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

The Electromagnetic Spectrum

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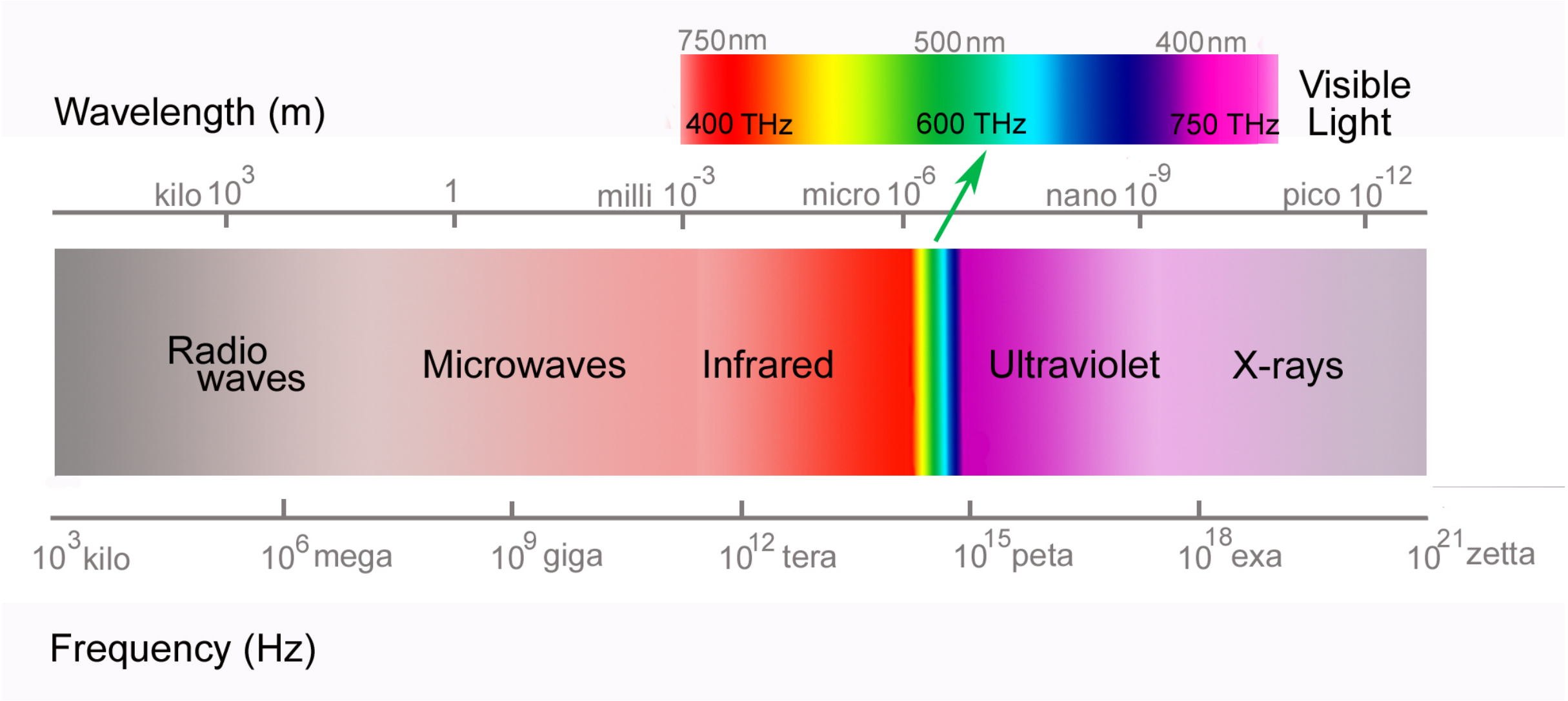
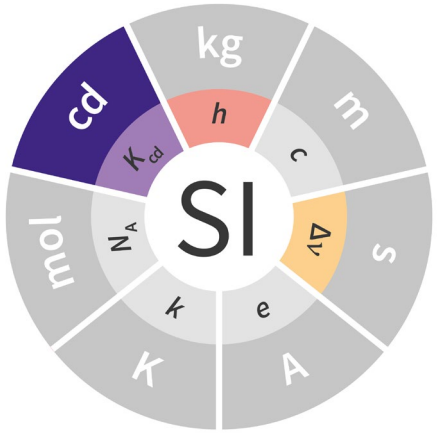


