First ICO-ICTP-TWAS Central American Workshop in Lasers, Laser Applications and Laser Safety Regulations

Laser Resonators

Dr. Eric Rosas

Centro Nacional de Metrología

México

INTERNATIONAL COMMISSION FOR OPTICS
COMMISSION INTERNATIONALE d'OPTIQUE

The Abdus Salam
International Centre for Theoretical Physics

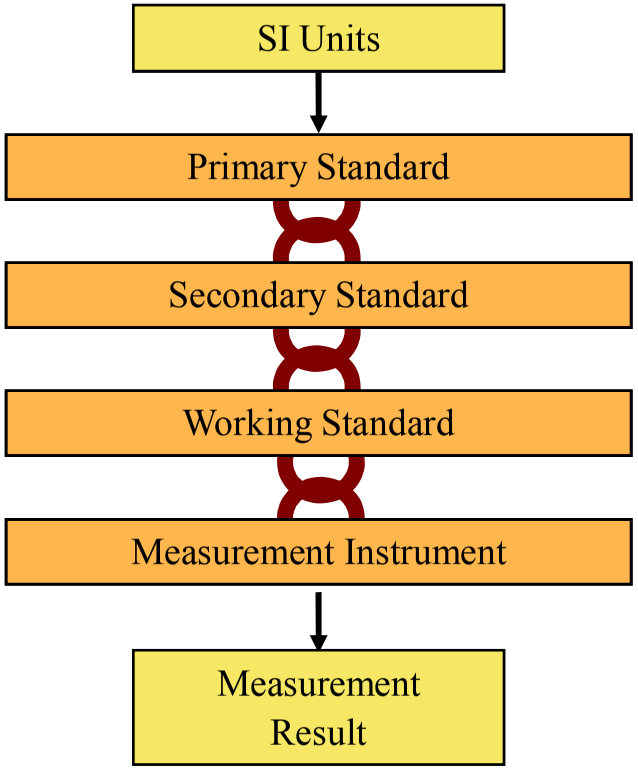
twas
the academy of sciences for the developing world

Contents

Metrological Traceability.

Property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty.

VIM, 3 Ed., 2008.



Calibration.

Operation that… establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and… uses this information to establish a relation for obtaining a measurement result from an indication.

VIM, 3 Ed., 2008.

Measurement Uncertainty.

Non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used.

