THz, making it among the most sensitive far-IR detectors systems ever demonstrated, and meeting the requirements for spaceborne spectroscopy. The QCD has also demonstrated single photon detection and counting of 1.5THz radiation. To date, the QCD's dynamic range has been limited to 10^2. In this work, we describe a QCD design that improves the dynamic range by two orders of magnitude, namely an antenna coupled QCD. At the heart of the QCD is a device dubbed the single Cooper-pair-box (SCB), comprised of a small island of superconducting material connected via a small tunnel junction to a reservoir also of superconducting material. Simulations predict that for a device with island volume 0.0044μm^3 and absorber 0.044 μm^3 the shot noise limited region will extend from 10^{-20} to 10^{-17} W, increasing the dynamic range by a factor of 100. While we are at the lower limit for a mesh absorber volume, using an antenna coupled device allows for a reservoir with this small volume and also a small volume island.

Session: Oral O8-7: Devices 3

Schedule: Friday 30 July 08:55 - Friday 30 July 09:10

Submitted by: Jordan Wheeler - National Institute of Standards of Technology

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Development of far-infrared to mm-wave feedhorn-coupled kinetic inductance detector arrays.

Jordan Wheeler, Jiansong Gao, Michael R. Vissers, Jason Austermann, Maxime Malnou, Johannes Hubmayr, Samantha Walker, Joel N. Ullom

National Institute of Standards and Technology

At the National Institute of Technology (NIST), our goal is to produce high pixel count arrays of Kinetic Inductance Detectors (KIDs) with background-limited sensitivity to address the needs of the most advanced far-IR to mm-wave cameras. This is accomplished via polarization-sensitive lumped element KIDs, where the inductive elements of two KIDs are coupled to orthogonal linear polarizations when placed behind the waveguide of a feedhorn. We have successfully deployed KID arrays for the BLAST-TNG experiment (250 um, 350 um, and 500 um arrays), the TolTEC camera (1.1 mm, 1.4 mm, and 2.0 mm arrays), and a recently delivered 1.1 mm array for Prime-Cam on the Fred Young Submillimeter Telescope (FYST). The initial dark characterization of the Prime-Cam array will be presented, along with the optical characterization of a witness device co-fabricated within the array wafer. We will show how this novel testing scheme facilitated rapid lithographic tuning of the array responsivity to optimize on-sky performance. Finally, the development of new arrays for FYST will be detailed. First, we will discuss new ultrastable Al/TiN hybrid KIDs baselined for the Epoch of Reionization Spectrometer that are 1/f noise-free to 50 mHz. Secondly, we will present the development of lower T_c TiN recipes with improved 1/f noise performance for future 350 um arrays.

Session: Oral O8-8: Devices 3

Schedule: Friday 30 July 09:10 - Friday 30 July 09:25

Submitted by: Pete Barry - Argonne National Laboratory

Optical performance of the microstrip-coupled lumped-element kinetic inductance detector

P. Barry [1], T. Brien [2], T. Cecil [1], C. Chang [1], S. Doyle [2], Z. Pan [1], G. Robson [2], S. Rowe [2], E. Shirokoff [3], Q. Y. Tang [3]

[1] Argonne National Laboratory
[2] Cardiff University
[3] University of Chicago

The kinetic inductance detector (KID) offers an elegant solution to building large-format arrays. In particular, arrays of lumped-element KIDs (leKID) are emerging as an attractive choice for future instruments operating at (sub)millimeter wavelengths, with several experiments now beginning to establish the first large-scale demonstrations of KID technology. Of these, the typical detector design is based on free-space absorber-coupled leKIDs, which are known to be well suited for single-colour imaging arrays. However, these designs are not easily integrated with the multi-colour on-chip transmission line filtering techniques that have been shown to offer improved focal plane efficiency for wide-band imaging and spectroscopic applications. Here we will discuss the recent development and performance of the microstrip-coupled leKID (mc-leKID); a simple KID implementation that permits efficient broadband radiation coupling through a thin-film superconducting mm-wave microstrip feedline. We discuss progress on the design and experimental validation of a waveguide-fed prototype pixel design, and will present results from recent laboratory-based optical measurements. Finally, we explore pathways to achieving the large-format arrays of mc-leKIDs that will be key for future mm-wave experiments.

