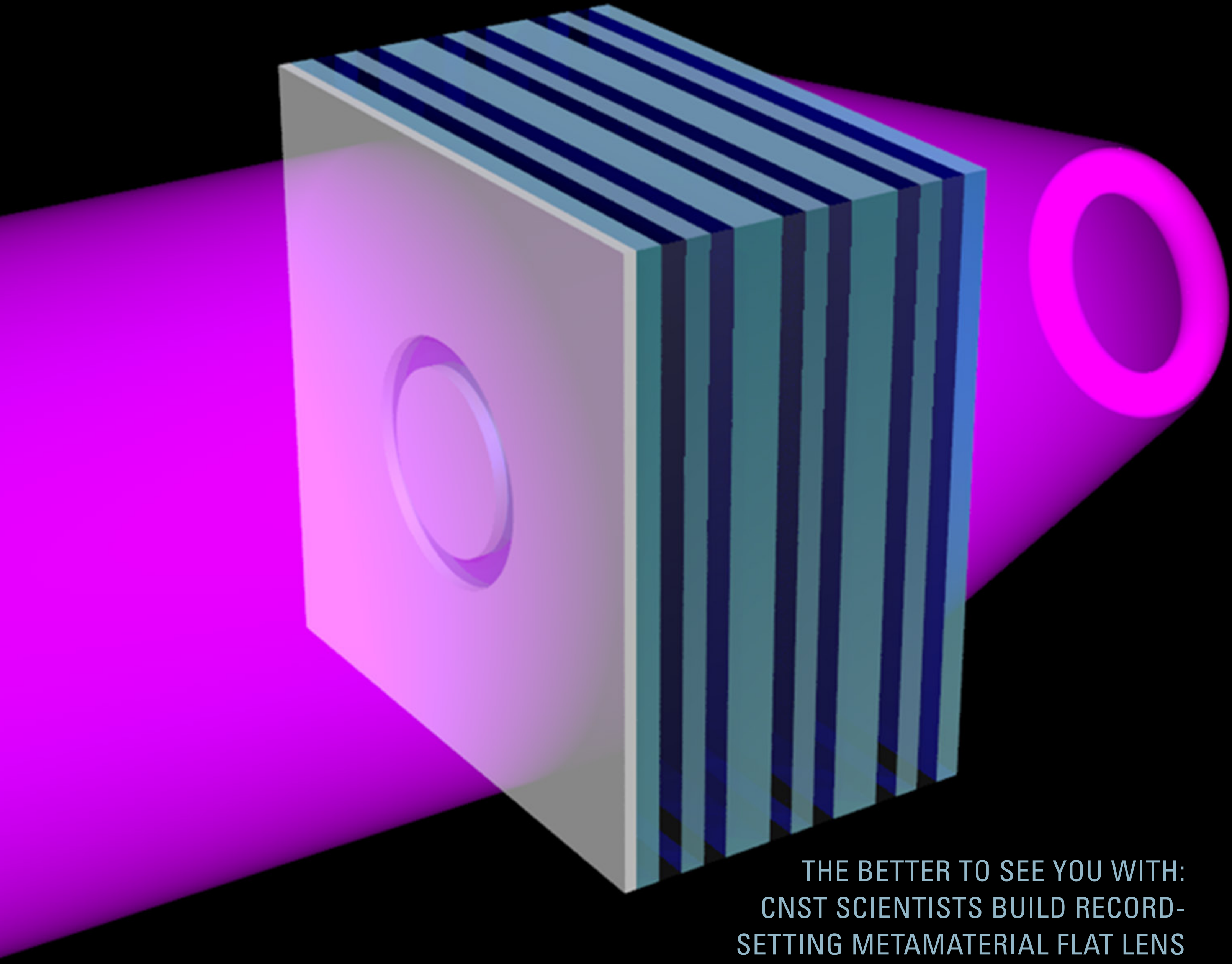
THE CNST NEWS

FALL 2013



THE BETTER TO SEE YOU WITH: CNST SCIENTISTS BUILD RECORD-SETTING METAMATERIAL FLAT LENS

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NIST
National Institute of
Standards and Technology
U.S. Department of Commerce

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ADDITIONAL CONTRIBUTOR |
MARK ESSER

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KRISTEN DILL

FROM THE DIRECTOR

While our NanoFab users and NanoLab collaborators quickly recognize the skills of our world-class researchers and experienced engineering staff, the CNST's success also depends on the technical staff who work behind the scenes building devices, maintaining tools, modifying processes, and developing custom software for the Center.

Particularly important to our day-to-day operations are our Engineering Technicians, who maintain and upgrade all the fabrication equipment, measurement tools, and laboratory support apparatus in the NanoFab. They aid researchers and assist in NanoFab operations. More than anyone else, their careful work ensures that a process used to build a device or to take a measurement on our commercial state-of-the-art equipment will be replicable months later.

Our Instrumentation Specialists, Glenn Holland and Steve Blankenship, seem able to build almost any mechanical device. They assist with all phases of experiment and instrumentation design. Before coming to the CNST, Glenn spent 22 years supporting research at the Naval Research Laboratory, performing computer-aided design of experimental apparatus and instruments. His designs have led to six U.S. Patents. Steve is an expert on computer automated design (CAD) of experimental instruments, including complex vacuum systems and custom vacuum components. While Steve's main expertise is in designing and building surface instrumentation and thin-film and molecular beam epitaxy systems, he also has a broad range of skills that can be applied to any experimental situation. In October, Steve was awarded the 2013 AVS George T. Hanyo Award "for outstanding contributions to the scanning tunneling microscopy user facilities and other laboratories" at the CNST.

Our Electronics Engineers construct specialized electronic instruments for controlling state-of-the-art scientific experiments. Since joining NIST in 1991, Alan Band has designed and supervised the construction of numerous electronic instruments. Of particular note are electronic devices associated with scanning tunneling microscopy, scanning electron microscopy with polarization analysis, and nanofabrication with laser-cooled atoms. He has won numerous awards for his work at NIST, including the NIST Bronze Metal. David Rutter's work at the CNST has included constructing numerous control circuits and building custom electronic devices for complex scanning tunneling microscopes.

Critically important for all aspects of CNST operations, our Information Technology staff keeps our information secure, provides system administration to keep our servers running, maintains our IT hardware, and provides programming support for both NanoFab operations and NanoLab instrumentation. As discussed on page 13, the CNST recently launched NEMO, a new system developed from the ground up by CNST IT Specialist Dylan Klomparens to allow users to manage the advanced equipment in the NanoFab. NEMO lets users reserve NanoFab equipment in advance using a web interface, activate and deactivate equipment, see who is using equipment, and view equipment status.

And keeping us safe, CNST Safety Officer and Property Manager Russ Hajdaj assists with the management and oversight of all aspects of the CNST Safety Program. He also manages and maintains CNST's chemicals, precious metals, and property. In December 2012, along with the NanoFab staff, Russ won the NIST Safety Award "for establishing and implementing an outstanding safety program in the NanoFab that protects the safety of researchers from industry, academia, NIST, and other government agencies, who range from novices to experts in nanofabrication."

Because nanotechnology created at the CNST is frequently developed under time pressure and with very high standards, it is easy to lose sight of all the support that makes such progress possible. If you see a member of our support staff and feel it is appropriate, please thank them for their efforts. And if a staff member does something exceptional to help you, please let us know about it so we can recognize their work as well.

Robert Celotta

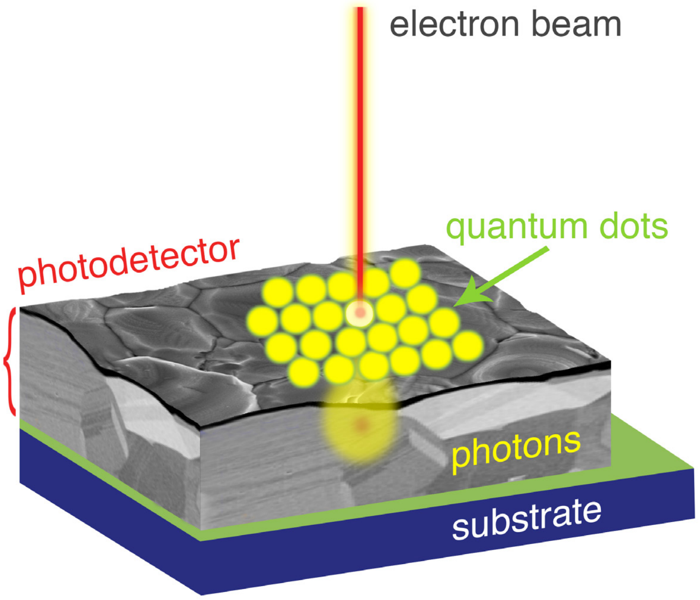
NEW QUANTUM DOT TECHNIQUE COMBINES THE BEST OF OPTICAL AND ELECTRON MICROSCOPY

It's not reruns of "The Jetsons", but researchers working at the CNST have developed a new microscopy technique that uses a process similar to how an old tube television produces a picture—cathodoluminescence—to image nanoscale features. Combining the best features of optical and scanning electron microscopy, the fast, versatile, and high-resolution technique allows scientists to view surface and subsurface features potentially as small as 10 nanometers in size.

The new microscopy technique, described in the journal *AIP Advances*, uses a beam of electrons to excite a specially engineered array of quantum dots, causing them to emit low-energy visible light very close to the surface of the sample, exploiting so-called "near-field" effects of light. By correlating the local effects of this emitted light with the position of the electron beam, spatial images of these effects can be reconstructed with nanometer-scale resolution.

The technique neatly evades two problems in nanoscale microscopy, the diffraction limit that restricts conventional optical microscopes to resolutions no better than about half the wavelength of the light (so about 250 nm for green light), and the relatively high energies and sample preparation requirements of electron microscopy that are destructive to fragile specimens like tissue.

