Sensors of temperature (contact-less)

AE3B38SME - Sensors and Measurement

Just a little bit of Physics

<u>Planck law</u>

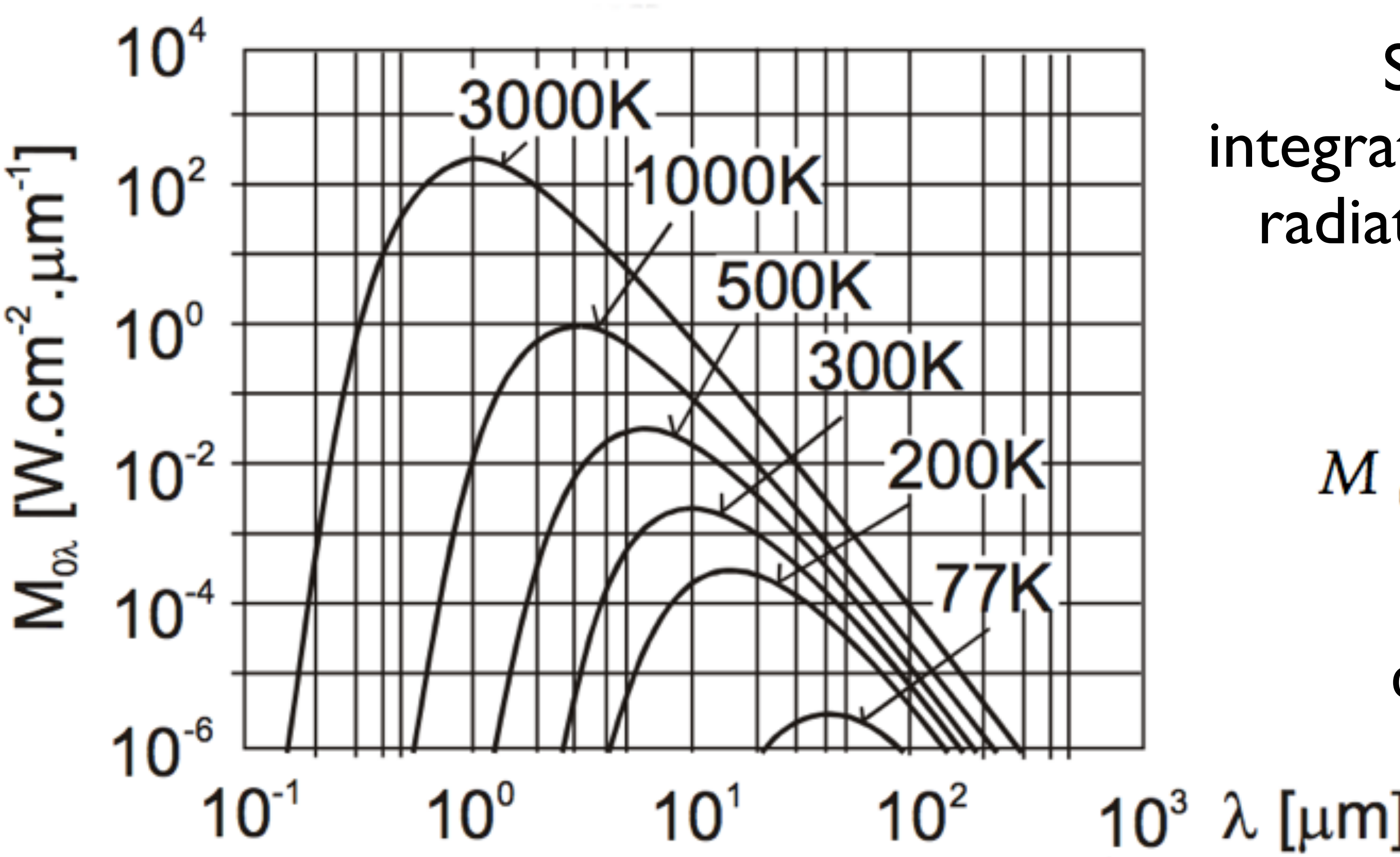
spectral density of radiation intensity [W/m^2]

$$M_{0\lambda} = \frac{c_1}{\lambda^5\left(e^{\frac{c_2}{\lambda T}} - 1\right)}$$

