Multi-Wavelength Pyrometer

Detian Yang

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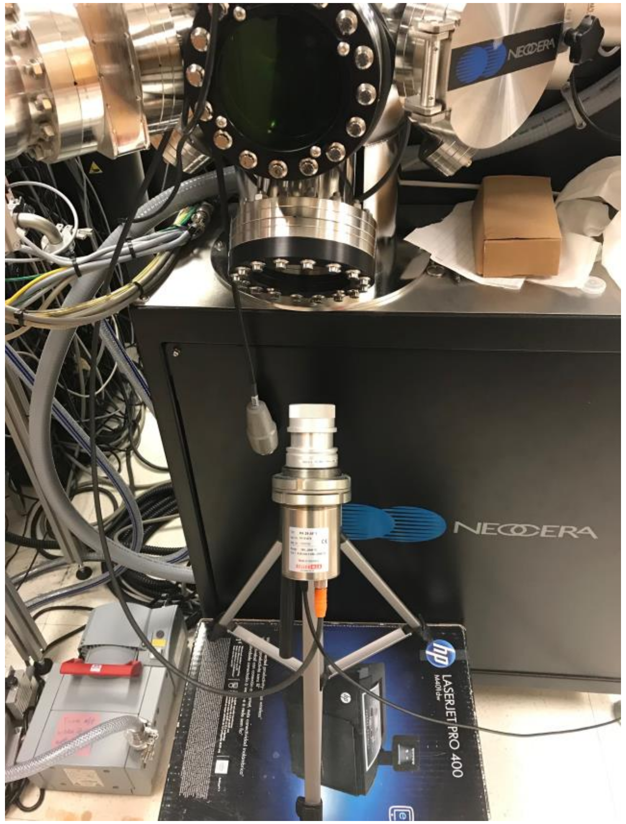
- Lab 333， PLD system
- pyrometer "PA 29 AF 1"
- Film temperature



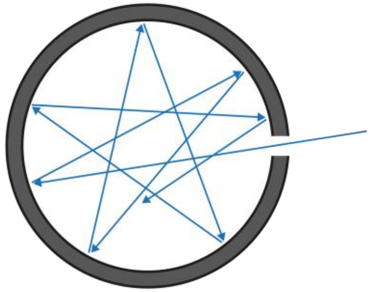
What is a pyrometer ?

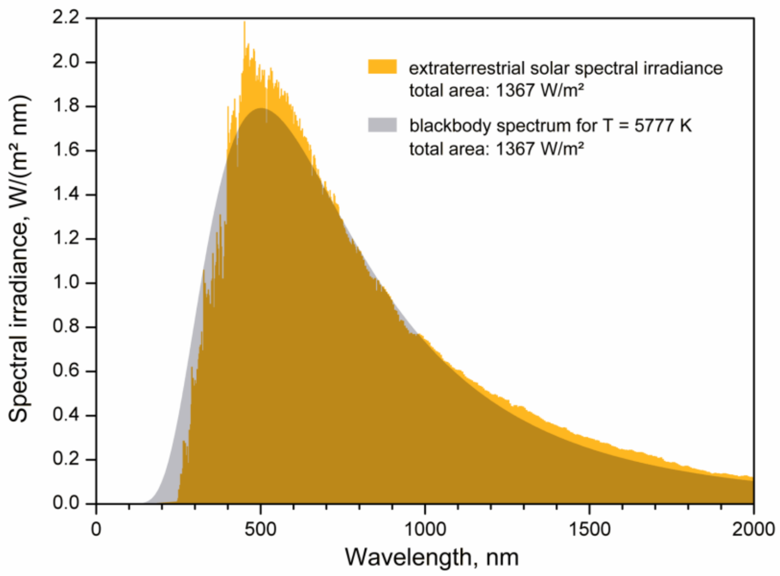
- A **pyrometer** 1) remote-sensing thermometer 2) radiation of the target

pros : moving objects or any surfaces that can not be reached or can not be touched(hostile, too far, perturb target temperature, damage target…..).

cons: depends on the intensity of light emitted by the heated body (>250 C).

Blackbody Radiation Equation and Emissivity





- Blackbody: idealized concept, 100% absorption, no reflection and transmission.
- Photons, identical spin-0 particle, Bose-Einstein statistics;

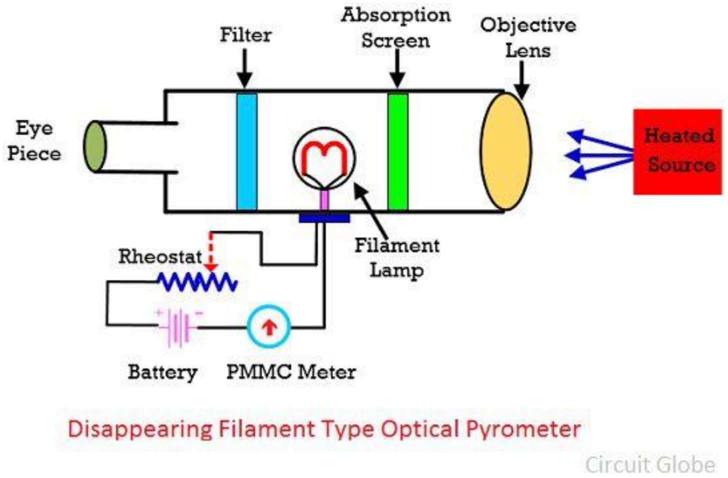
$$L_\lambda = \frac{2hc^2}{\lambda^5}\left[e^{hc/\lambda K_B T} - 1\right]^{-1}$$

where L_λ=radiance in energy per unit area per unit time per steradian per unit wavelength interval,
h=Planck's constant,
c=the speed of light,
λ=the wavelength of the radiation,
k_B=Boltzmann's constant, and
T=the absolute temperature.