CNST researcher Nikolai Zhitenev, a co-developer of the technique, had the idea a few years ago to use a phosphor coating to produce light for near-field optical imaging, but at the time, no phosphor was available that was thin enough. Thick phosphors cause the light to diverge, severely limiting the image resolution. This changed when the NIST researchers teamed with researchers from a company that builds highly engineered and optimized quantum dots for lighting applications. The quantum dots potentially could do the same job as a phosphor, and be applied in a coating both homogenous and thick enough to absorb the entire electron beam while also sufficiently thin so that the light produced does not have to travel far to the sample.



Much like in an old tube television where a beam of electrons moves over a phosphor screen to create images, the new microscopy technique works by scanning a beam of electrons over a sample that has been coated with specially engineered quantum dots. As shown in this schematic, the dots absorb the energy and emit it as visible light that interacts with the sample at close range. The scattered photons are collected using a similarly closely placed photodetector (not depicted), allowing an image to be constructed.

The collaborative effort found that the quantum dots, which have a unique core-shell design, efficiently produced low-energy photons in the visible spectrum when energized with a beam of electrons. A potential thin-film light source in hand, the group developed a deposition process to bind them to specimens as a film with a controlled thickness of approximately 50 nm.

Much like in an old tube television where a beam of electrons moves over a phosphor screen to create images, the new technique works by scanning a beam of electrons over a sample that has been coated with the quantum dots. The dots absorb the electrons' energy and emit it as visible light that interacts with and penetrates the surface over which it has been coated. After interacting with the sample, the scattered photons are collected using a closely placed photodetector, allowing an image to be constructed. The first demonstration of the technique was used to image the natural nanostructure of the photodetector itself. Because both the light source and detector are so close to the sample, the diffraction limit doesn't apply, and much smaller objects can be imaged.

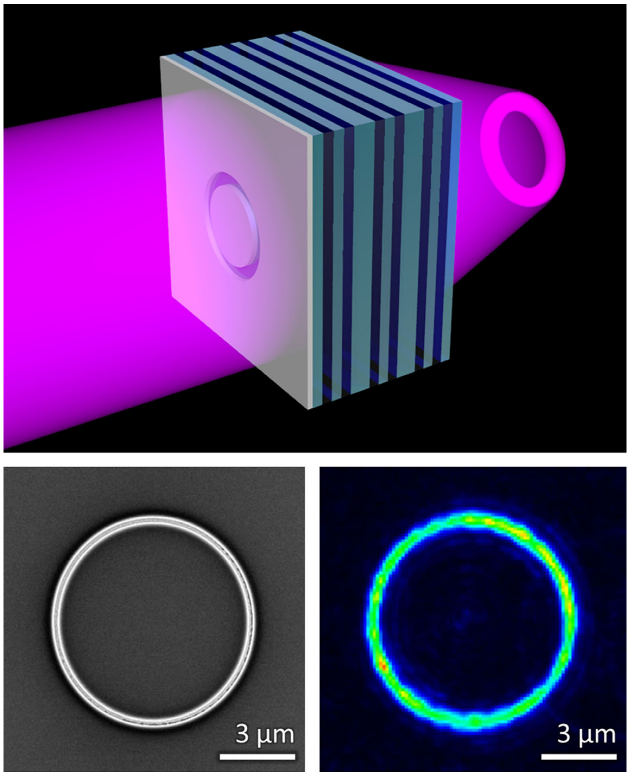
"Initially, our research was driven by our desire to study how inhomogeneities in the structure of polycrystalline photovoltaics could affect the conversion of sunlight to electricity and how these devices can be improved," says Heayoung Yoon, the lead author of the paper. "But we quickly realized that this technique could also be adapted to other research regimes, most notably imaging for biological and cellular samples, wet samples, samples with rough surfaces, as well as organic photovoltaics. We are anxious to make this technique available to the wider research community and see the results."

This work was a collaboration among researchers from NIST; the Maryland NanoCenter at the University of Maryland, College Park; Worcester Polytechnic Institute; QD Vision; and Sandia National Laboratories.

High-resolution photocurrent microscopy using near-field cathodoluminescence of quantum dots, H. P. Yoon, Y. Lee, C. D. Bohn, S.-H. Ko, A. G. Gianfrancesco, J. S. Steckel, S. Coe-Sullivan, A. A. Talin, and N. B. Zhitenev, *AIP Advances* **3**, 062112 (2013).

SCIENTISTS BUILD RECORD-SETTING METAMATERIAL FLAT LENS

For the first time, scientists working at the CNST have demonstrated a new type of lens that bends and focuses ultraviolet (UV) light in such an unusual way that it can create ghostly, 3D images of objects that float in free space. The easy-to-build lens could lead to improved photolithography, nanoscale manipulation and manufacturing, and even high-resolution three-dimensional imaging, as well as a number of as-yet-unimagined applications in a diverse range of fields.



Top: A CNST team has created an ultraviolet (UV) metamaterial formed of alternating nanolayers of silver (green) and titanium dioxide (blue). The metamaterial has an angle-independent negative refractive index, enabling it to act as a flat lens. When illuminated with UV light (purple) a sample object of any shape placed on the flat slab of metamaterial is projected as a three-dimensional image in free space on the other side of the slab. Here a ring-shaped opening in an opaque sheet on the left of the slab is replicated in light on the right. Bottom left: Scanning electron micrograph of a ring-shaped opening in a chromium sheet located on the surface of a flat slab of metamaterial. Bottom right: Optical micrograph of the image projected beyond the slab under UV illumination, demonstrating that the metamaterial slab acts as a flat lens.

"Conventional lenses only capture two dimensions of a three-dimensional object," says one of the paper's co-authors, Ting Xu. "Our flat lens is able to project three-dimensional images of three-dimensional objects that correspond one-to-one with the imaged object."

An article published in the journal *Nature* explains that the new lens is formed from a flat slab of metamaterial with special characteristics that cause light to flow backward—a counter intuitive situation in which waves and energy travel in opposite directions, creating a negative refractive index.

Naturally occurring materials such as air or water have a positive refractive index. You can see this when you put a straw into a glass of water and look at it from the side. The straw appears bent and broken as a result of the change in index of refraction between air, which has an index of 1, and water, which has an index of about 1.33. Because the refractive indices are both positive, the portion of the straw immersed in the water appears bent forward with respect to the portion in air.

The negative refractive index of metamaterials causes light entering or exiting the material to bend in a direction opposite what would occur in almost all other materials. For instance, if we looked at our straw placed in a glass filled with a negative-index material, the immersed portion would appear to bend backward, completely unlike the way we're used to light behaving.

In 1967, Russian physicist Victor Veselago described how a material with both negative electric permittivity and negative magnetic permeability would have a negative index of refraction. (Permittivity is a measure of a material's response to an applied electric field, while permeability is a measure of the material's response to an applied magnetic field.)

Veselago reasoned that a material with a refractive index of -1 could be used to make a lens that is flat, as opposed to traditional refractive lenses, which are curved. A flat lens with a refractive index of -1 could be used to directly image three-dimensional objects, projecting a three-dimensional replica into free space.

A negative-index flat lens like this has also been predicted to enable the transfer of image details substantially smaller than the wavelength of light and create higher-resolution images than are possible with lenses made of positive-index materials such as glass.

It took over 30 years from Veselago's prediction for scientists to create a negative-index material in the form of metamaterials, which are engineered on a subwavelength scale. For the past decade, scientists have made metamaterials that work at microwave, infrared, and visible wavelengths by fabricating repeating metallic patterns on flat substrates. However, the smaller the wavelength of light scientists want to manipulate, the smaller these features need to be, which makes fabricating the structures an increasingly difficult task. Until now, making metamaterials that work in the UV has been impossible because it required making structures with features as small as 10 nanometers, or 10 billionths of a meter.

Moreover, because of limitations inherent in their design, metamaterials of this type designed for infrared and visible wavelengths have, so

(continued)

SCIENTISTS BUILD RECORD-SETTING METAMATERIAL FLAT LENS (CONT.)

far, been shown to impart a negative index of refraction to light that is traveling only in a certain direction, making them hard to use for imaging and other applications that rely on refracted light.

To overcome these problems, researchers working at the CNST took inspiration from a theoretical metamaterial design recently proposed by a group at the FOM Institute for Atomic and Molecular Physics in Holland. They adapted the design to work in the UV—a frequency range of particular technological interest.

According to co-authors Xu, Amit Agrawal and Henri Lezec, aside from achieving record-short wavelengths, their metamaterial lens is inherently easy to fabricate. It doesn't rely on nanoscale patterns, but instead is a simple sandwich of alternating nanometer-thick layers of silver and titanium dioxide, the construction of which is routine. And because its unique design consists of a stack of strongly coupled waveguides sustaining backward waves, the metamaterial exhibits a negative index of refraction to incoming light regardless of its angle of travel.

This realization of a Veselago flat lens operating in the UV is the first such demonstration of a flat lens at any frequency beyond the microwave. By using other combinations of materials, it may be possible to make similarly layered metamaterials for use in other parts of the spectrum, including the visible and the infrared.

The metamaterial flat lens achieves its refractive action over a distance of about two wavelengths of UV light, about half a millionth of a meter—a focal length challenging to achieve with conventional refractive optics such as glass lenses. Furthermore, transmission through the metamaterial can be turned on and off using higher frequency light as a switch, allowing the flat lens to also act as a shutter with no moving parts.

"Our lens will offer other researchers greater flexibility for manipulating UV light at small length scales," says Lezec. "With its high photon energies, UV light has a myriad of applications, including photochemistry, fluorescence microscopy, and semiconductor manufacturing. That, and the fact that our lens is so easy to make, should encourage other researchers to explore its possibilities."