wavelength

$c_1 = 3.74\ 10^{-16}\ \mathrm{Wm}^2$

$c_2 = 1.44\ 10^{-2}\ \mathrm{m\ K}$

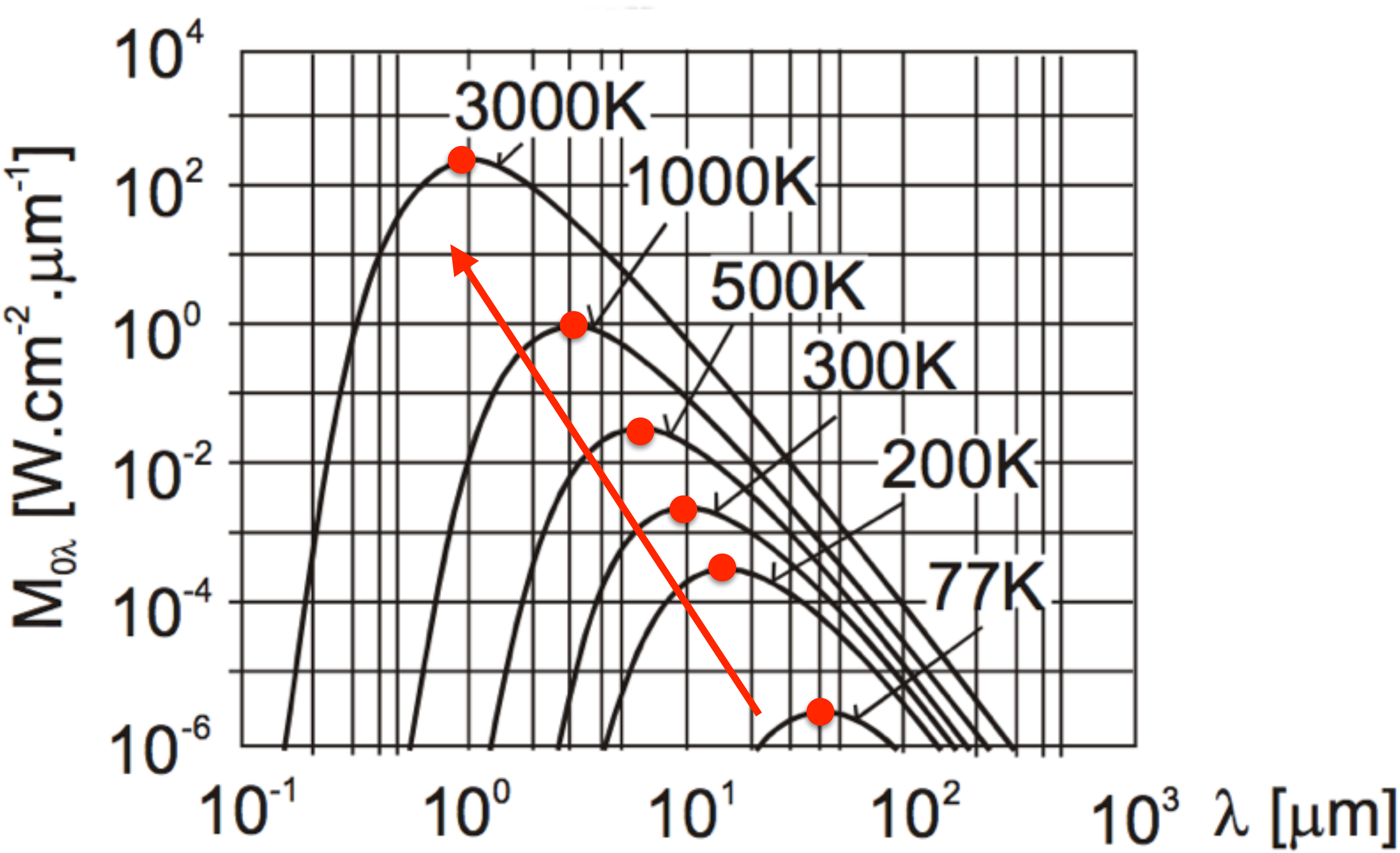


Stefan-Boltzman law:
integrating the spectral density of radiation we obtain the totale radiation emitted