$$\epsilon = \frac{\text{thermal radiation from a surface}}{\text{the radiation from blackbody}}, \text{T fixed;}$$

Brightness Pyrometer

- $\epsilon = \frac{\text{thermal radiation from a surface}}{\text{the radiation from blackbody}}$, T fixed;



Disappearing Filament Type Optical Pyrometer

For non-blackbodies,

$$H_\lambda = \epsilon L_\lambda = \epsilon \frac{2hc^2}{\lambda^5} [e^{hc/\lambda K_B T} - 1]^{-1}$$

In the brightness method of pyrometry, H_λ and ϵ are measured at a known wavelength, λ, and, therefore, T can be calculated.

Cons: ϵ unknow or estimated to a low degree of accuracy;
ϵ can depends on thermal and environmental history;

Ratio Pyrometer

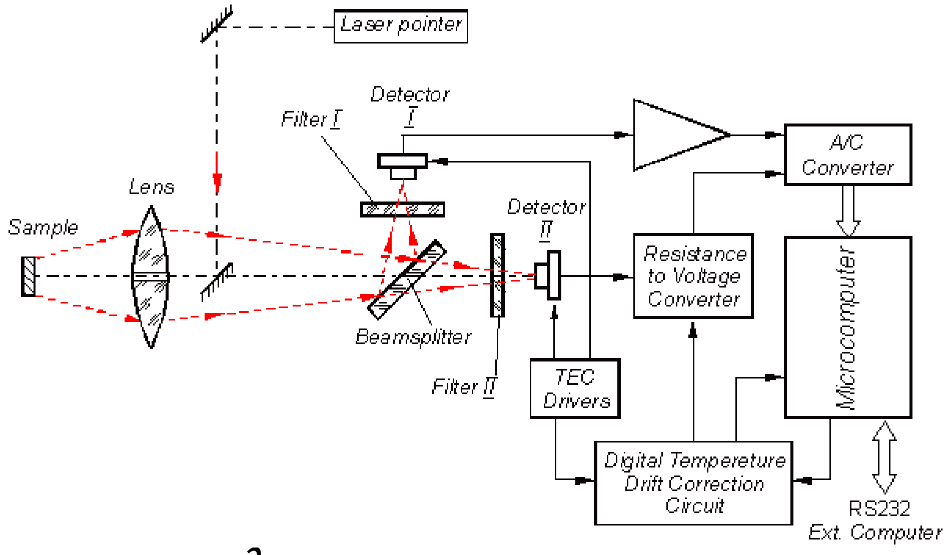
- Graybody assumption ： ϵ independent of frequency

$$H_{\lambda_i} = \epsilon \frac{2hc^2}{{\lambda_i}^5}\left[e^{hc/\lambda_i K_B T} - 1\right], i = 1, 2$$

low temp, short wavelength

$$e^{hc/\lambda_i K_B T} - 1 \sim e^{hc/\lambda_i K_B T}$$

$$\frac{H_{\lambda_1}}{H_{\lambda_2}} = \left(\frac{\lambda_2}{\lambda_1}\right)^5 e^{\frac{hc}{K_B T}\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)}$$



$$T = \frac{hc}{K_B}\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)/[\ln(\frac{H_{\lambda_1}}{H_{\lambda_2}}) \text{ -5}\ln\left(\frac{\lambda_2}{\lambda_1}\right)]$$

Ratio Pyrometer

- Tradeoffs:

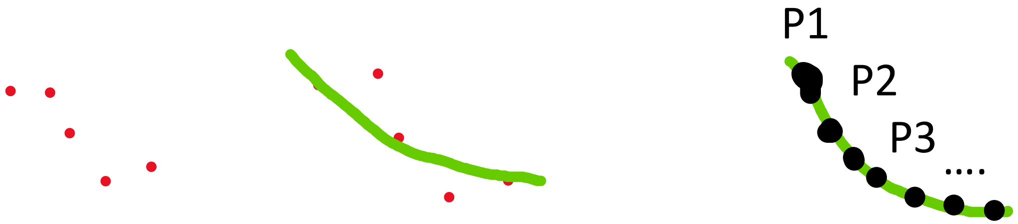
$\Delta\lambda = |\lambda_1 - \lambda_2|$ **increases** → **Higher precision of Planck Radiation equation**

↘ **worse graybody assumption**

Cons: depend on target emissivity and affected $by\ gaseous\ absroptions\ from\ workpiece\ or\ environment$

Multi-wavelength Pyrometer

- 1) Get primary data points: $\left(\lambda_i, H_{\lambda_i}\right), \mathrm{i} = 1,2,3, \ldots \mathrm{n}, \quad \lambda_0 < \lambda_i < \lambda_0 + \delta, \ \delta \ small\ enough$;
- 2) fit $\left(\lambda_i, H_{\lambda_i}\right)$ into a mathematical function $H(\lambda)$;
- 3) Get statistically significant number N(N>>n) of points $\left(\widetilde{\lambda_i}, \widetilde{H_{\lambda_i}}\right)$from $H(\lambda)$
- 4) use $\left(\widetilde{\lambda_i}, \widetilde{H_{\lambda_i}}\right)$ to get many two-wavelength temperature and calculate their average.



1) 2) 3)

(P1, P2)-> T1
(P2, P3)-> T2
....
(Pi, Pi+1)-> Ti

$$T = \frac{1}{N}\sum_{i}^{N} T_i$$

4)