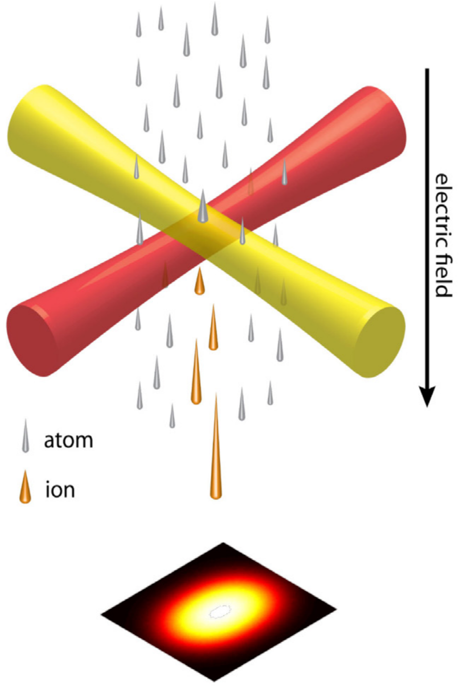
The new work was performed in collaboration with researchers from the Maryland NanoCenter at the University of Maryland, College Park; Syracuse University; and the University of British Columbia, Kelowna, Canada.

All-angle negative refraction and active flat lensing of ultraviolet light, T. Xu, A. Agrawal, M. Abashin, K. J. Chau, and H. J. Lezec, *Nature* **497**, 470–474 (2013).

NEW ION SOURCE FOR FOCUSED ION BEAMS USES COLD ATOMIC BEAM

Researchers from the CNST and zeroK Nanotech Corporation have demonstrated a new ion source that may enable focused ion beams with high brightness and resolution for nanoscale fabrication and measurement applications in fields ranging from semiconductor manufacturing to biotechnology. Working under a cooperative research and development agreement (CRADA), the researchers have constructed the first prototype of a low-temperature ion source (LoTIS), which utilizes the extremely cold temperatures attainable with laser cooling to produce a highly collimated, bright ion beam.

Unlike the magneto-optical trap ion source (MOTIS), a previous NIST technology that uses lasers and magnetic fields to trap and cool a group of atoms in three dimensions before ionizing the atoms and extracting a beam, LoTIS begins by generating a cold, but slowly moving atomic beam using a two-dimensional magneto-optical trap. The beam of atoms is then compressed and further cooled to below 30 μK using counter-propagating polarized laser beams that slow the atoms in a region where the laser beams intersect. The atom beam then enters an ionizing laser beam. The result is a source with much higher brightness than the MOTIS. High brightness translates into an ability to focus an ion beam to very small dimensions because it allows more current to be concentrated into a smaller spot.



Schematic of the LoTIS ion source. A laser-cooled and compressed atom beam is ionized by crossed laser beams. The resulting ion beam has the requisite brightness for creating a focal spot less than a nanometer in diameter with currents in the picoampere range.

Based on their measurements and modeling of the source, the researchers predict cesium beams created with LoTIS will have focal spot sizes of less than a nanometer with currents in the picoampere range. Such performance would go well beyond the capabilities of the gallium liquid metal ion sources commonly used in industry, and promises to answer key needs for the next generation of nanoscale manufacturing. Major applications for the LoTIS include semiconductor circuit editing and nanoscale secondary ion mass spectrometry (SIMS).

The LoTIS technology, initially developed at NIST by the research team, has been patented and is now under license to zeroK Nanotech.

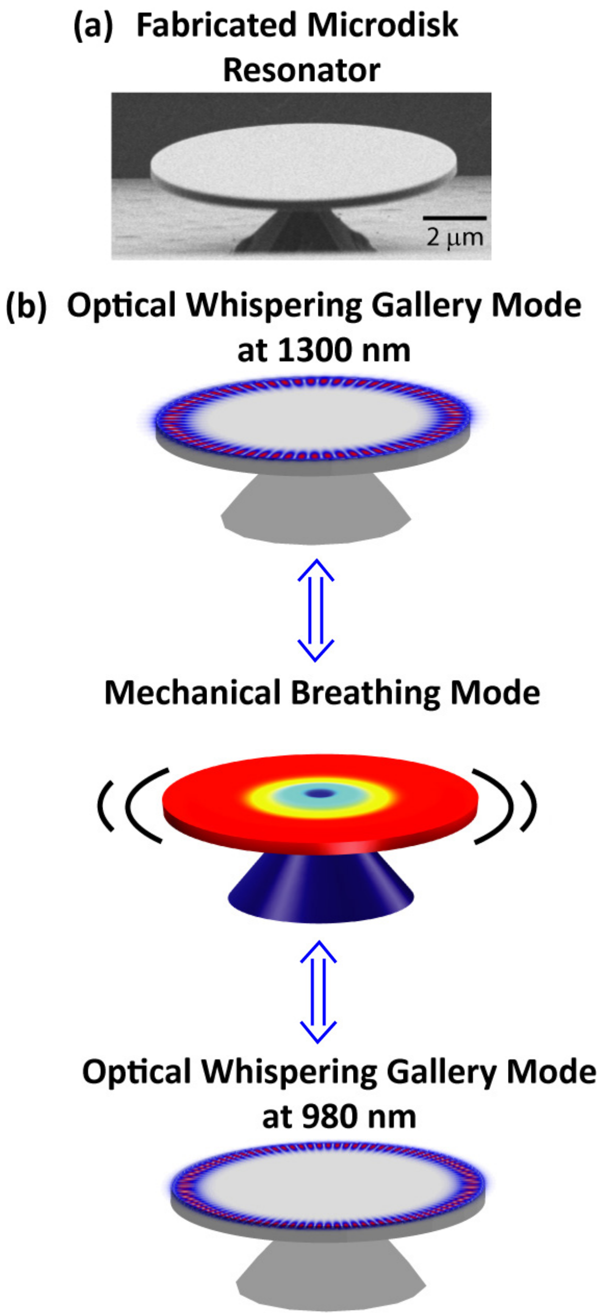
Cold atomic beam ion source for focused ion beam applications, B. Knuffman, A. V. Steele, and J. J. McClelland, *Journal of Applied Physics* **114**, 044303 (2013).

WIDEBAND WAVELENGTH CONVERSION USING CAVITY OPTOMECHANICS

A team of researchers at the CNST, the University of Maryland, and the California Institute of Technology have demonstrated optical wavelength conversion using interactions between radiation pressure and mechanical vibrations in a nanoscale cavity optomechanical system. Along with recent demonstrations by other groups, this work shows that radiation pressure forces may be useful in a variety of signal transduction applications. In particular, wavelength conversion interfaces based on cavity optomechanics can operate over ranges and in material systems in which traditional frequency conversion techniques cannot be applied.

Working in the CNST NanoFab allowed the researchers to fabricate an optomechanical resonator consisting of a 350 nm thick, 10 μm-diameter silicon nitride disk supported on a small silicon pedestal whose top is less than 200 nm in diameter. The microdisk simultaneously confines optical modes, frequencies of light that circulate around the disk's periphery in "whispering gallery" orbits, and a mechanical "breathing" mode that results in the expansion and contraction of the disk out from its center. The disk motion, which changes its size, also influences the optical modes because their frequencies are dependent on the disk circumference. Additionally, the tight optical confinement present in these structures makes the radiation pressure forces strong enough to influence the mechanical motion. Thus, the system's optics and mechanics interact with each other, allowing energy to be converted between the optical and mechanical systems.

The researchers use the interaction of two whispering gallery optical modes with the mechanical breathing mode. Optical energy at an input wavelength aligned with one of the optical modes is transferred to an output wavelength aligned with a second optical mode. This is accomplished through the interaction with the mechanical system, which serves as a bridge to link the two optical modes together. The researchers demonstrated that they can upconvert and downconvert signals over an optical wavelength span of 300 nm, between the 1300 nm and 980 nm wavelength bands that are frequently used in telecommunications. They believe that even wider ranges of wavelength conversion should be possible using the same geometry.



(a) Fabricated Microdisk Resonator

(b) Optical Whispering Gallery Mode at 1300 nm

Future work will focus on improving the conversion efficiencies, which are currently limited to about 20 % within the cavity and 0.5 % for the device as a whole. Reducing noise, including thermal noise, which is the dominant noise source in current devices, can enable operation with extremely weak input signals, potentially all the way down to the single photon states of light used in quantum information processing applications.

Optical wavelength conversion mediated by radiation pressure interacts with a mechanical mode. (a) A scanning electron micrograph of a fabricated silicon nitride microdisk resonator. (b) Schematic showing wavelength conversion between optical "whispering gallery" modes at 1300 nm and 980 nm wavelengths. The conversion is achieved through interaction with a mechanical breathing mode that serves as a bridge between the two optical modes.

Electromagnetically induced transparency and wideband wavelength conversion in silicon nitride microdisk optomechanical resonators, Y. Liu, M. Davanço, V. Aksyuk, and K. Srinivasan, *Physical Review Letters* **110**, 223603 (2013).

THE REINS OF CASIMIR: ENGINEERED NANOSTRUCTURES COULD OFFER WAY TO CONTROL QUANTUM EFFECT ONCE MYSTERY IS SOLVED

You might think that a pair of parallel plates hanging motionless in a vacuum just a fraction of a micrometer away from each other would be like strangers passing in the night—so close but destined never to meet. Thanks to quantum mechanics, you would be wrong.

Scientists working to engineer nanoscale machines know this only too well as they have to grapple with quantum forces and all the weirdness that comes with them. These quantum forces, most notably the Casimir effect, can play havoc if you need to keep closely spaced surfaces from coming together.