$$M_0 = \int_0^\infty M_{0\lambda}\, d\lambda = \sigma T^4$$

$\sigma = 5{,}67.1010^{-8}\mathrm{Wm}^2\mathrm{K}^{-4}$

The maximum shifts for different temperature

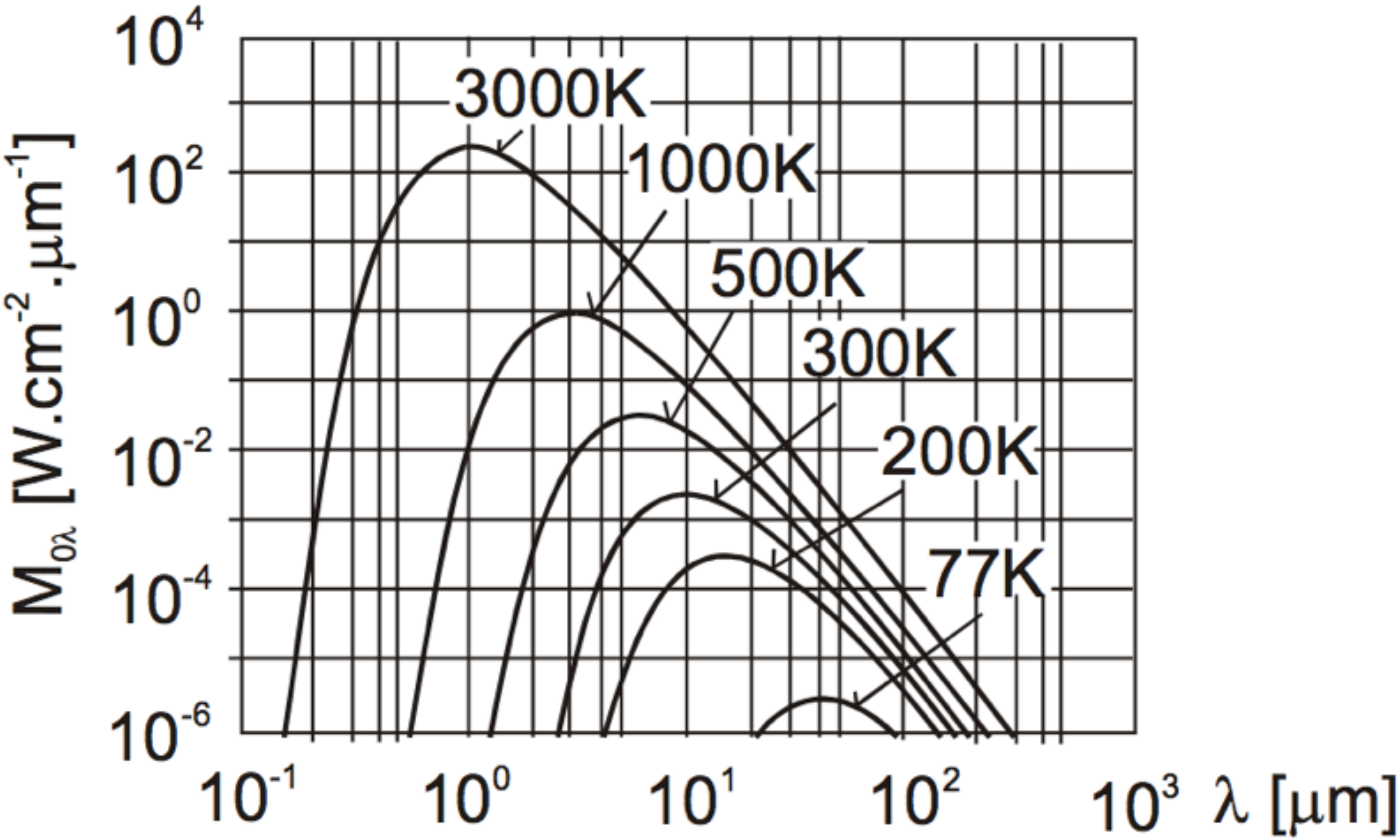


Wien shift law

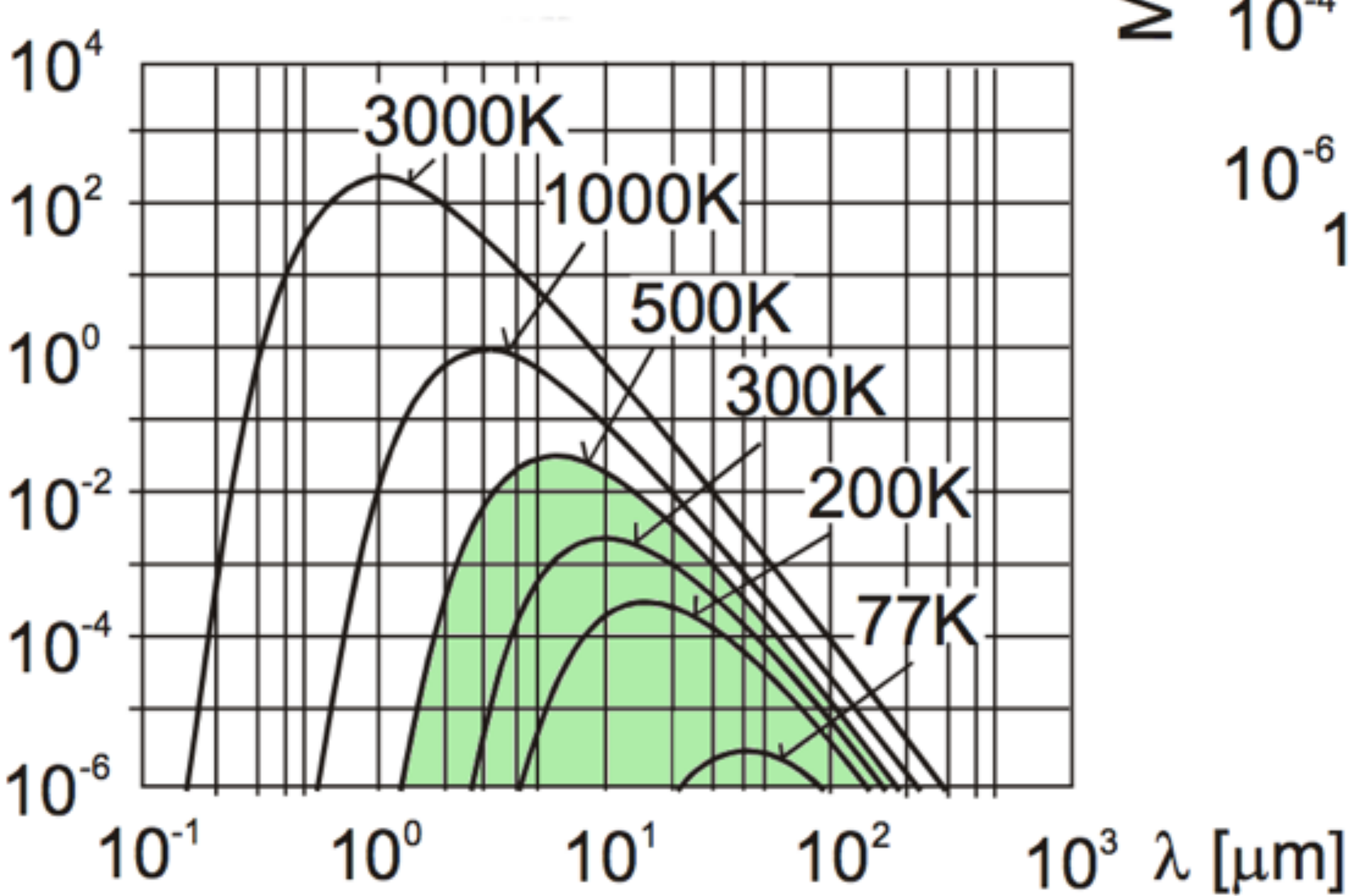
$$\lambda_m = \frac{b}{T}$$

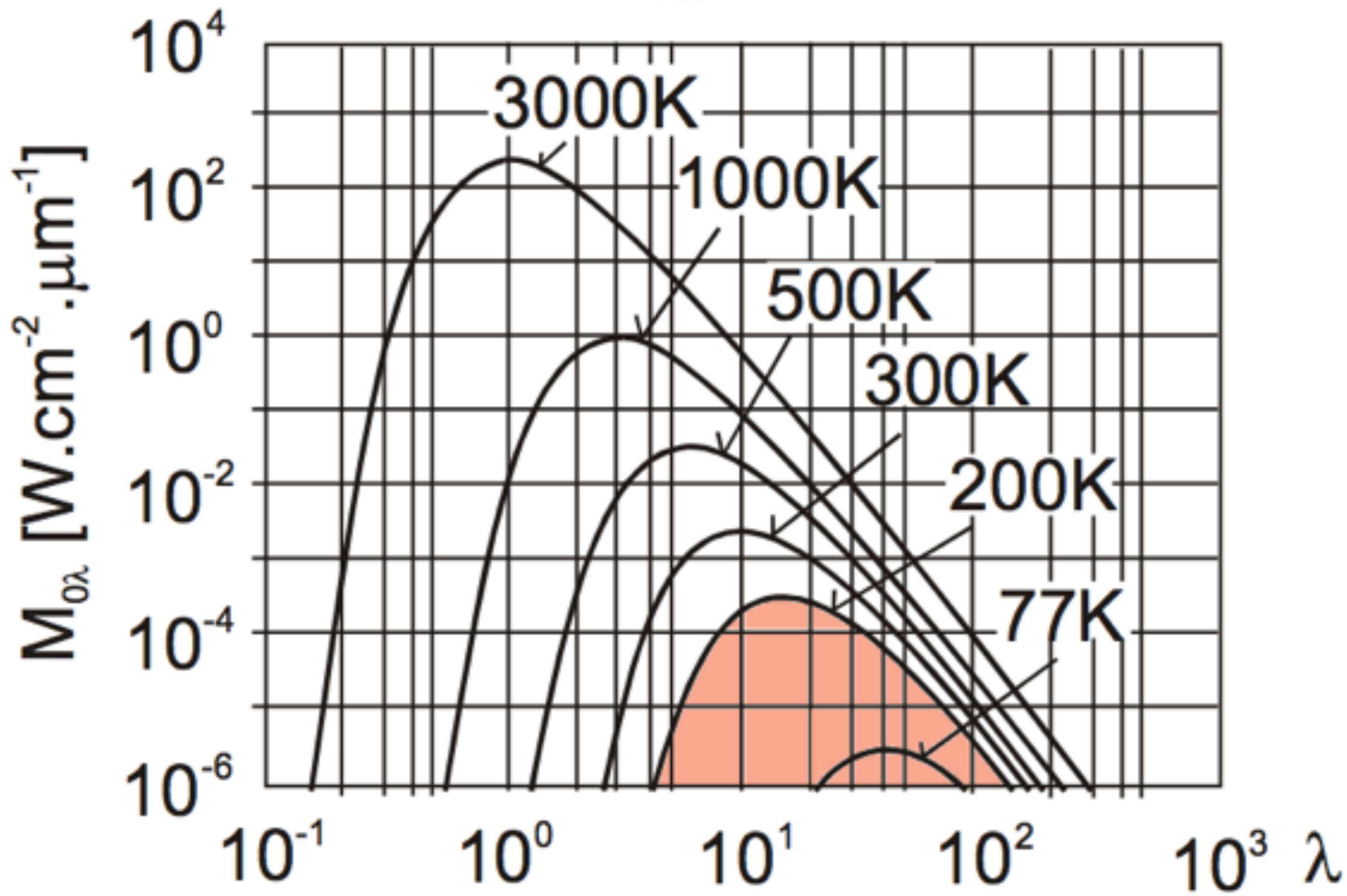
b = 2 898 µm K

Note: curves do never intersect!