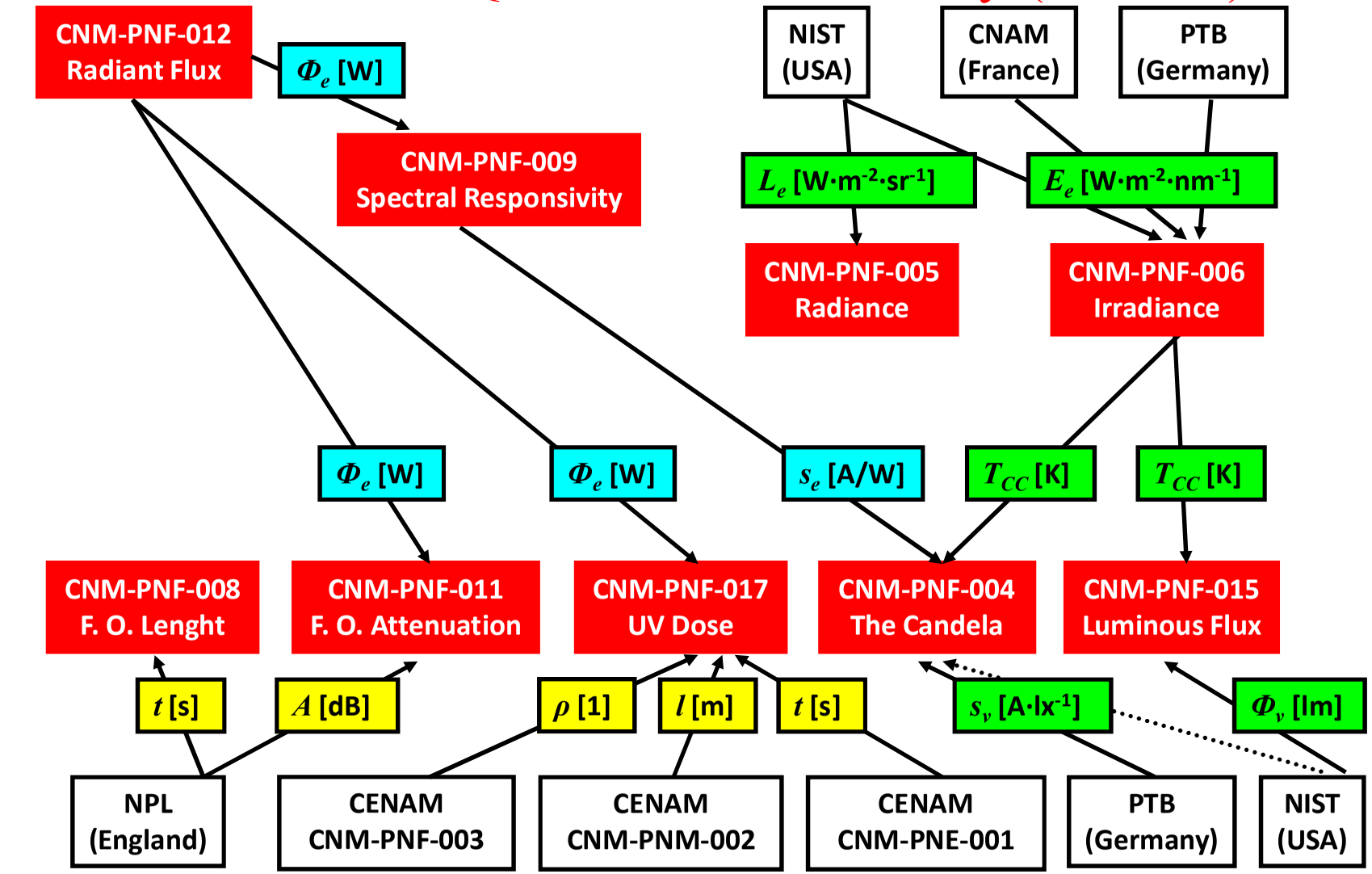
VIM, 3 Ed., 2008.

Quantity.

Property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference.

VIM, 3 Ed., 2008.

Radiometric Quantities Traceability (Mexico).



Radiant Flux or Radiant Power.

Radiant Flux, Radiant Power: (Φ_e, Φ, P)

Power emitted, transmitted or received in the form of radiation.

CIE 17.4, 1987.

Energy Q radiated by a source, per unit time t:

$$\Phi_e = \frac{Q}{t}$$

SI Unit: Watt = Joule per second

Unit symbol: W = $J \cdot s^{-1}$

"Optical" Watt Realization.

Realization of a given quantity definition, reported with a certain value and measurement uncertainty.

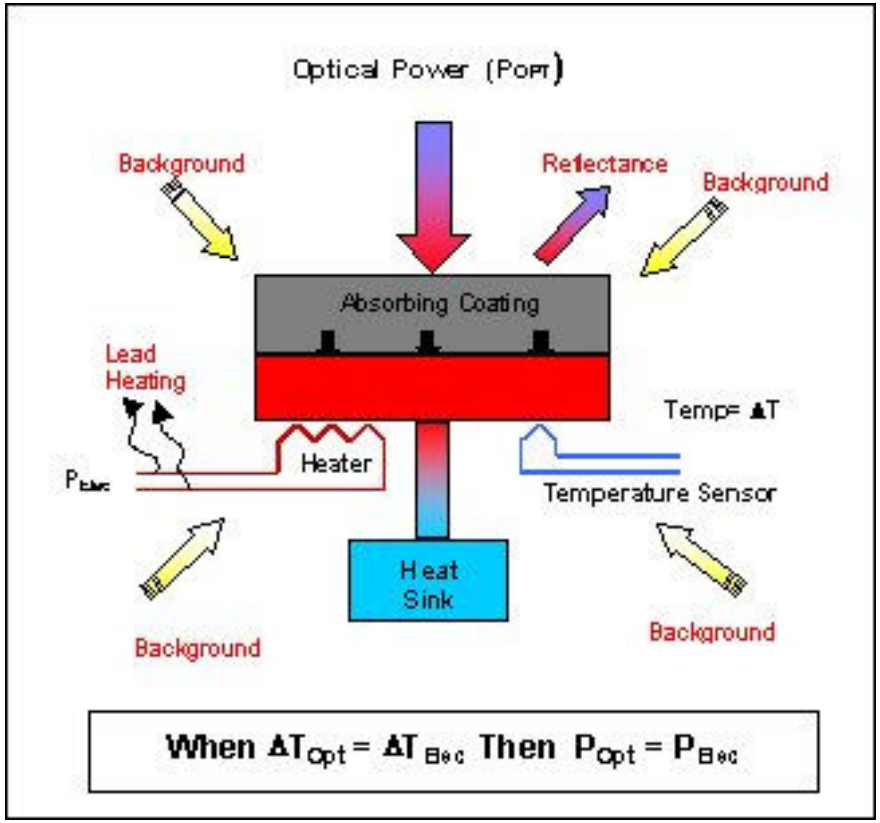
The "optical" Watt is realized by using an Electrical Substitution Radiometer.