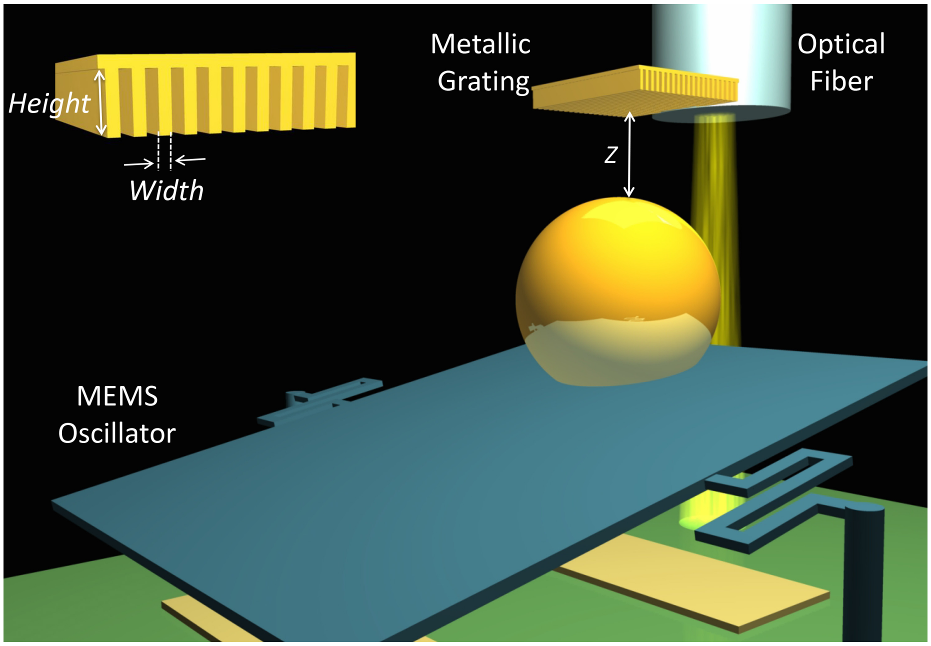
Controlling these effects may also be necessary for making small mechanical parts that never stick to each other, for building certain types of quantum computers, and for studying gravity at the microscale.

Now, a large collaborative research group involving scientists from a number of federal labs, including the CNST, and major universities, has observed that these sticky effects can be increased or lessened by patterning one of the surfaces with nanoscale structures. The discovery, described in *Nature Communications*, opens a new path for tuning these effects.

But as often happens with quantum phenomena, the work raises new questions even as it answers others.

One of the insights of quantum mechanics is that no space, not even outer space, is ever truly empty. It's full of energy in the form of quantum fluctuations, including fluctuating electromagnetic fields that seemingly come from nowhere and disappear just as fast.

Some of this energy, however, just isn't able to "fit" in the sub-micrometer space between a pair of electromechanical contacts. More energy on the outside than on the inside results in a kind of "pressure" called the Casimir force, which can be powerful enough to push the contacts together and stick.



Researchers measured the Casimir attraction between a metallic grating and a gold coated sphere. They found that the attraction between the nanostructured surface and the sphere decreased much more rapidly than theory predicts when the two surfaces were moved away from each other.

Prevailing theory does a good job describing the Casimir force between featureless, flat surfaces and even between most smoothly curved surfaces. However, according to NIST researcher and co-author of the paper, Vladimir Aksyuk, existing theory fails to predict the interactions they observed in their experiment.

"In our experiment, we measured the Casimir attraction between a gold-coated sphere and planar gold surfaces patterned with rows of periodic flat-topped ridges, each less than 100 nanometers across, separated by somewhat wider gaps with deep sheer-walled sides," says Aksyuk. "We wanted to see how a nanostructured metallic surface would affect the Casimir interaction, which had never been attempted with a metal surface before. Naturally, we expected that there would be reduced attraction between our grooved surface and the sphere regardless of the distance between them because the top of the grooved surface presents less total surface area and less material. However, we knew the Casimir force's dependence on the surface shape is not that simple."

Indeed, what they found was more complicated. According to Aksyuk, when they increased the separation between the surface of the sphere and the grooved surface, the researchers found that the Casimir attraction decreased much more quickly than expected. When they moved the sphere farther away, the force fell by a factor of two below the theoretically predicted value. When they moved the sphere surface close to the ridge tops, the attraction per unit of ridge top surface area increased.

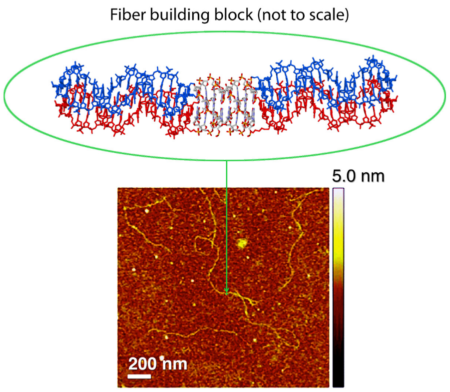
"Theory can account for the stronger attraction, but not for the too-rapid weakening of the force with increased separation," says Aksyuk. "So this is new territory, and the physics community is going to need to come up with a new model to describe it."

This work was performed in collaboration with scientists from Los Alamos National Laboratory; the University of Maryland, College Park; Argonne National Laboratory; and Indiana University – Purdue University Indianapolis.

Strong Casimir force reduction through metallic surface nanostructuring, F. Intravaia, S. Koev, I. W. Jung, A. A. Talin, P. S. Davids, R. S. Decca, V. A. Aksyuk, D. A. R. Dalvit, and D. López, *Nature Communications* **4**, (2013).

STIFFENING THE BACKBONE OF DNA NANOFIBERS

An international collaboration including researchers from the CNST and the Universidad San Francisco de Quito, Ecuador have fabricated a self-assembled nanofiber from a DNA building block that contains both duplex (two-stranded) and quadruplex (four-stranded) DNA. This work is a first step toward the creation of new structurally heterogeneous (quadruplex/duplex), yet controllable, DNA-based materials exhibiting novel properties suitable for bottom-to-top self-assembly for nanofabrication, including self-organization of both inorganic materials (nanoparticles) and molecular electronics components.



Top: Schematic showing association of two duplex precursors into a quadruplex fiber building block. The duplex regions of the building block are shown in red and blue; the quadruplex region is shown in gray. Bottom: Atomic force microscopy image of quadruplex DNA nanofibers. These fibers can be 2 µm or more in length.

The new nanofibers are constructed from duplex DNA precursors that first form quadruplex DNA in the presence of potassium ions and then connect together to form a fiber. DNA quadruplexes are unusual structures that can form from DNA sequences that are rich in the nucleotide guanine. Each strand in the duplex DNA precursor contains an internal run of eight guanines, which creates a region of guanine-guanine mismatches, plus one segment that extends past the duplex region to create a single-stranded overhang. When potassium ions are added, the duplex precursors self-assemble into quadruplex structures, and then into duplex/quadruplex fibers. These fibers were detected in bulk using electrospray mass spectrometry and gel electrophoresis. Single-molecule analysis using atomic force microscopy revealed fiber lengths ranging from 250 nm to 2000 nm. Because interaction between four strands of DNA takes place in some fiber segments, the final structures appear to be stiffer than DNA-based structures built from duplex-only subunits. This increased stiffness should lead to improved DNA patterning for nanotechnology applications. In contrast to DNA origami and DNA tile structures that are based solely on duplex DNA, the researchers believe that by varying the sequence of duplex and quadruplex subunits they ultimately will be able to create DNA building blocks that remain intact at temperatures ranging from room temperature to 100 °C.

According to CNST Project Leader Veronika Szalai, this work will allow future integration with other programmable self-assembly methods such as DNA origami, as well as with other nanomaterial components such as quantum dots, to create new multi-functional biological-based nanomaterials.

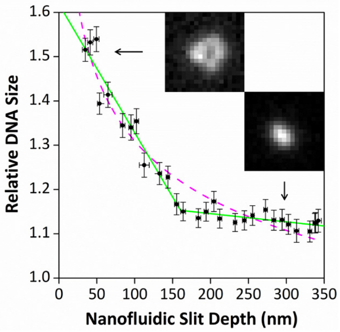
Synapsable quadruplex-mediated fibers, M. A. Mendez and V. A. Szalai, *Nanoscale Research Letters* **8**, 210 (2013).

DNA SIZE AND SHAPE UNEXPECTEDLY CONNECTED IN NANOFLUIDIC CONFINEMENT

Understanding the behavior of DNA in a fluid confined to a nanoscale space is a persistent challenge in polymer science and is increasingly important for engineering nanofluidic devices for manipulating and measuring DNA for forensic and healthcare applications. NIST researchers from the Material Measurement Laboratory, the Physical Measurement Laboratory, and the CNST have used a rigorous statistical analysis to study the size of single DNA molecules confined in nanofluidic slits between two surfaces and have discovered an unexpected result: changes in DNA size depend both on the local confinement conditions imposed externally by the slits and on the internal constraints due to the shape of the DNA backbone.

The researchers had previously used fluorescence microscopy to make quantitative measurements of DNA size during the spontaneous transport of DNA molecules down a nanofluidic staircase of connected slits. Confined to the shallowest slit at the top of the staircase, a DNA molecule diffuses across that slit. The DNA tends to step down to the next deeper slit when it reaches the edge.

The transport of the DNA to the bottom of the staircase ends as the molecule is trapped in the deepest slit. The slit depths, ranging from just a few nanometers to several hundred nanometers, are shallow enough to change the size of a DNA molecule. The researchers noticed that as the nanofluidic slits get deeper around the critical length scale at which the DNA backbone can be considered as stiff, the DNA molecules unexpectedly seem to contract either more gradually or more abruptly, depending on whether the DNA backbone is linear (open-ended) or circular (closed-loop).



The apparent size of a circular DNA molecule confined to a nanofluidic slit, relative to its unconfined size, is plotted as a function of slit depth. Around a critical length scale related to the stiffness of the DNA backbone, the size of circular DNA changes more abruptly (green solid line) than gradually (magenta dash line). Fluorescence micrographs show circular DNA molecules confined to shallower and deeper slits.