Two different approaches:
1- total radiation



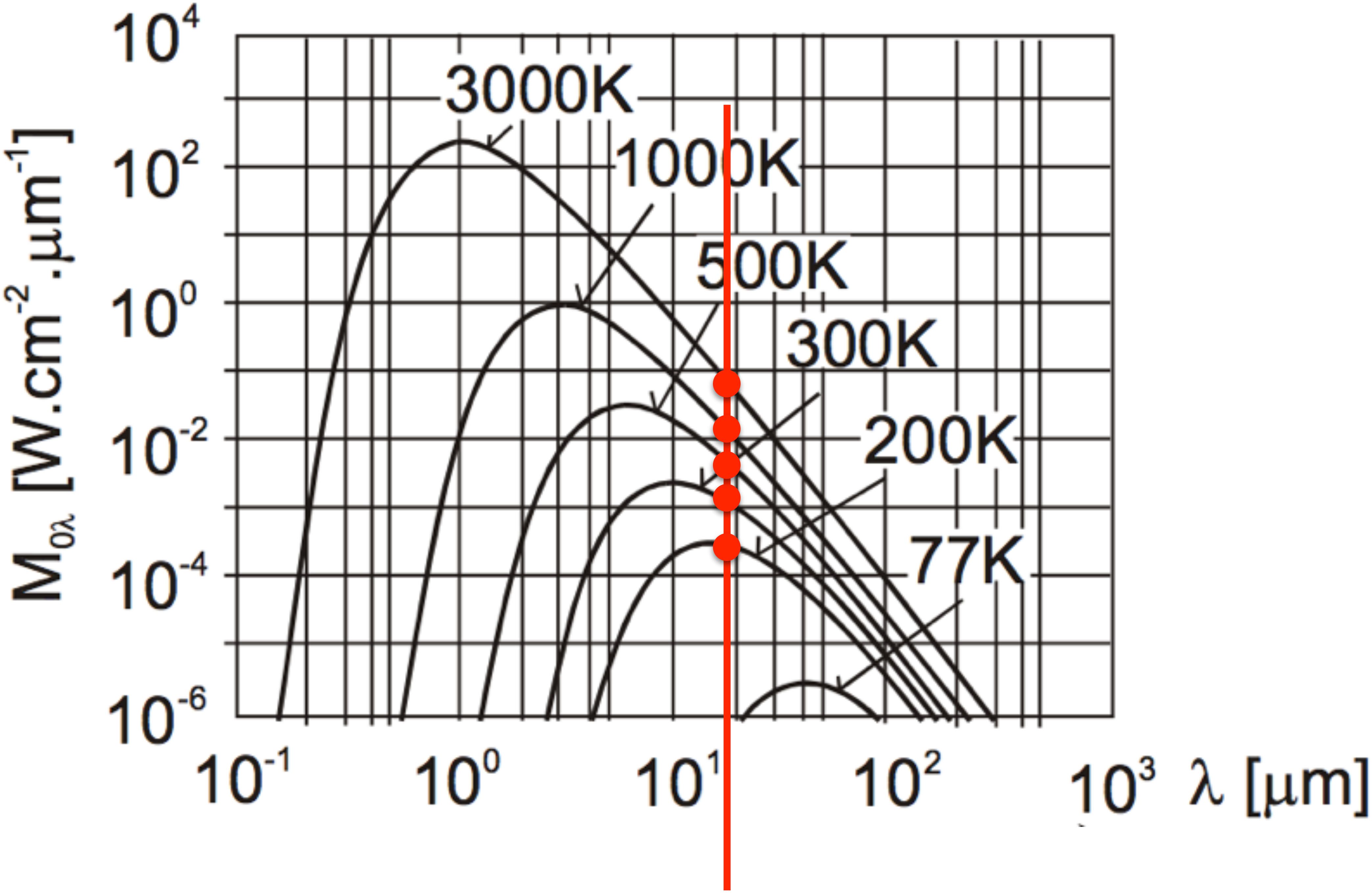


OS521

$ 300,- (as of 2013)
accuracy: ±1% of reading
range: -18 to 540°C, optical sys. 20:1

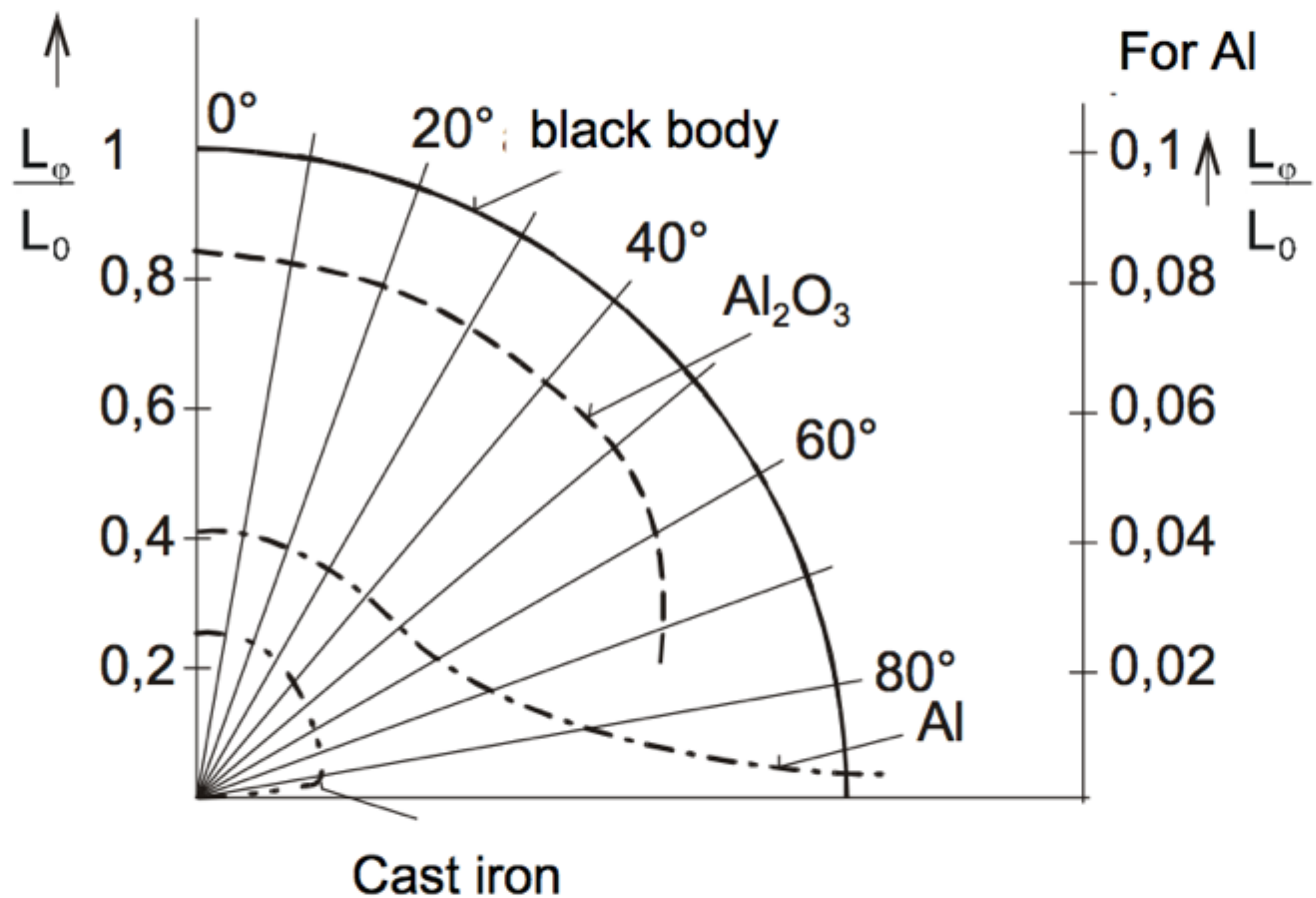
OS530L
$ 500,- (as of 2013)
accuracy: ±1% of reading,
range: -18 to 538°C , optical sys.
laser point target finding (focusing)

Two different approaches:
2- narrow band
(ideally, single wavelength)