Electrical Substitution Radiometer.

An *ESR* uses a thermometer to measure the temperature increment of a thermal detector, relative to a heat sink constant temperature, between electrical and optical intermittent heating cycles.

The power is adjusted to produce the same thermal detector temperature increment for both warming "types", then the optical and electrical powers can be considered as equivalent.

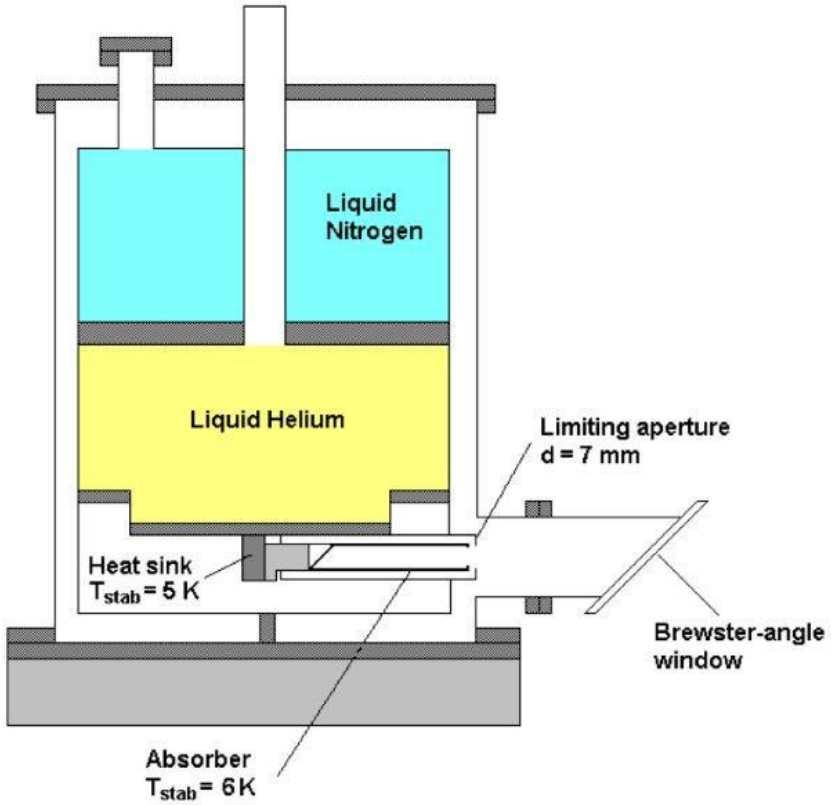
$$P_{\text{opt}} = \frac{1}{\tau \cdot \alpha} P_{\text{el}}$$



Dark Signal Reduction.