By applying a statistical analysis to their previous measurements, the researchers have confirmed their surprising observation that the size of the circular DNA changes more abruptly with slit depth than the linear DNA. However, their analysis does not preclude the possibility that a similar transition occurs for linear DNA in shallower slits. The researchers envision that their new methodology and unexpected results will motivate further research to clarify the many physical and chemical phenomena relevant to the behavior of DNA confined to nanoscale spaces. In addition, nanofluidic devices could be used to separate or otherwise manipulate mixtures of DNA molecules based on their shape, as seemingly small changes in confinement around a critical length scale would have unexpectedly large effects on DNA behavior.

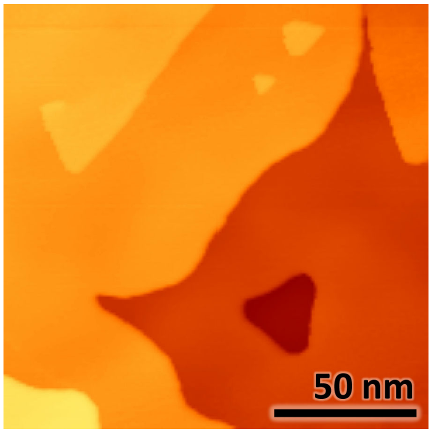
A localized transition in the size variation of circular DNA in nanofluidic slitlike confinement, E. A. Strychalski, S. M. Stavis, and J. Geist, *AIP Advances* **3**, 042115 (2013).

RESEARCHERS PROBE THE PROPERTIES OF NOVEL TOPOLOGICAL INSULATORS

Researchers from the CNST, the University of Maryland, and Seoul National University, Korea have achieved electric-field control of the energy levels at the surface of two potentially important materials, bismuth selenide (Bi_2Se_3) and antimony telluride (Sb_2Te_3). These materials are topological insulators, which are hybrid materials that are electrical insulators in their interiors but are exotic, graphene-like conductors at their surfaces.

Understanding how to use electric fields to control the energy levels at the surfaces of such topological insulators could make these materials extremely promising for a variety of electronic applications. This type of electric field control mirrors the gating used to turn on and off the field effect transistors found in countless everyday electronic devices. Achieving this control while characterizing the material's surface directly with scanning tunneling microscopy—in principle an ideal method to observe the effects of electric fields—has been particularly challenging, because the typical processing needed to create the required electrodes damages the surface to be studied. The CNST researchers and their collaborators have overcome this challenge by developing high temperature sample holders that contain both the gating electrode and a dielectric upon which topological insulator films can be grown in-situ using molecular-beam epitaxy. The specially fabricated samples holders, made in the CNST NanoFab, incorporate strontium titanate substrates with pre-patterned electrodes, allowing pristine films to be deposited *after* the electrode fabrication process.

Using the gating electrode to apply an electric field, the researchers are able to tune the doping of the top surfaces of the Bi_2Se_3 and Sb_2Te_3 topological insulator devices in order to vary their surface energy levels. In a particularly noteworthy result, the gating measurements indicate that for ultra-thin Sb_2Te_3 it may be possible to reversibly change the material from an ordinary insulator to a topological insulator and thereby switch "on and off" special properties that can exist at the thin film boundaries that may be useful in electrical device applications.



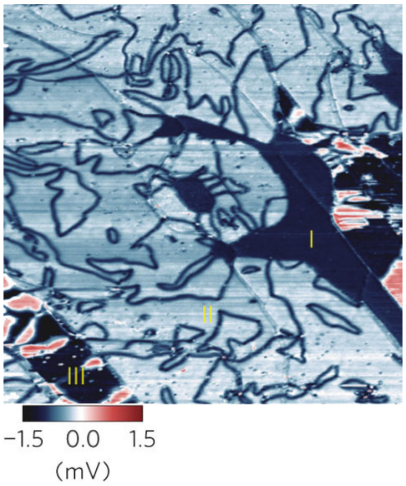
Scanning tunneling microscopy topographic image of a bismuth selenide film grown by molecular-beam epitaxy on a strontium titanate substrate. Terraces with thicknesses between 2 and 5 atomic layers can be found on the same film.

Scanning tunneling microscopy of gate tunable topological insulator Bi_2Se_3 thin films, T. Zhang, N. Levy, J. Ha, Y. Kuk, and J. A. Stroscio, *Physical Review B* **87**, 115410 (2013).
Electric field tuning of the surface band structure of topological insulator Sb_2Te_3 thin films, T. Zhang, J. Ha, N. Levy, Y. Kuk, and J. Stroscio, *Physical Review Letters* **111**, 056803 (2013).

U.S. AND KOREA COLLABORATE ON GRAPHENE RESEARCH

Researchers from the CNST and the Republic of Korea's national metrology institute—the Korea Research Institute of Standards and Science (KRISS)—have recently developed a unique nanoscale measurement technique and used it to observe structural disorder in graphene that is fabricated on a silicon carbide substrate. Graphene, a material made of carbon in a one atom-thick sheet, has promising applications in areas ranging from flexible displays to high speed transistors; but such applications will require new methods for large area fabrication and for detecting underlying fabrication-related structural defects.

The team's approach relies on local thermopower measurements that use heat transfer from a scanning probe tip to the sample surface, thereby allowing extremely sensitive imaging of nanometer scale disorder in graphene layers. The technique enables the direct observation of nanoscale structural changes in a material by measuring changes in the heat transfer associated with modifications in a material's local electronic properties. Through such local thermopower measurements, the team discovered a boundary between two regions of the graphene layer that have different crystal orientations. The creation of these different regions results from two stacked graphene layers being rotated or translated with respect to each other.



Thermopower image of epitaxial graphene. The three distinct indexed regions correspond to (I) monolayer graphene, (II) bilayer graphene, and (III) trilayer graphene.

The researchers believe these initial measurements demonstrate a new scanning probe measurement technique that will have significant applications in developing technologies based on graphene and other emerging electrical materials.

The team includes researchers from the CNST, the KRISS, the Korea Advanced Institute of Science and Technology (KAIST), the Korea Research Institute of Chemical Technology, Pohang University of Science and Technology, and Seoul National University.

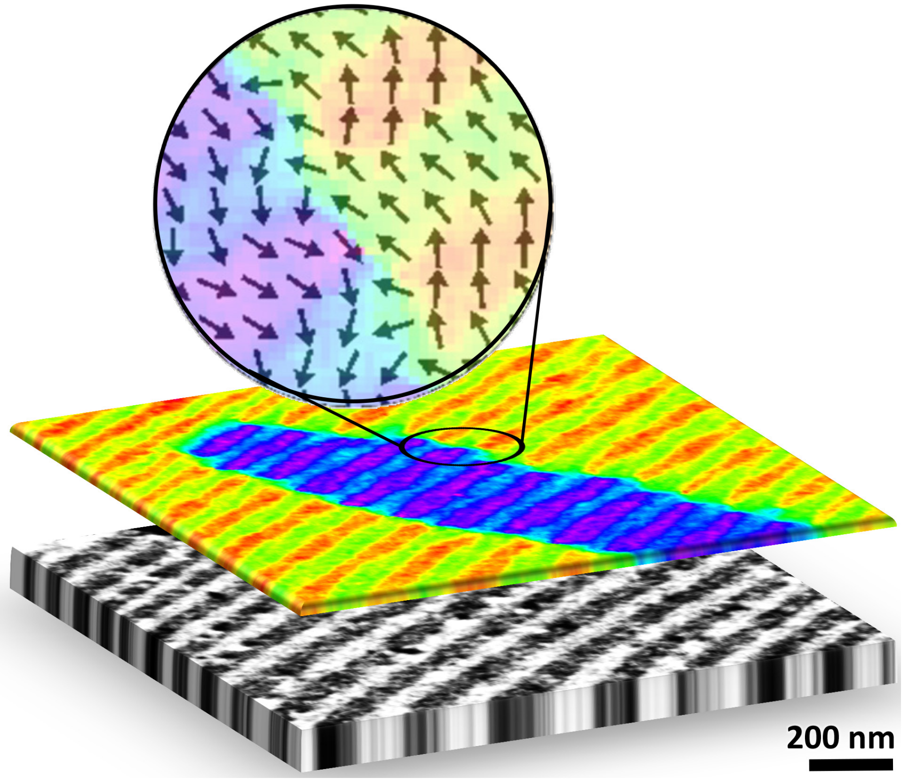
Thermoelectric imaging of structural disorder in epitaxial graphene, S. Cho, S. D. Kang, W. Kim, E.-S. Lee, S.-J. Woo, K.-J. Kong, I. Kim, H.-D. Kim, T. Zhang, J. A. Stroscio, Y.-H. Kim, and H.-K. Lyeo, *Nature Materials* **12**, 913–918 (2013)

A STEP TOWARDS ENERGY-EFFICIENT VOLTAGE CONTROL OF MAGNETIC DEVICES

Researchers from the CNST and the University of California, Berkeley have discovered a way to create simultaneous images of both the magnetic and the electric domain structures in ferromagnetic/ferroelectric multilayer materials. In a ferroelectric material, the polarization, or direction, of the internal electric field can be controlled by applying a voltage across the film; in a ferromagnetic material, current-induced magnetic fields are usually used to control the magnetization direction. By combining these two types of materials, it is possible to create low-power magnetic devices, including memory that can be controlled by electric fields (applied voltage) instead of less energy-efficient magnetic fields (applied current). Measuring how the magnetization in a ferromagnet realigns in response to changes in the electric polarization of an adjacent ferroelectric is an important step towards making such low-power devices possible.

The researchers used scanning electron microscopy with polarization analysis (SEMPA) to directly image the magnetization direction in thin ferromagnetic films made of cobalt-iron that were grown on thicker ferroelectric substrates made of bismuth ferrite. While taking the SEMPA measurements, which use low-energy secondary electrons to visualize the magnetization in the thin cobalt-iron film, they also imaged the ferroelectric domains using a separate detector to measure higher-energy backscattered electrons from the buried bismuth ferrite. Because these electrons are much higher in energy, they can exit from deeper in the sample, allowing the ferroelectric to be imaged beneath the ferromagnetic film.