Problems

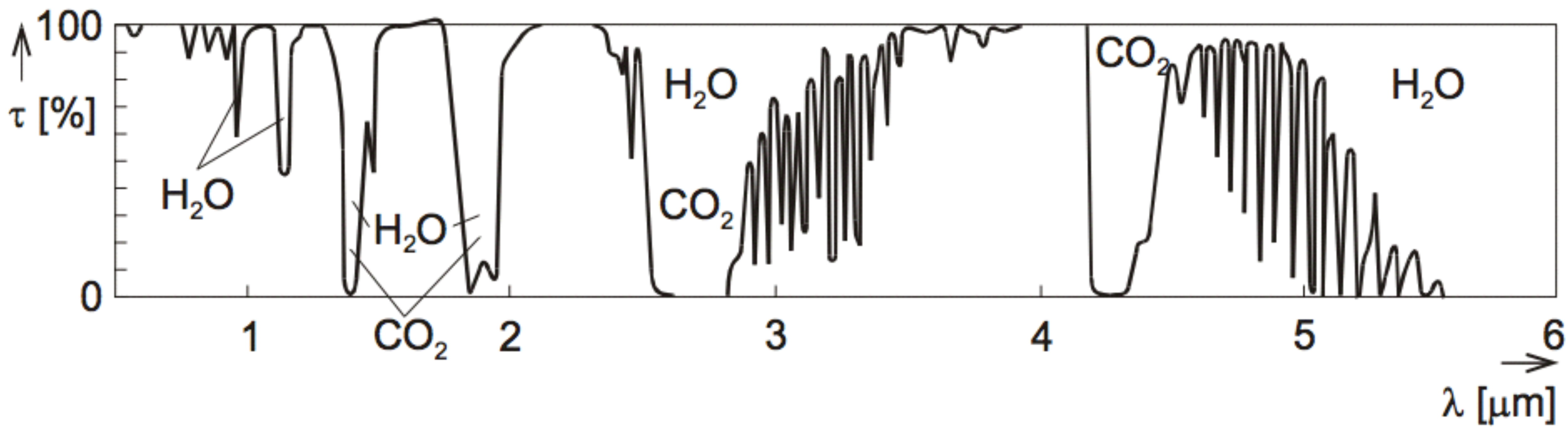
Radiation vs. angle for black body and various real materials:

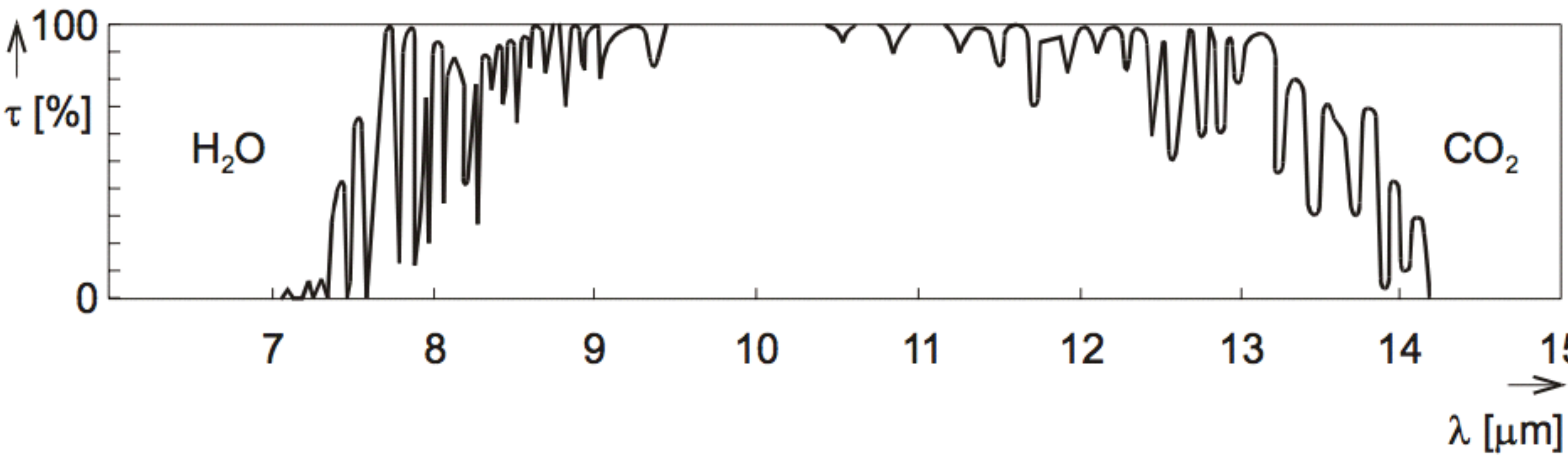


ideally measurement should be done perpendicular

Problems

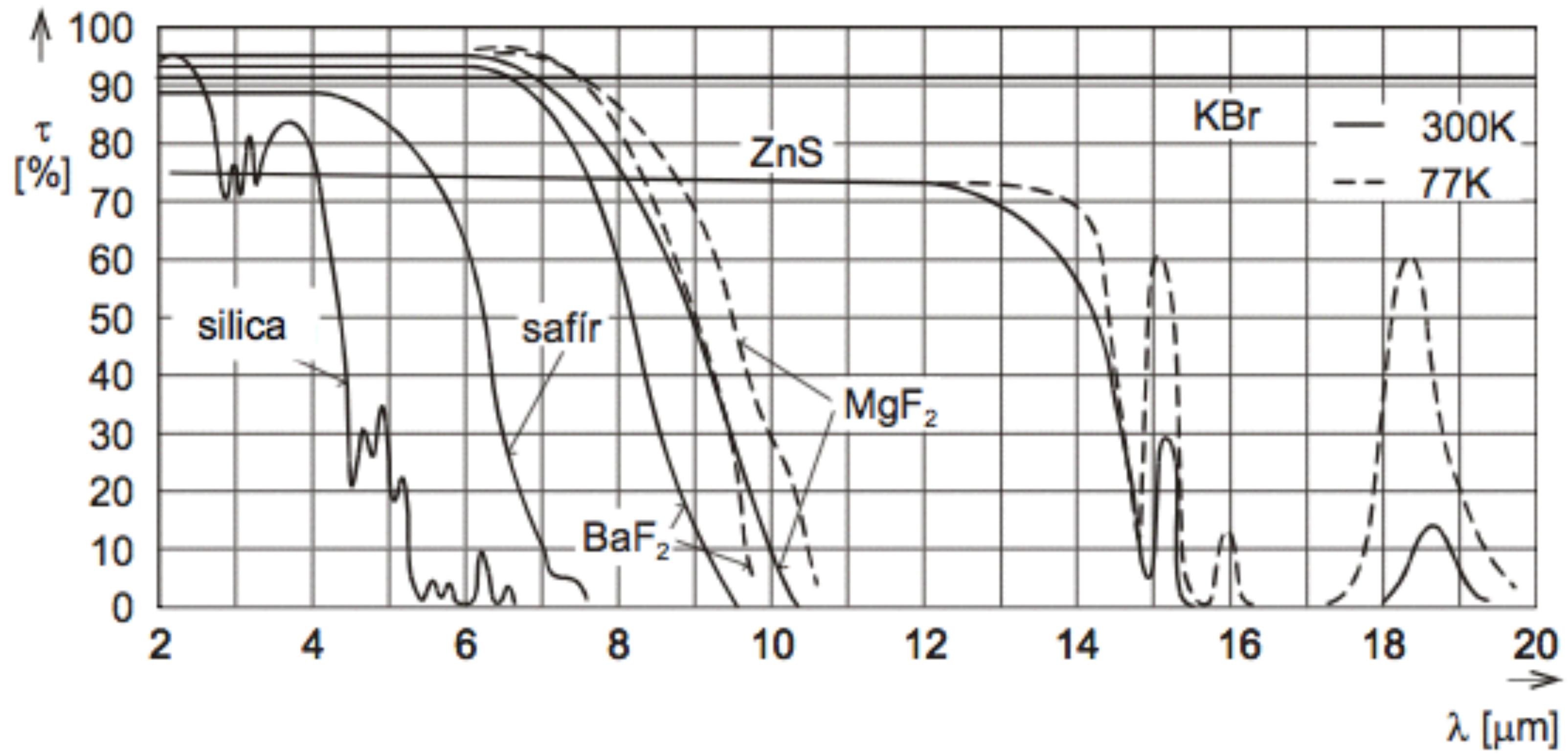
Transmissivity of the medium between target and measurement device