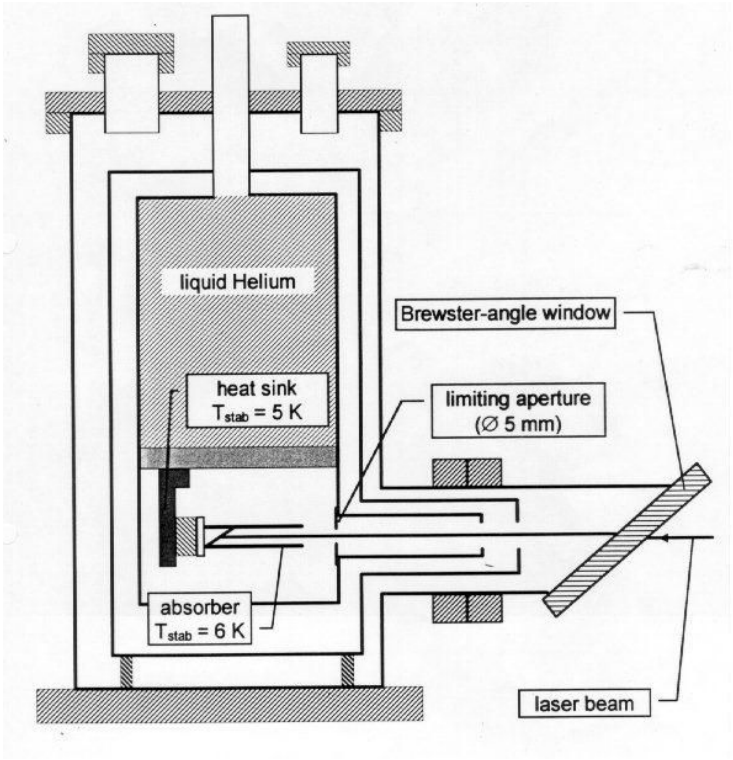
At cryogenic temperatures the heat specific capacity of the absorber reduces about 1 000 times. Such a low heat specific capacity allows the construction of highly absorbent and relatively large cavities, with short response times.

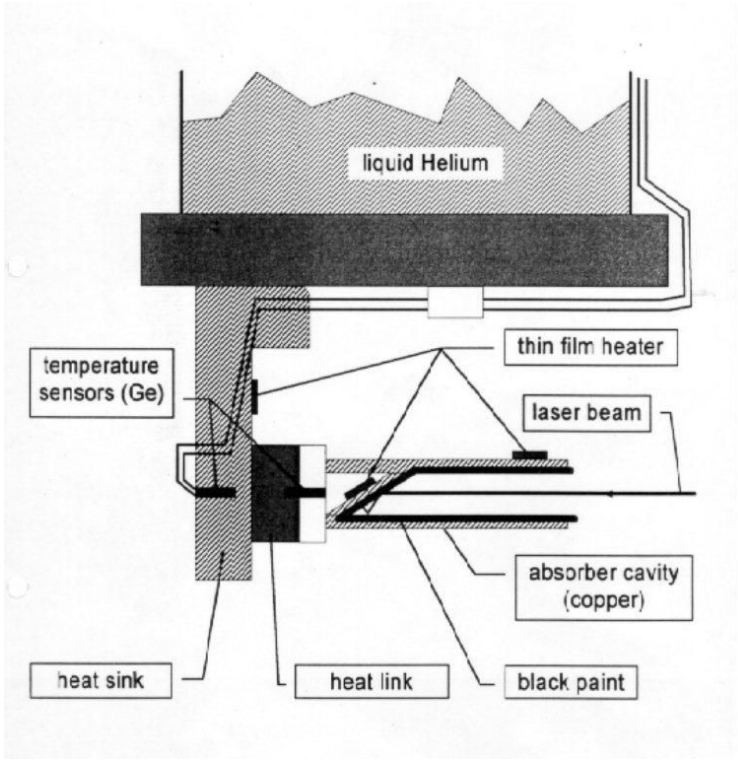
To prevent the dark signal from reaching the radiometric detector, this is operated at cryogenic temperatures, below 20 K; (~ -253 °C), which requires to produce vacuum inside the absorbing ERS cavity.



Cryogenic Radiometry.

At room temperature the dark signal fluctuations, as well as the energy losses in the heater electrical circuit connections, reduce the signal to noise ratio, affecting the readings accuracy.





Radiant Flux Mexican Standard

± 0,018 % (k=2)

Operating range
10 µW to 0.5 mW
Cavity spectral range
200 nm to 50 µ m
Operating wavelenght
$\lambda = 638.2$ nm
Cavity absorbance
$\alpha = 99.985\ 6$ %
Window transmittance
$\tau = 99.952\ 2$ %
Detector responsivity
$s = 2.6\ \mathrm{K \cdot mW^{-1}}$
Aperture diameter
$\phi = 7$ mm
Detector response time
$t = 4$ s

Spectral Responsivity.

Spectral Responsivity (of a detector): ($s(\lambda)$)

Quotient of the detector output $dY(\lambda)$ by the monochromatic detector input $dX_e(\lambda)=X_{e,\lambda}(\lambda)\cdot d\lambda$ in the wavelength interval $d\lambda$ as a function of he wavelenght λ.