The SEMPA and backscattered electron images provided new information about the coupling between the two layers that occurs at their interface. Although bismuth ferrite is primarily ferroelectric, it also has antiferromagnetic properties (it has no net magnetization). However, when a ferromagnetic film is deposited on top of a bismuth ferrite film, the bismuth ferrite becomes slightly ferromagnetic and its induced magnetization changes along with the adjacent cobalt-iron's magnetization. It has been theorized that when the ferroelectric polarization in the bismuth ferrite is switched by an electric field, the small ferromagnetic component also switches and in turn changes the direction of the cobalt-iron magnetization. The SEMPA and backscattered electron images showed that the local, nanoscale direction of the magnetization of the cobalt-iron film nearly aligns with both the interfacial direction of the ferroelectric polarization and with the induced ferromagnetism of the bismuth ferrite. By modeling the deviation from perfect alignment, the researchers were able to infer the strength of the interaction at the interface between the two materials.



Scanning electron microscope images of a cobalt film grown on a bismuth ferrite substrate. The color SEMPA image shows the direction of the magnetization in the ferromagnet, and the black and white backscattered electron image shows the domain structure of the underlying ferroelectric. The two images were acquired simultaneously, allowing quantitative measurements of the ferromagnetic/ferroelectric correlations.

Because these initial experiments have been promising, the researchers plan to add electrical contacts to small patterned cobalt-iron elements and to use SEMPA to conclusively observe whether their magnetization can be changed electrically.

Interfacial coupling in multiferroic/ferromagnet heterostructures, M. Trassin, J. D. Clarkson, S. R. Bowden, J. Liu, J. T. Heron, R. J. Paull, E. Arenholz, D. T. Pierce, and J. Unguris, *Physical Review B* **87**, 134426 (2013).

NEW NANOSCALE IMAGING METHOD FINDS APPLICATION IN PLASMONICS

Researchers from the CNST and the University of Maryland have shown how to make nanoscale measurements of critical properties of plasmonic nanomaterials—specially engineered nano-structures that modify the interaction of light and matter for a variety of applications, including sensors, cloaking (invisibility), photovoltaics, and therapeutics.

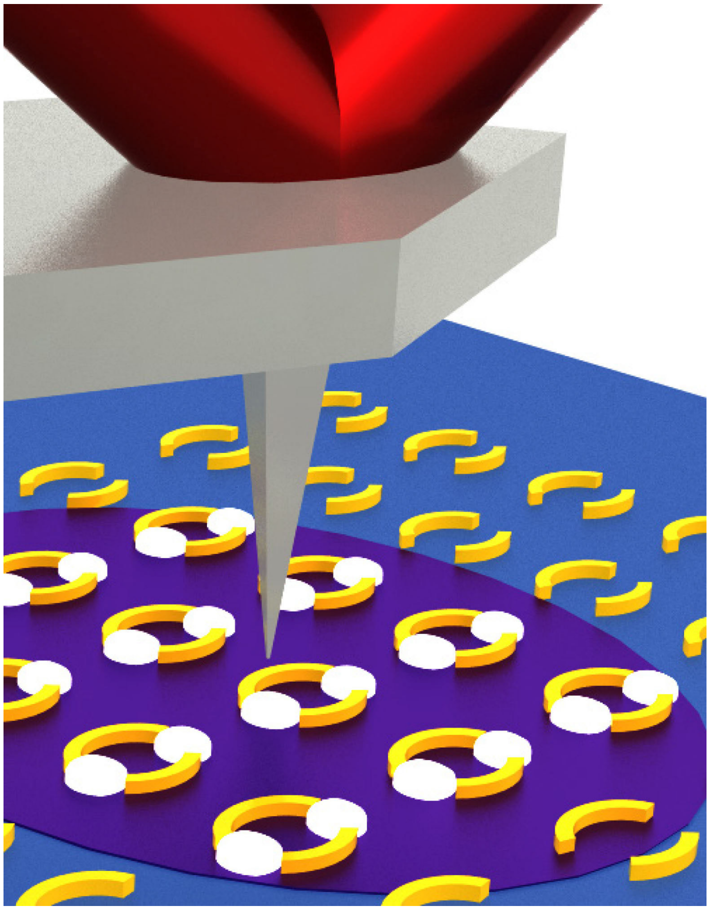
Their technique is one of the few that allows researchers to make actual physical measurements of these materials at the nanoscale without affecting the nanomaterial's function.

Plasmonic nanomaterials are made of specially engineered nanoscale structures that can enhance the interaction between light and matter. The shape and size of these nanostructures can be adjusted to tune these interactions. Theoretical calculations are frequently used to understand and predict the optical properties of plasmonic nanomaterials, but few experimental techniques are available to study them in detail. Researchers need to be able to measure the optical properties of individual structures and how each interacts with the surrounding material directly in a way that doesn't affect how the structure functions.

"We want to maximize the sensitivity of these resonator arrays and study their properties," says lead researcher Andrea Centrone. "In order to do that, we needed an experimental technique that we could use to verify theory and to understand the influence of nanofabrication defects that are typically found in real samples. Our technique has the advantage of being extremely sensitive spatially and chemically, and the results are straightforward to interpret."

The research team turned to photothermal induced resonance (PTIR), an emerging chemically-specific materials analysis technique, and showed it can be used to image the response of plasmonic nanomaterials excited by infrared (IR) light with nanometer-scale resolution.

The team used PTIR to image the absorbed energy in ring-shaped plasmonic resonators. The nanoscale resonators focus the incoming IR light within the rings' gaps to create "hot spots" where the light absorption is enhanced, which makes for more sensitive chemical identification. For the first time, the researchers precisely quantified the absorption in the hot spots with nanoscale resolution and showed that for the samples under investigation, it is approximately 30 times greater than areas away from the resonators.



Infrared laser light (purple) from below a sample (blue) excites ring shaped nanoscale plasmonic resonator structures (gold). Hot spots (white) form in the rings' gaps. In these hot spots, infrared absorption is enhanced, allowing for more sensitive chemical recognition. A scanning AFM tip detects the expansion of the underlying material in response to absorption of infrared light.

The researchers also showed that plasmonic materials can be used to increase the sensitivity of IR and PTIR spectroscopy for chemical analysis by enhancing the local light intensity, and thereby, the spectroscopic signal.

Their work further demonstrated the versatility of PTIR as a measurement tool that allows simultaneous measurement of a nanomaterial's shape, size, and chemical composition—the three characteristics that determine a nanomaterial's properties. Unlike many other methods for probing materials at the nanoscale, PTIR doesn't interfere with the material under investigation; it doesn't require the researcher to have prior knowledge about the material's optical properties or geometry; and it returns data that is more easily interpretable than other techniques that require separating the response of the sample from the response of the probe.

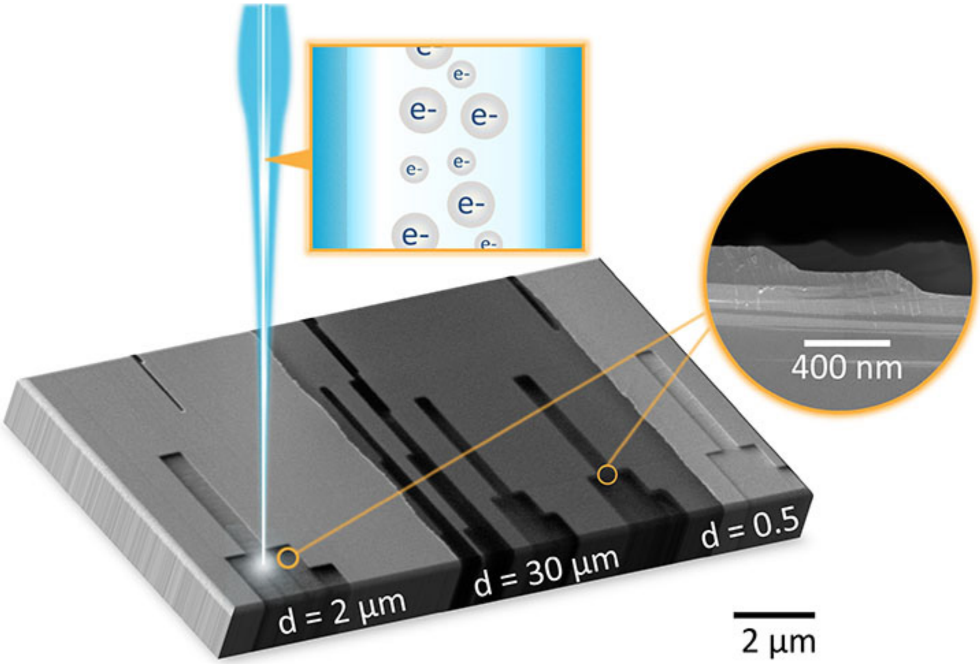
Nanoscale imaging of plasmonic hot spots and dark modes with the photothermal-induced resonance technique, B. Lahiri, G. Holland, V. Aksyuk, and A. Centrone, *Nano Letters* **13**, 3218–3224 (2013).

NEW GRAYSCALE TECHNIQUE OPENS A THIRD DIMENSION FOR NANOSCALE LITHOGRAPHY

Engineers from the CNST have developed a new technique for fabricating high aspect ratio three-dimensional (3D) nanostructures over large device areas using a combination of electron beam (e-beam) lithography, photolithography, and resist spray coating. While it has long been possible to make complicated 3D structures with many mask layers or expensive grayscale masks, the new technique enables researchers to etch trenches and other high aspect ratio structures with nanometer scale features without using masks and in only two process stages.

The fabrication of 3D semiconductor and dielectric structures that are patterned by exposing resist with varying intensity grayscale gradients has been essential to a broad range of applications such as digital lenses, micro-electromechanical systems, and fluidic medical devices.