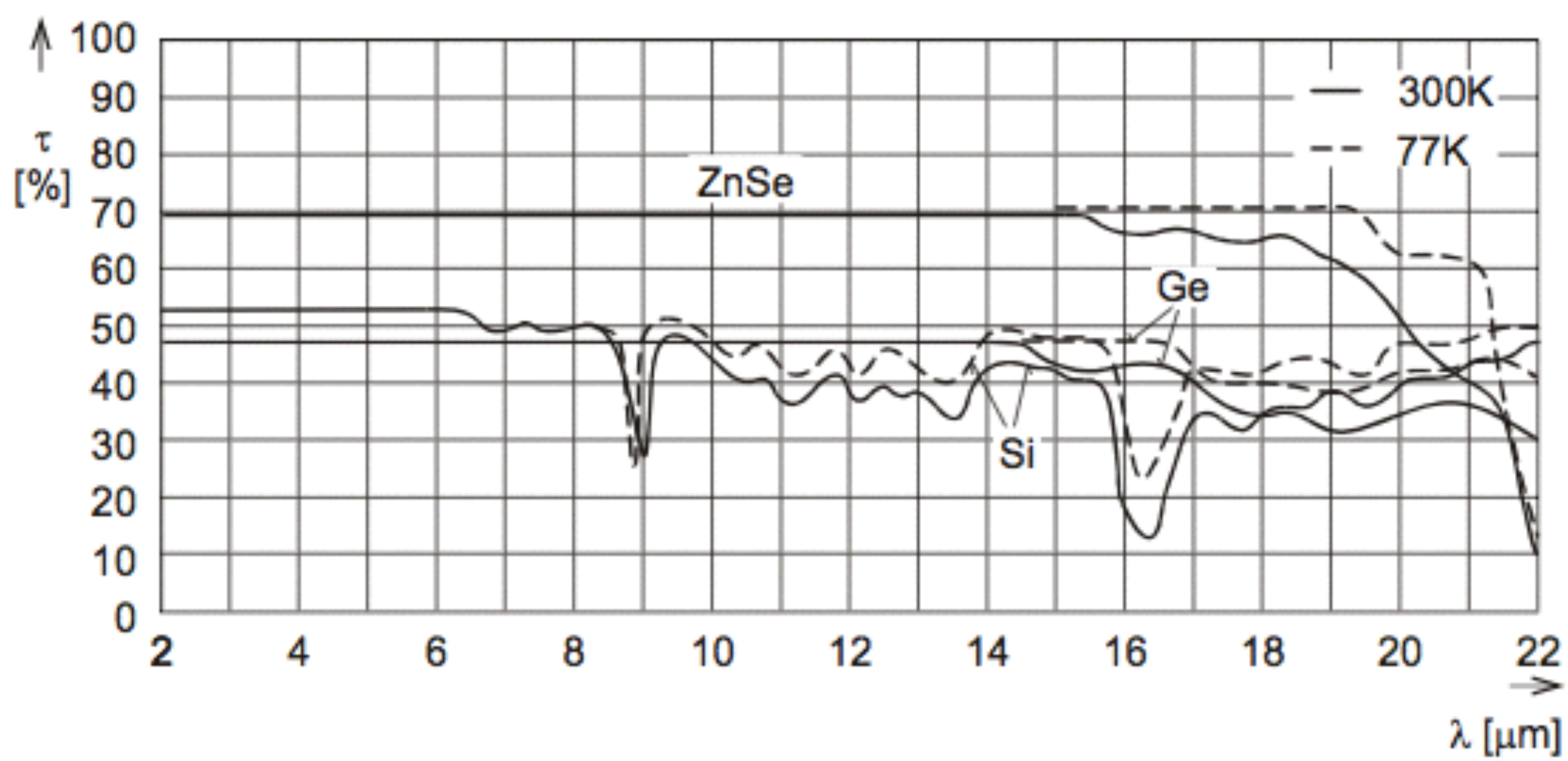




Problems

Transmissivity of the materials used in the optics used to concentrate radiation

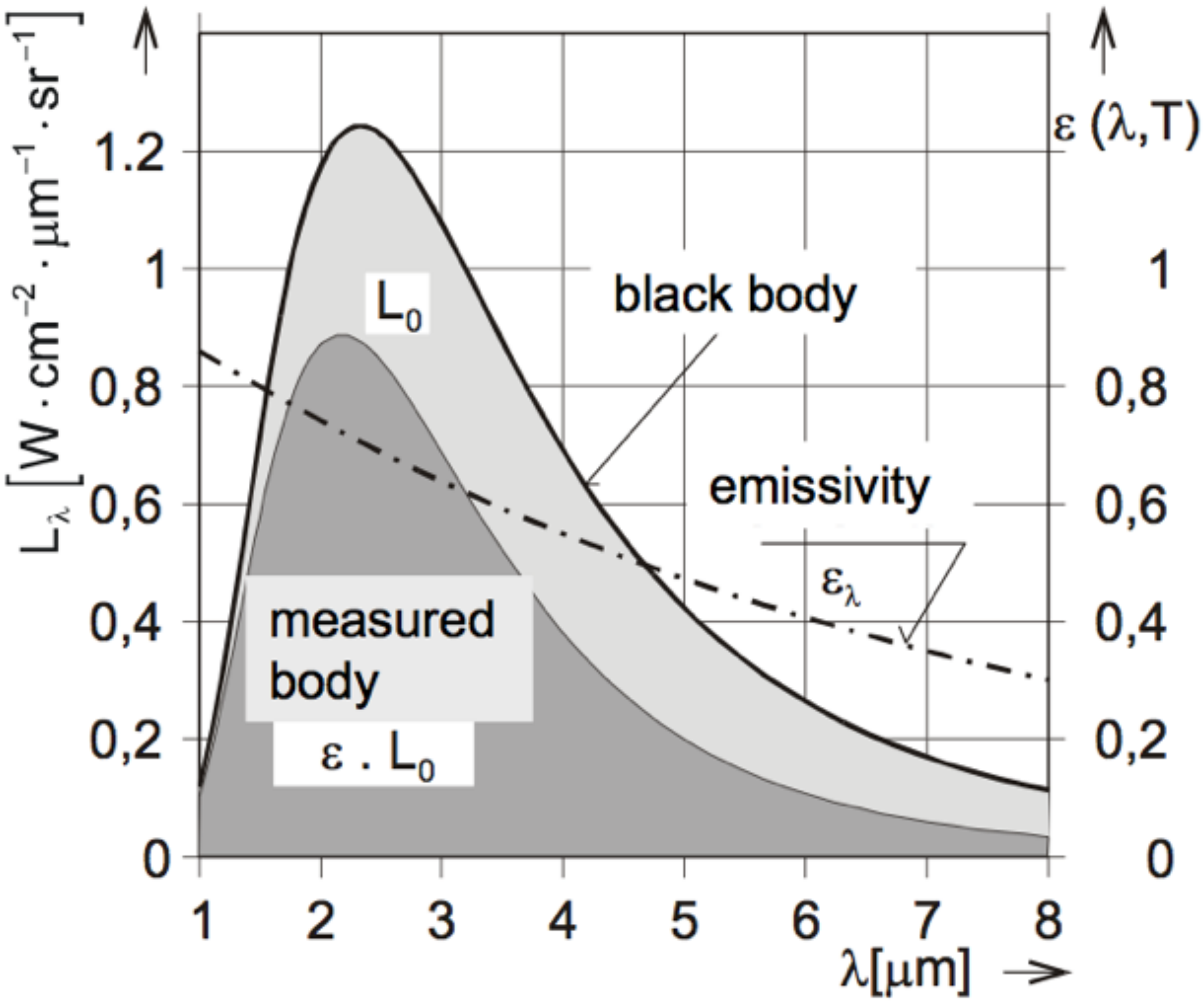




Problems

Emissivity