Measurement Scale – SI Units

Credit: ©BIPM

May 20, 2019 – Redefinition of the SI Units

Hyperfine structure transition frequency cesium-133	$\Delta\nu_{Cs} = 9192631770\ s^{-1}$
Speed of light	$c = 299792458\ m \cdot s^{-1}$
Planck constant	$h = 6.62607015 \times 10^{-34}\ kg \cdot m^2 \cdot s^{-1}$
Elementary charge	$e = 1.602176634 \times 10^{-19}\ A \cdot s$
Boltzmann constant	$k = 1.380649 \times 10^{-23}\ kg \cdot m^2 \cdot K^{-1} \cdot s^{-2}$
Avogadro constant	$N_A = 6.02214076 \times 10^{23}\ mol^{-1}$
Luminous efficacy of monochromatic radiation (540 THz)	$K_{cd} = 683\ cd \cdot sr \cdot s^3 \cdot kg^{-1} \cdot m^{-2}$



Credit: ©BIPM

The candela, symbol cd, is the SI unit of luminous intensity in a given direction. It is defined by taking the fixed numerical value of the luminous efficacy of monochromatic radiation of frequency 540 x 10^{12} Hz, K_{cd}, to be 683 when expressed in the unit $lm \cdot W^{-1}$, which is equal to $cd \cdot sr \cdot W^{-1}$, or $cd \cdot sr \cdot kg^{-1} \cdot m^{-2} \cdot s^3$, where the kilogram, meter and second are defined in terms of h, c and $\Delta\nu_{Cs}$.