Unlike devices that rely on conventional masks, which have areas that simply transmit or block light to form a pattern, the fabrication of these devices has typically relied on 3D grayscale masks which have varying levels of transparency and depend on the use of proprietary materials. Because the chemistry is proprietary and because the masks are prepared using complicated processes best suited to small surface areas, they are often prohibitively expensive. The next generation of these devices requires lower costs, larger surface areas, and ever-smaller feature sizes.



Scanning electron micrograph (SEM) showing a top-view along with an SEM (inset) showing a cross-sectional view of grayscale structures fabricated using a combination of e-beam lithography, photolithography, and resist spray coating. The superimposed schematic illustrates e-beam direct writing of nanoscale vertical staircases (SEM inset) on a substrate with microscale grayscale topography. The initial grayscale patterns were generated on a laserwriter. After reactive ion beam etching, the patterns were simultaneously written into 2 µm, 0.5 µm, and 30 µm deep features.

The researchers' new approach capitalizes on the high throughput capability of photolithography to generate large area grayscale structures with large processing flexibility and the ability of e-beam lithography to add grayscale features smaller than 200 nm. The first phase of this mix-and-match approach is to pattern a layer of photoresist by exposing it with a focused laser beam. By locally modulating the intensity of the light to form a grayscale gradient, varying levels of photoreaction in the photoresist are generated. After the sample is immersed in the developer solution, material is dissolved in areas corresponding to the degree of induced photoreaction, leaving the photoresist layer with varying thicknesses matching the initial exposure pattern.

The sample is exposed to a deep reactive ion etch (DRIE) which removes substrate material at varying depths that depend on the thickness of the photoresist, transferring the 3D photoresist pattern vertically into the substrate to form deep grayscale micro-structures. The second phase applies similar processing steps but with feature sizes ten times smaller. First, a high pressure e-beam resist spray coating is applied to obtain conformal coverage of the high-aspect ratio topography produced in the first phase. Then, by manipulating a high-energy e-beam with nanometer-scale resolution, patterned grayscale step heights are directly written in the e-beam resist in different locations. Finally, the resist is developed and the sample is exposed to DRIE as it was in the first step.

The two stage process results in a vertical feature sizes of 45 ± 6 nm within a substrate structure that varies from 2 µm to 30 µm deep and with horizontal feature sizes of 100 nm to 200 nm and an overall pattern size potentially as large as a whole wafer.

CNST NanoFab Process Engineer Liya Yu anticipates that the ability to fabricate high aspect-ratio grayscale nanostructures will expand the practical applications of grayscale lithography and dramatically widen the range of device structures available to device designers.

The evaluation of photo/e-beam complementary grayscale lithography for high topography 3D structure, L. Yu, R. J. Kasica, R. N. Newby, L. Chen, and V. K. Luciani, *Proceedings of SPIE* **8682**, 868212 (2013).

NANOFAB ADDS NEW HIGH RESOLUTION X-RAY DIFFRACTION SYSTEM

The NanoFab has added a new Rigaku SMARTLAB X-Ray Diffractometer (XRD), which is designed for completely automated analysis of thin films, nanomaterials, and powders. This state of the art XRD can be used to determine the crystal structure and identify the phases of thin films and bulk materials. It is easy to use and is fully equipped with modules for performing a variety of advanced X-ray diffraction measurements such as X-ray reflectivity, grazing incidence diffraction, out-of-plane and in-plane diffraction, and small angle X-ray scattering (SAXS).

The system allows users to perform the following measurements: X-ray reflectivity measurements to determine film thickness and roughness with nanometer precision; X-ray powder diffraction to identify the phase of powders and thick films; pole figures for texture or orientation analysis; reciprocal space maps for information on epitaxial thin films; and rocking curves to study dislocation density, misalignment of crystal planes, and inhomogeneity of thin films. The X-ray system is also equipped with a small angle X-ray scattering attachment for the determination of pore sizes or particle sizes of samples.

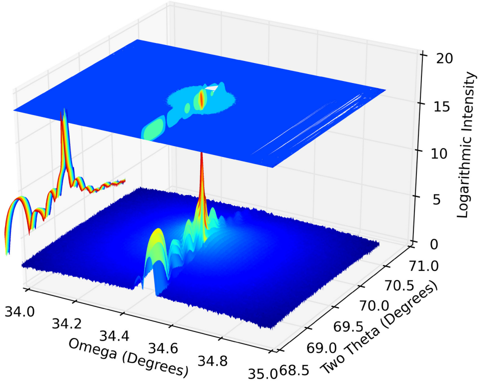
This XRD system is extremely versatile, allowing samples to be measured under a range of controlled environments, including fixed room temperature or while they are heated up to 1100 °C in vacuum, in air, or in inert gasses.

The NanoFab's new Rigaku SMARTLAB X-Ray Diffractometer (shown above with NanoFab Process Engineer Kerry Siebein) is designed for completely automated crystal structure and phase analysis of thin films, nanomaterials, and powders.

The system includes a high intensity 9 kW rotating anode X-ray generator that allows for extremely fast measurements. According to NanoFab Process Engineer Kerry Siebein, "X-ray reflectivity measurements that would take hours on other systems can now be completed in fifteen to twenty minutes, and reciprocal space maps that would take days can now be completed in a few hours."

The XRD has a user-friendly computer controlled alignment system and a fully automated optical system. It is now available to users and can be reserved through the NEMO system.

For more information, contact Kerry Siebein, 301-975-8458, kerry.siebein@nist.gov.



Reciprocal space map of NIST standard reference material 2000, a 50 nm-thick silicon-germanium epitaxial layer deposited on a silicon substrate, courtesy of Donald Windover, Material Measurement Laboratory. The intense peak is caused by diffraction from the substrate wafer and the oscillation pattern is used to determine epitaxial film thickness. The orientation and peak shapes of the oscillations provide information about epitaxial film quality, wafer cut alignment, and dislocation densities. The NanoFab XRD took 6.7 hours to generate this intensity map, a factor of 10 to 20 less time than using a conventional sealed-tube system.

CNST DEVELOPS AND DEPLOYS NEW NANOFAB MANAGEMENT SYSTEM

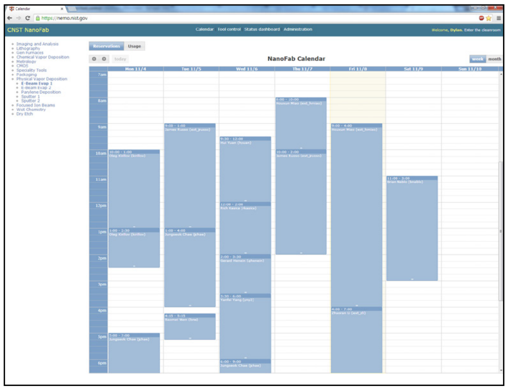
The CNST has deployed a new laboratory equipment management system which it developed from the ground up. The web-based program, known as the *NanoFab Equipment Management & Operations (NEMO)* system, allows onsite NanoFab users to make tool reservations, controls access to tools in the NanoFab, and streamlines logistics and communication.

NEMO provides onsite users an experience that is simple, intuitive, and quick. Its click-and-drag web interface gives users the ability to easily create and modify tool reservations. To ensure that tools are ready when users arrive, the program automatically sends configuration information to the appropriate NanoFab staff members for tools that need to be configured prior to use. Users can easily view who is in the NanoFab and which tools are available.

The program is a major update to the Center's NanoFab computing infrastructure, and replaces the OpenCoral laboratory management program.

The CNST plans to continuously improve NEMO in order to provide additional features and services to NanoFab users. According to CNST IT specialist Dylan Klomparens, who created the system, in addition to equipment reservations, NanoFab users will soon have the ability to reserve and use CAD software licensed by the CNST at cost-effective hourly rates.

To provide us with feedback about NEMO or learn more about it, please contact the NanoFab User Office, nanofabuseroffice@nist.gov.



NEMO's tool reservation calendar allows onsite NanoFab users to make and change reservations with a simple click-and-drag.

STEVE BLANKENSHIP WINS AVS GEORGE T. HANYO AWARD FOR OUTSTANDING PERFORMANCE IN TECHNICAL SUPPORT OF RESEARCH

Steve Blankenship, an Instrumentation Specialist in the CNST, has been awarded the 2013 George T. Hanyo Award by the AVS "for outstanding contributions to the scanning tunneling microscopy user facilities and other laboratories at the Center for Nanoscale Science and Technology at the National Institute of Standards and Technology."

The award, established in 1996 by the Kurt J. Lesker Company in the memory of George T. Hanyo, a highly skilled, long-time employee of the company, recognizes outstanding performance in technical support of research or development in areas of interest to the AVS. The award is intended for a technical support staff member who is typically mentioned in the "Acknowledgements" sections of published papers but, with the possible exception of papers describing new apparatus or procedures, is rarely an author or co-author.

Steve was presented with the award on October 30, 2013 at the AVS 60th International Symposium and Exhibition in Long Beach, California.

Steve Blankenship holds the Hanyo award certificate at the 2013 AVS International Symposium and Exhibition. Left to right: John Russell, Jr. (Naval Research Laboratory, AVS Trustee), Blankenship, Susan Sinnott (University of Florida, AVS President).