CIE 17.4, 1987.

$$s(\lambda) = \frac{dY(\lambda)}{dX_e(\lambda)}$$

SI Unit symbol: $A\cdot W^{-1}$

Spectral Responsivity Mexican Standard

$\pm 0.74 \times 10^{-3}$ % (k=2)

Irradiance.

Irradiance (at a point of a surface): (E_e, E)

Quotient of the radiant flux $d\Phi_e$ incident on an element of the surface containing the point, by the area dA of that element.

CIE 17.4, 1987.

$$E_e = \frac{d\Phi_e}{dA}$$

SI Unit symbol: $W \cdot m^{-2}$

Spectral Irradiance Mexican Standard

± 3 % (k=2)

References

1. A. E. Siegman, *Lasers*, University Science Books, Mill Valley, (1986).
2. P. W. Milonni, J. H. Eberly, *Lasers*, John Wiley & Sons, New York, (1988).
3. H. Kogelnik, T. Li, *Laser Beams and Resonators*, Appl. Opt. **5**(10), (1966).
4. A. E. Siegman, *Unstable optical resonators*, Appl. Opt. **13**(2), 1974).
5. S. A. Self, *Focusing of spherical Gaussian beams*, Appl. Opt. **22**(5), (1983).
6. B. Ya. Zel'dovich, V. I. Popovichev, V. V. Ragul'skii, F. S. Faizulov, *Connection between the wavefronts of the reflected and exciting light in stimullated mandel'shtam Brillouin scattering*, JETP Lett. **15**, (1972).
7. B. Ya. Zel'dovich, N. F. Philipetsky, V. V. Shkunov, *Principles of phase conjugation*, Springer-Verlag, Berlin, (1985).
8. P. A. Bélanger, A. Hardy, A. E. Siegman, *Resonant modes of optical cavities with phase-conjugate mirrors*, Appl. Opt. **19**(4), (1980).

9. J. F. Lam, W. P. Brown, *Optical resonators with phase-conjugate mirrors*, Opt. Lett. **5**(2), (1980).

10. E. Rosas, V. Aboites, M. J. Damzen, *Transient evolution and spatial mode size analysis of adapive laser resonators*, Opt. Commun. **156**, (1998).

11. E. Rosas, V. Aboites, M. J. Damzen, *Fundamental spatial mode size control of holographic laser resonators*, J. Opt. Commun. **29**, (1998).

12. E. Rosas, V. Aboites, M. J. Damzen, *FWM interaction transfer matrix for self-adaptive laser oscillators*, J. Opt. Commun. **174**, (2000).

13. J. J. Soto-Bernal, E. Rosas, V. Pinto-Robledo, Aboites, M. J. Damzen, *Spatial mode size analysis of a diode-side-pumped Nd:YVO_4 laser resonator*, J. Opt. Commun. **184**, (2000).

14. E. Rosas, J. J. Soto-Bernal, M. Trew, G. J. Crofts, M. J. Damzen, *Continuous-wave diode-pumped Nd:YVO_4 holographic laser oscillator*, Rev. Mex. Fís. **47**, (2001).

15. M. J. Damzen, M. Trew, E. Rosas, G. J. Crofts , *Continuous-wave Nd:YVO_4 grazing-incidence laser with 22.5 W output power and 64 % conversion efficiency*, J. Opt. Commun. **196**, (2001).

16. BIPM, CEI, FICC, ILAC, ISO, UICPA, UIPPA, OIML, *Vocabulaire international d'unités*, JCGM:200, Third Ed., Switzerland, (2008).

17. CIE, *Vocabulaire electrotechnique international*, CIE Publication **17.4**, Switzerland (1987).

18. BIPM, *Calibration and measurement capabilities catalog*, BIPM, http://kcdb.bipm.org/appendixC/default.asp, (2009-03-27).

19. BIPM, CEI, FICC, ISO, OIML, UICPA, UIPPA, *Guide pour l'expression de l'incertitude de mesure*, First Ed., Switzerland, (1995).

20. CENAM, *Catálogo de patrones nacionales de México*, Secretaría de Economía, http://www.cenam.mx/patrones/Default.aspx, (2009-03-27).

End of Session Five.

Thank you very much for your attendance.