Session: Oral O8-9: Devices 3

Schedule: Friday 30 July 09:25 - Friday 30 July 09:40

Submitted by: Ritoban Basu Thakur - California Institute of Technology

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Development of Superconducting On-chip Fourier Transform Spectrometer devices

R. Basu Thakur, N. Klimovich, S. Shu, P. K. Day, P. Masukopf, F. Faramarzi, E. Shirokoff, A. Steiger

Superconducting thin film transmission lines fabricated from NbN and NbTiN demonstrate Non Linear Kinetic Inductance (NLKI), where the supercurrent alters the kinetic inductance in a predictable non-linear manner. We utilize NLKI to obtain current controlled phase delay in such transmission lines. Via on-chip hybrids we can divide/combine power between two transmission lines creating an on-chip interferometer, as the delay in each line is controlled independently. We call this a Superconducting On-chip Fourier Transform Spectrometer (SOFTS) device. We describe the design, fabrication and characterization of SOFTS in 25-40 GHz (Ka band) and 70-110 GHz (W band). These lithographed SOFTS can be arrayed into kilo-pixel focal planes, i.e., to realize integral field spectrographs in the mm and sub-mm bands. We outline the instrumentation development of SOFTS and their utility for CMB spectral measurements and Line Intensity Mapping.

Session: Oral O8-10: Devices 3

Schedule: Friday 30 July 09:40 - Friday 30 July 09:55

Submitted by: Nicholas Zobrist - University of California, Santa Barbara

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Progress on improving the energy resolution of optical to near-IR MKIDs

Nicholas Zobrist, Gregoire Coiffard, Miguel Daal, Hawkins Clay, Ben Mazin

University of California, Santa Barbara

MKIDs sensitive to optical and near-IR radiation are single photon counting and energy resolving sensors. Already, kilo-pixel arrays of these detectors have been deployed at several ground-based observatories and are being used to extend our current capabilities in the fields of high-contrast imaging and time domain astronomy. The attainable science goals for these devices, however, depend strongly on the precision at which we can measure each photon's energy. For example, achieving the theoretical limit in the energy resolution would allow them to resolve most of the expected spectral features of planets orbiting other stars. In pursuit of this objective, much work has been done in the past few years to understand the current limits on the MKID's resolving power. We will present our current progress addressing these limitations and discuss the best results we have achieved to date.

Session: Oral O8-11: Devices 3

Schedule: Friday 30 July 09:55 - Friday 30 July 10:10

Submitted by: Takashi Noguchi - National Astronomical Observatory of Japan / RIKEN

Contribution of residual quasiparticles to the resonance properties of MKID resonators

T. Noguchi [1,2], S. Mima [2], C. Otani [2]

[1] National Astronomical Observatory of Japan
[2] RIKEN

We have systematically studied the resonance characteristics of Al and Nb superconducting resonators from the viewpoint of the contribution of residual quasiparticles.

It is found that both the measured quality factors and the fractional frequency change as a function of temperature for both the Al and Nb resonators agree very well with those predicted by the residual resistance considering not only the Kondo effect but also the contribution of phonon scattering and electron-electron scattering.

It is known that the wavefunction of a quasiparticle is modulated by the perturbation of the microwave voltage under the microwave field and the quasiparticle state splits into many levels. Consequently, transitions of quasiparticles to the lower energy states occur and the number of quasiparticles near the Fermi level, which mainly contribute to the normal conductivity, decreases with increasing the strength of the microwave field. Therefore, the reduction of the inverse internal quality factor with increasing the readout microwave power can be attributed to the decrease of the quasiparticle number or the normal conductivity, due to the energy redistribution of the quasiparticles under the strong microwave field in the resonator. It is found by the fitting of $1/Q_i$ as a function of internal microwave voltage in the resonator that the measured internal quality factors agree well with the calculated quasiparticle number as a function of the readout microwave power.

Session: Oral O8-12: Devices 3

Schedule: Friday 30 July 10:10 - Friday 30 July 10:25

Submitted by: Juliang Li - Argonne national lab

Strategies for reducing frequency scatter in large arrays of superconducting resonators

J. Li, P. S. Barry, T. Cecil, C. Chang, M. Lisovenko, Z. Pan, V. Yefremenko

Argonne National Lab

Superconducting resonators are now found in a broad range of applications that require high-fidelity measurement of low energy signals. A common feature across almost all of these applications is the need for increased numbers of resonators to further improve sensitivity, and the ability to read out large numbers of resonators, without the need for additional cryogenic complexity, is a primary motivation. One of the major limitations of current resonator arrays is the observed scatter in the resonator frequencies when compared to the initial design. Here we present recent progress toward identifying the dominant underlying causes of resonator scatter, discerning the important differences between stochastic variation inherent to the fabrication process, and systematic deviations due to the electric and magnetic environment. With an array of both lumped-element, and transmission line resonators designed to probe these effects directly, we investigate and quantify the systematic variation of our process across the full scale of a 6 inch wafer. To address the cause of the underlying stochastic component, we explore several methods to identify the dominant sources, focusing on improving thin-film non-uniformities and lithographic tolerances. Based on these results, we present a number of strategies to control and mitigate frequency scatter in future large-format arrays of superconducting resonators.

Index of Submitters