Credit: Hans Michel/Courtesy BIPM

Primary Source - Blackbody

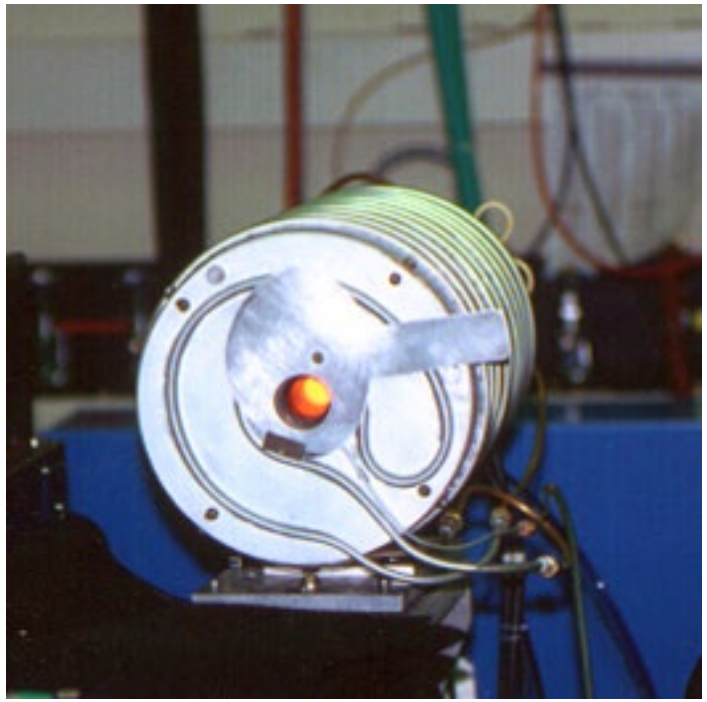
Plank's Law

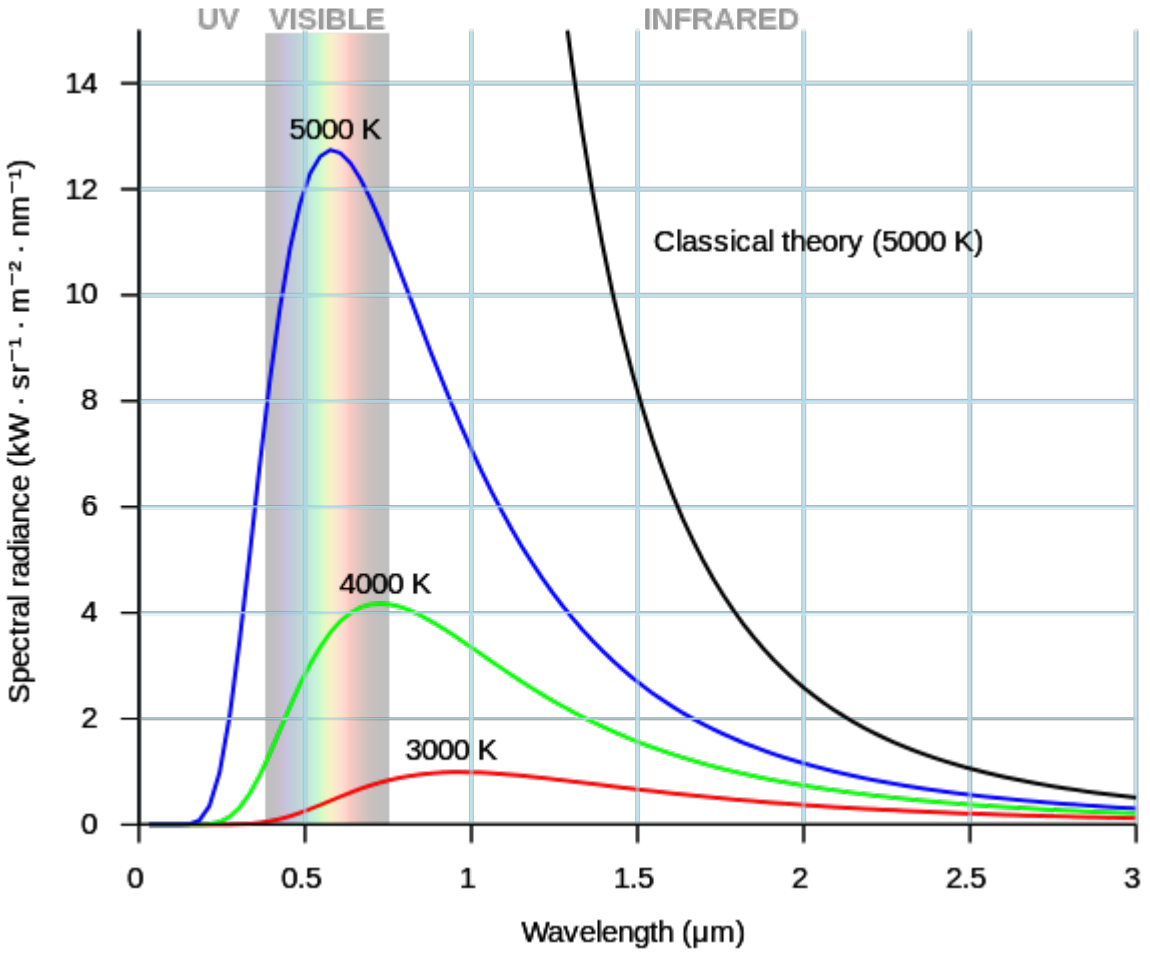
$$L_{\mathrm{b}}(\lambda) = \frac{2hc^2}{n^2\lambda^5}\frac{1}{\exp\left(hc/(n\lambda k_B T)\right) - 1}$$

h = Plank's constant
c = speed of light
$n(\lambda)$ = index of refraction of medium
k_B = Boltzmann's constant
λ = wavelength of light
T = temperature