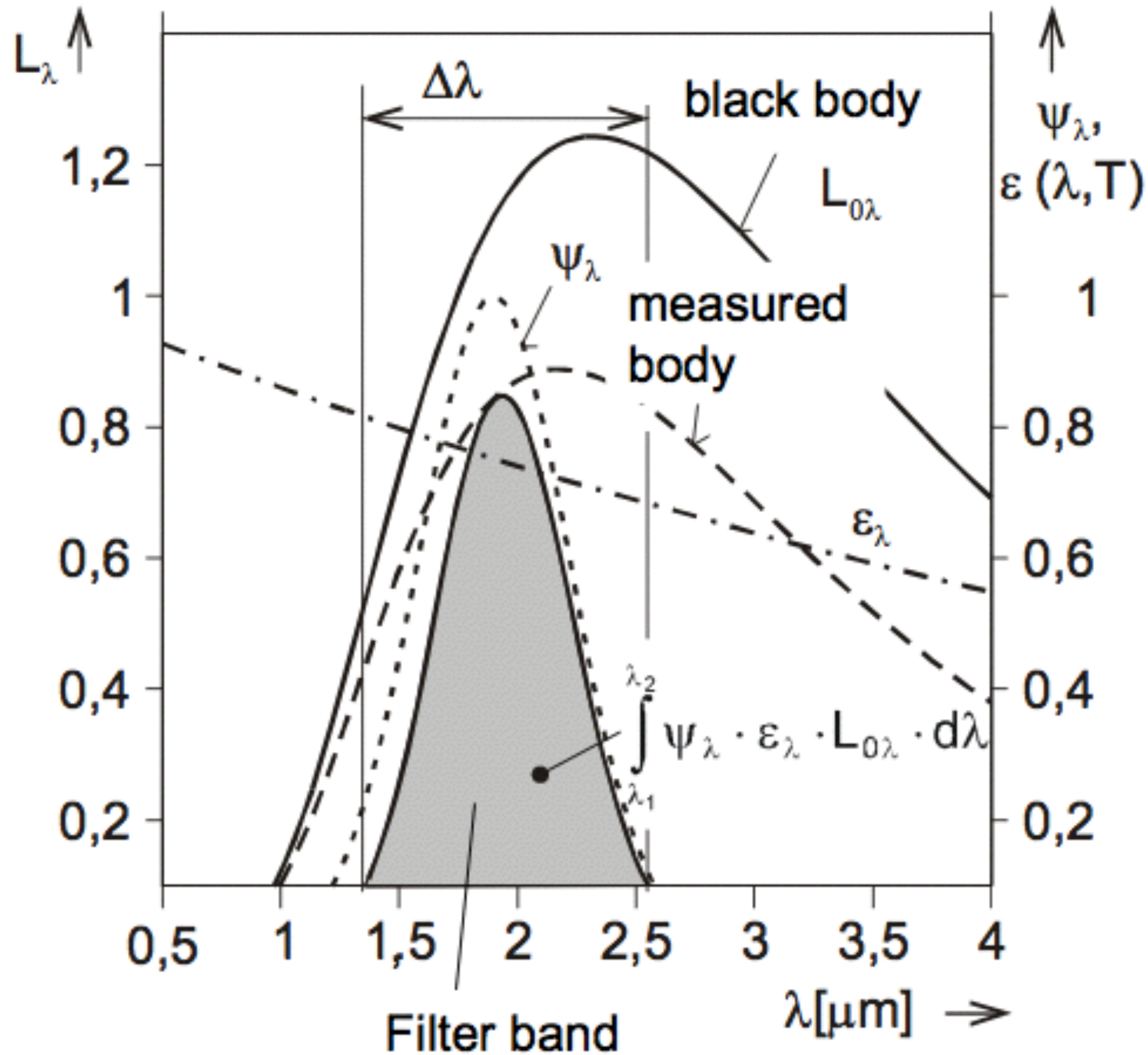
$$M_0 = \sigma T^4 = \sigma \varepsilon \tau_p T_S^4 \Rightarrow T_S = T_o \sqrt[4]{\frac{1}{\varepsilon \tau_p}}$$



$$\frac{dT_S}{T_S} = -0{,}25 \frac{d\varepsilon}{\varepsilon}$$

LARGE!