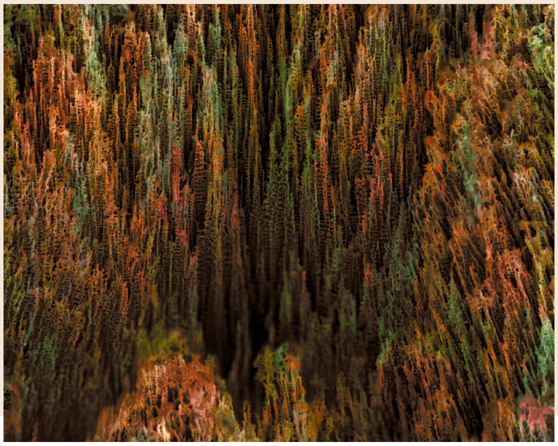
NANOFAB SCHEDULE FOR THE WINTER HOLIDAY PERIOD

DAY	DATE	EVENT	STAFF SUPPORT
Wednesday	November 27	Day before Thanksgiving	7 am to 10 pm
Thursday	November 28	Thanksgiving	None
Friday	November 29	Day after Thanksgiving	7 am to 10 pm
Tuesday	December 24	Christmas Eve	7 am to 3 pm
Wednesday	December 25	Christmas Day	None
Tuesday	December 31	New Year's Eve	7 am to 3 pm
Wednesday	January 1	New Year's Day	None

When the NanoFab is closed, after-hours access using the buddy system is available with advance approval.

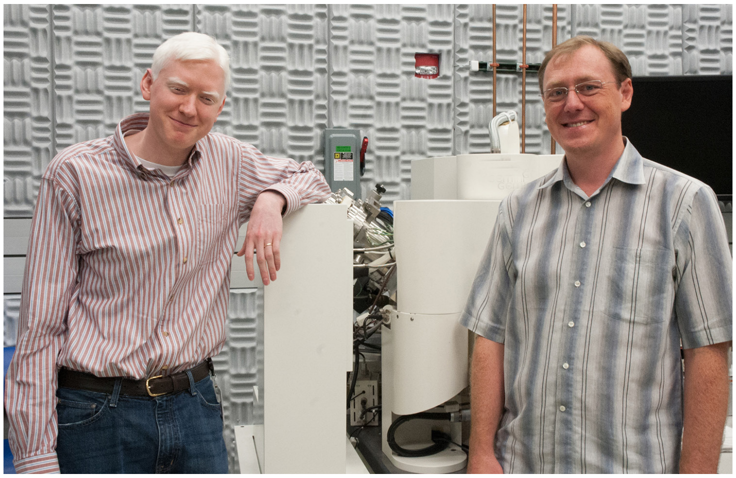
FALL IN THE NANOFAB

Composite multi-focal scanning electron micrograph of DRIE-etched silicon taken using the NanoFab's Helios 650 Dual Beam SEM/FIB by CNST Process Engineer Joshua Schumacher. With false color added, the image, titled "Happy Little Si-Etched Trees" as an homage to artist Bob Ross, captures the colors of fall at the CNST and won third place in the 8th Annual FIB/DB User Club Meeting image competition held at the FEI NanoPort in Hillsboro, Oregon in October, 2012.



RESEARCHERS INTRODUCE BLIND STUDENTS TO NANOSCALE SCIENCE

In July 2013, 45 blind and visually impaired high school students from around the country gathered at Towson University for a weeklong event designed to expose them to science careers long believed to be impossible for the blind. Twenty of those students participated in an exciting educational program on nanoscale science led by CNST Project Leader Vladimir Aksyuk, who has participated in this event for the last three years, and CNST/University of Maryland Postdoctoral Researcher Kevin Twedt, who is visually impaired.


Physicists Kevin Twedt (left), who is visually impaired, and Vladimir Aksyuk (right) led a two day educational program to introduce a group of blind and visually impaired high school students to nanotechnology.

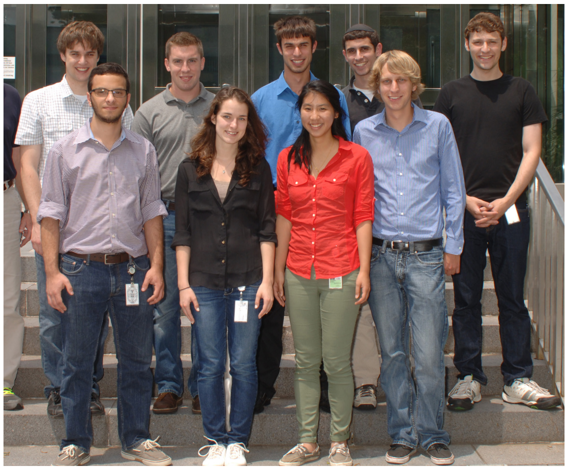
During six hours of hands-on activities spread over two days, the students learned the basics of size and scale, the metric system, and received an introduction to the nanoscale. They then learned the techniques scientists use to create and measure nanoscale structures. By probing canes against floor models of different shapes and sizes, they were exposed to how an atomic force microscope probe senses topographic changes on a surface. Using plastic models, they explored the structural relationships between carbon atoms forming either planar graphene or three-dimensional carbon nanotubes. Finally, by scanning a laser pointer across black shapes on white paper and using a photodiode with an audio output that got louder in white regions and quieter in dark regions, the students learned how a scanning electron microscope creates images by scanning a beam of electrons across a surface.

"Most of these students had never really considered careers in science or knew that they are possible for blind people," says Twedt, who has had 20/200 vision since birth. "In a few days, the students gained an appreciation for the work scientists do and perhaps some will consider going into science later on."

The science, technology, engineering, and math (STEM) program, known as the STEM-X program was sponsored by National Federation of the Blind, under the auspices of its National Center for Blind Youth in Science.

SUMMER STUDENTS WORK WITH LEADING RESEARCHERS AT THE CNST

The CNST welcomed its 2013 class of summer student researchers. Nine Summer Undergraduate Research Fellowship (SURF) students, one returning CNST/UMD Undergraduate Researcher, and six High School students learned about the latest nanotechnology fabrication and measurement techniques. They participated in a wide variety of research projects ranging from developing a data acquisition system for high-spatial resolution spectroscopy in photovoltaic devices to simulating carbon nanotube growth under different synthesis conditions. The SURF program is sponsored by NIST and the National Science Foundation.


The CNST SURF students were among 187 at NIST attending seminars, going on lab tours, and presenting their work at an end-of-summer colloquium. Left to right, top row: Blankenau, Briggs, Trettenero, Mehlman, and Bern. Bottom row: Khalil, Tolstaya, Sytwu, and Straley.

Summer Undergraduate Researchers

Noah (Adam) Bern, Cornell University
Philip Trettenero, University of Illinois at Urbana-Champaign
Michael Briggs, SUNY, University at Albany
Osama Khalil, Arizona State University
Jonathan (Yoni) Mehlman, Yeshiva University
Timothy Straley, Colorado School of Mines

Summer Undergraduate Researchers

Katherine Sytwu, Rutgers, The State University of New Jersey
Ekaterina (Kate) Tolstaya, University of Maryland
Brian Blankenau, Kansas State University

CNST/UMD Undergraduate Researcher

Cory Latham, Virginia Polytechnic Institute and State University

High School Researchers

Trevin Gandhi, Loudoun County Academy of Science, MD
Andrew T. Wang, Winston Churchill High School, MD
Elizabeth McMichael, Poolesville High School, MD
Lisa Shimomoto, Poolesville High School, MD
Andrew Z. Wang, Poolesville High School, MD
Ryan Wong, Poolesville High School, MD

CNST Center for Nanoscale Science & Technology

CENTER FOR NANOSCALE SCIENCE AND TECHNOLOGY

The CNST is a national user facility purposely designed to accelerate innovation in nanotechnology-based commerce. Its mission is to operate a national, shared resource for nanoscale fabrication and measurement and develop innovative nanoscale measurement and fabrication capabilities to support researchers from industry, academia, NIST, and other government agencies in advancing nanoscale technology from discovery to production. The Center, located in the Advanced Measurement Laboratory Complex on NIST's Gaithersburg, MD campus, disseminates new nanoscale measurement methods by incorporating them into facility operations, collaborating and partnering with others, and providing international leadership in nanotechnology.

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SUPPORTING THE DEVELOPMENT OF NANOTECHNOLOGY FROM DISCOVERY TO PRODUCTION

Center for Nanoscale Science and Technology
National Institute of Standards and Technology
100 Bureau Drive, MS 6200
Gaithersburg, MD 20899-6200
Phone: 301-975-8001
E-mail: cnst@nist.gov

CNST RELEASES NEW BROCHURE

In August, the CNST released a new *CNST Brochure*. In addition to providing an overview of the CNST, it features separate sections highlighting the resources available in the NanoFab and the NanoLab.

The brochure provides a detailed list of the commercial tools and processes available in the NanoFab at economic hourly rates, along with descriptions of the key capabilities available in each process area. It also describes the next generation of tools and processes under development in the NanoLab, which are available through collaboration with our multidisciplinary research staff.

The brochure can be downloaded at www.nist.gov/cnst/upload/CNST_brochure.pdf. To receive a hard copy, please email cnst@nist.gov with your request and mailing address.

VISIT THE CNST BOOTH AT THE

2013 MRS FALL MEETING & EXHIBIT

2013 MATERIALS RESEARCH SOCIETY FALL MEETING

HYNES CONVENTION CENTER

BOSTON, MASSACHUSETTS

DECEMBER 1 – 6, 2013

CNST LAUNCHES UPDATED NANOFAB WEBSITE

The CNST has released a major update to the NanoFab website. The updated website includes significant new content describing how to apply for and work in the NanoFab, status information and news, a FAQ, and a complete redesign of the site's navigation.

Along with the new site, the NanoFab is introducing a new NanoFab Project Application. The simple application process is designed to get researchers into the NanoFab in a few weeks. The single application, to be used by all applicants (from both inside and outside NIST), includes a simplified format designed to efficiently collect only the information required for the CNST to identify the project's participants and evaluate the project's technical feasibility and merit. In addition to guidance provided on how to complete the application, a selection of fictional examples are available that illustrate the nature and scope of the information required.

Over the coming months, the CNST will continue to improve the website, updating and enhancing the information provided about the tools and processes available in the NanoFab.

To provide us with feedback about the website, or to learn more about the NanoFab, please contact the NanoFab User Office, nanofabuseroffice@nist.gov.