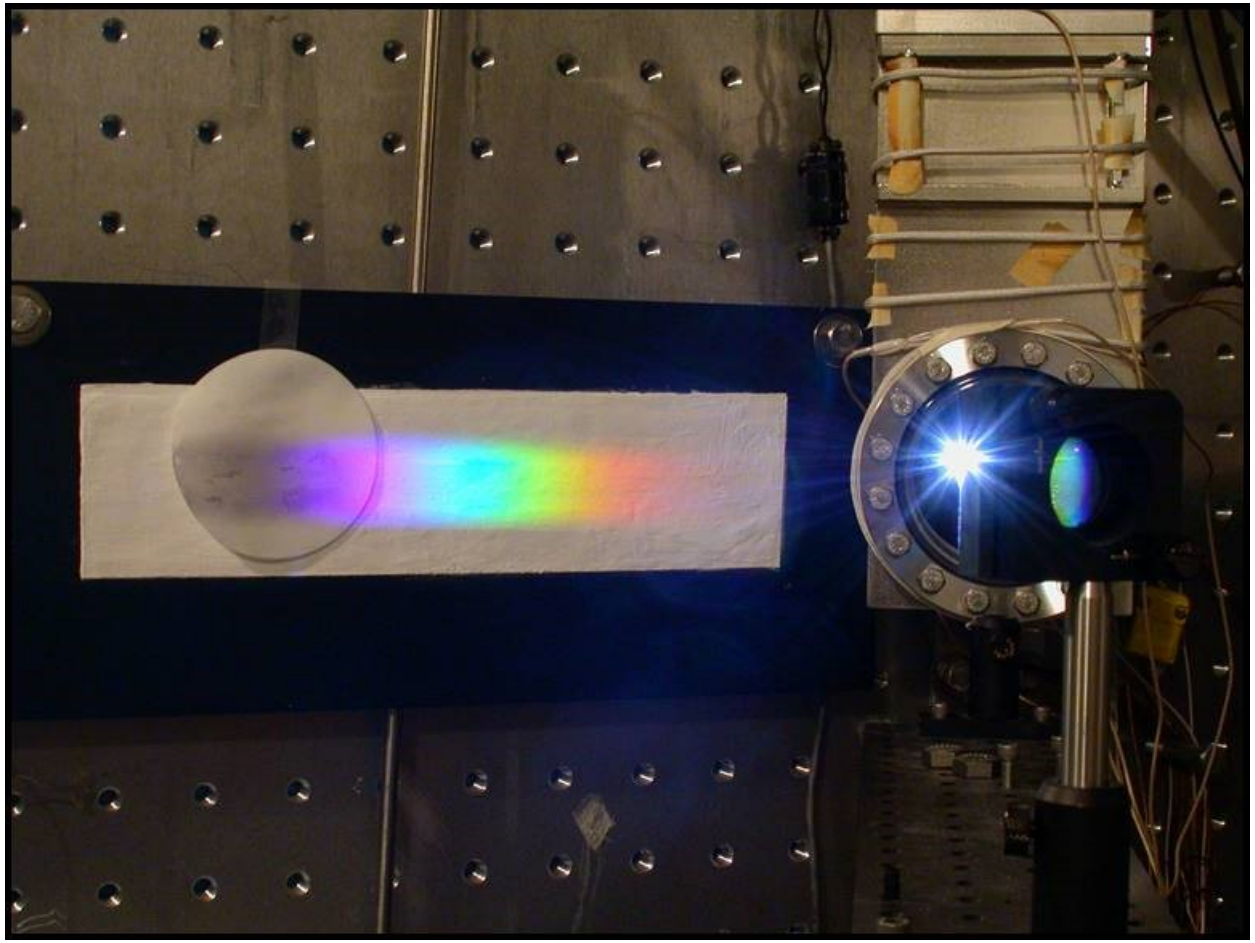
Gold-point Blackbody

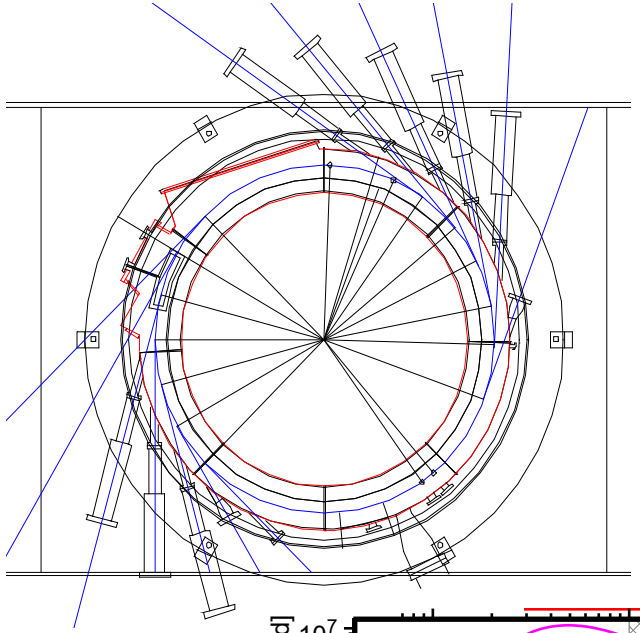
1337.33 K

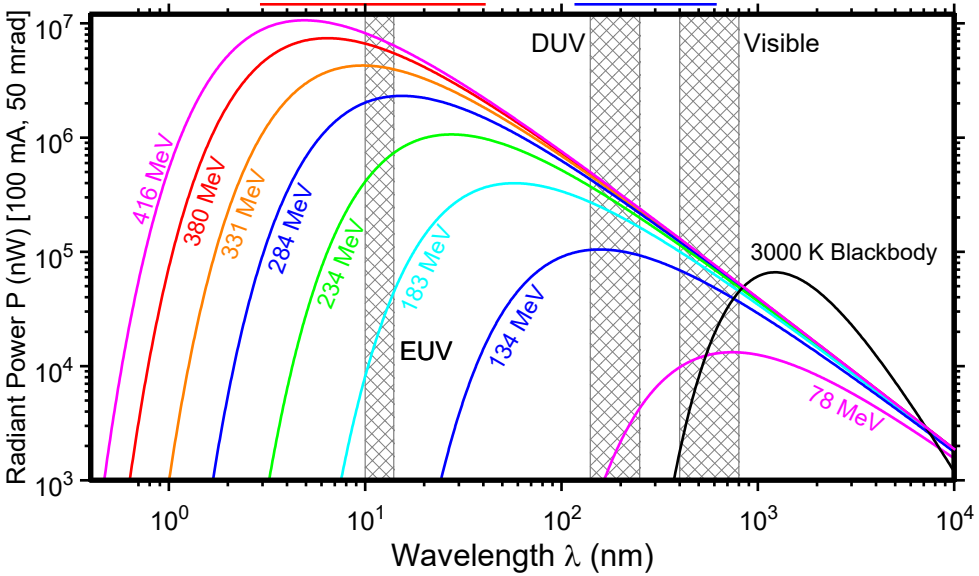




Primary Source - Synchrotron





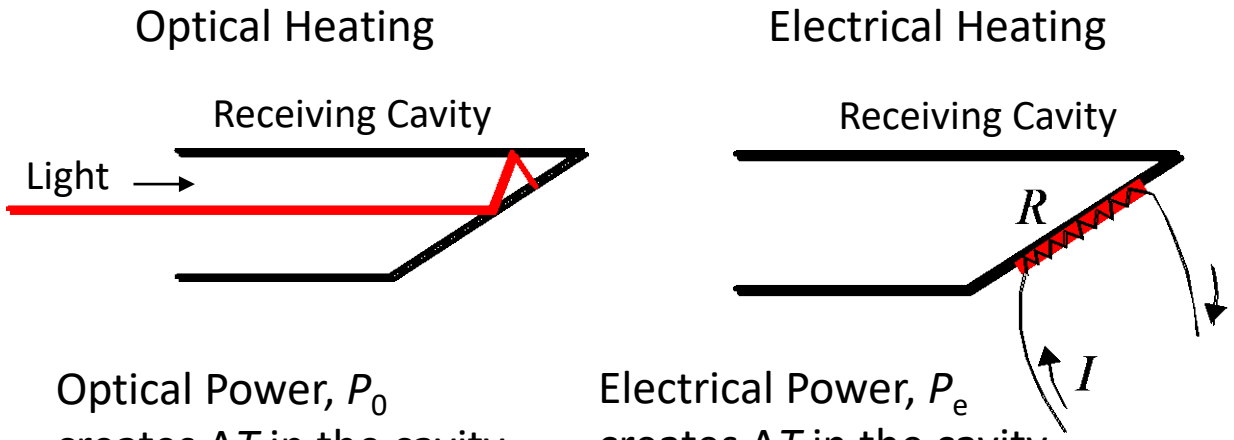


Source spectral radiance calculated - Schwinger equation

Depends on Plank's & Boltzmann constants and speed of light

Primary Detector – Cryogenic Radiometer

Electrical Substitution Radiometer

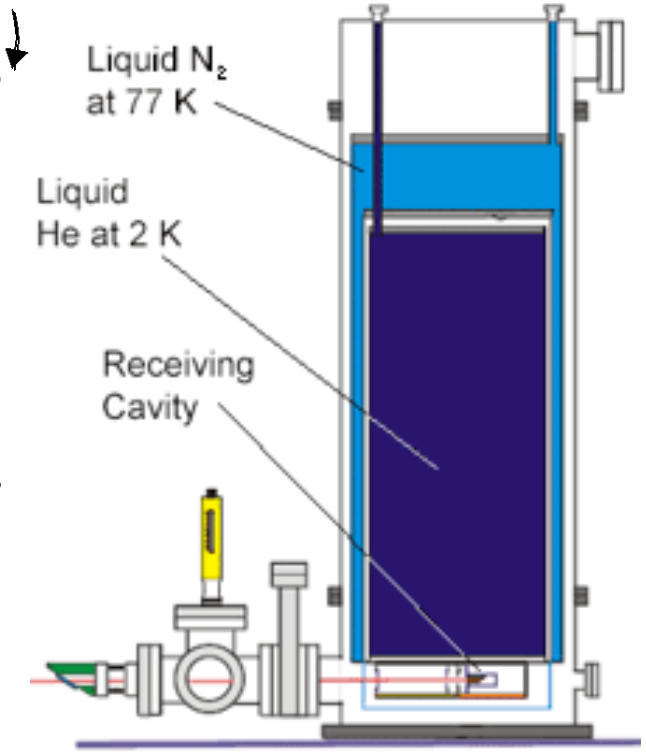


Optical Power, P_0 creates ΔT in the cavity

Electrical Power, P_e creates ΔT in the cavity

The same ΔT. Thus, $P_0 = P_e = I^2 R$

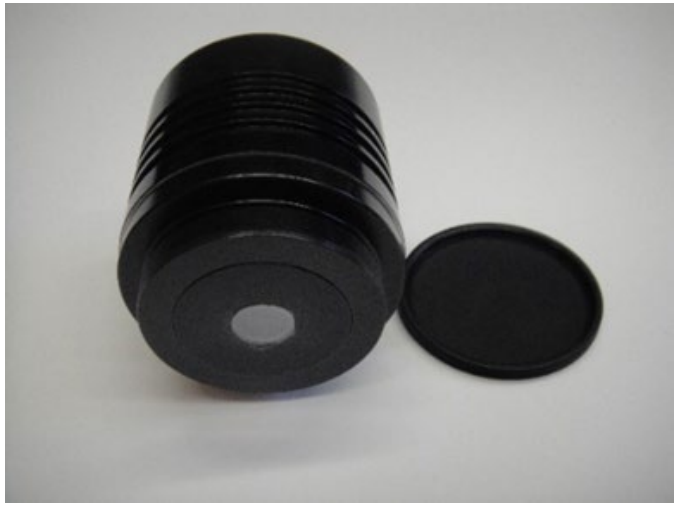
Optical Watt is measured based on the Electrical Watt.



Measurement Scale – Summary

Wavelength (nm)	Expanded Uncertainty (*k*=2) %
200	1.07
250	0.95
300	0.97
350	0.99
400	1.04

Wavelength (nm)	Expanded Uncertainty (k=2) %
250	1.74
350	1.27
450	0.91
555	0.77
900	0.57



Wavelength (nm)	Expanded Uncertainty (k=2) %
200	4.7
250	1.8
300	1.0
350	0.82
400	0.60

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