Narrow band pyrometer



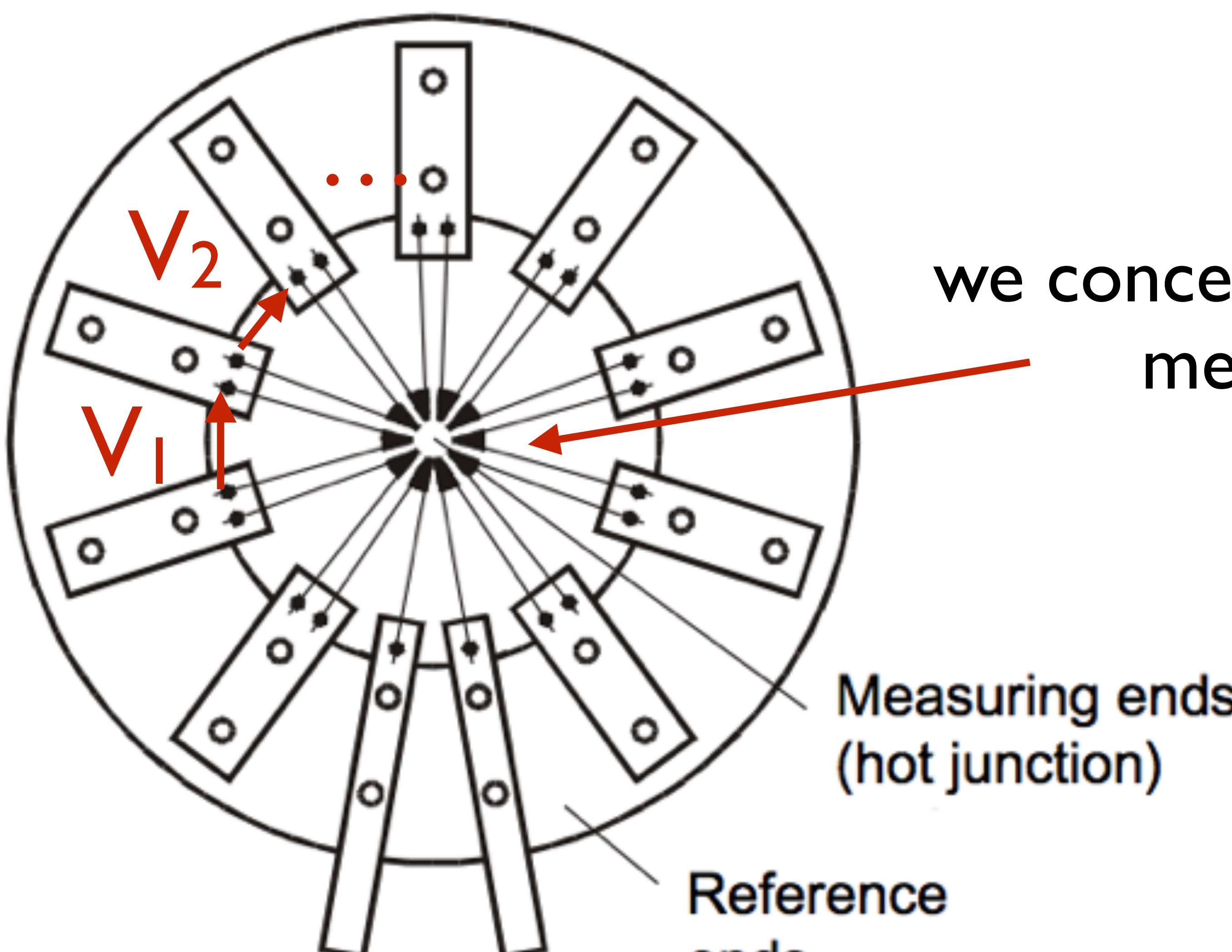
How to choose the emissivity?

- knowledge of the material
- calibration
- attaching a patch with known emissivity and let it warm up at the same temperature of the body to be measured

How to measure radiation?

1- thermopile

Set of thermocouple in series witch common cold end.
Hot end typically in vacuum.
Either made of thin metallic ribbons or in Si technology

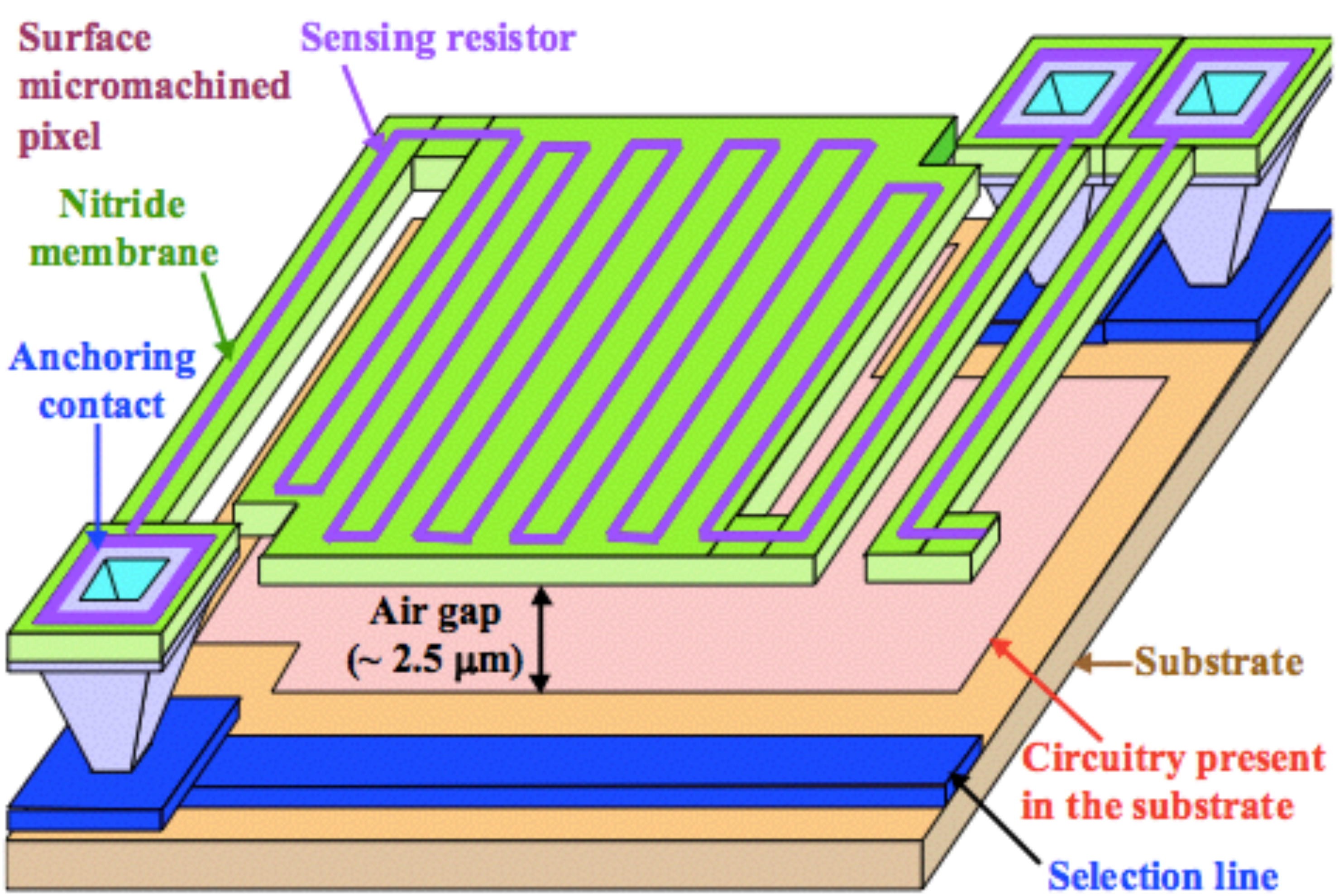


we concentrate heat here and then we measure the temperature

How to measure radiation?

2- Bolometers

Based on resistive sensors of temperature
Thin layers of oxides (e.g. MnO, MgO, NiO,...) deposited on non-conductive substrate



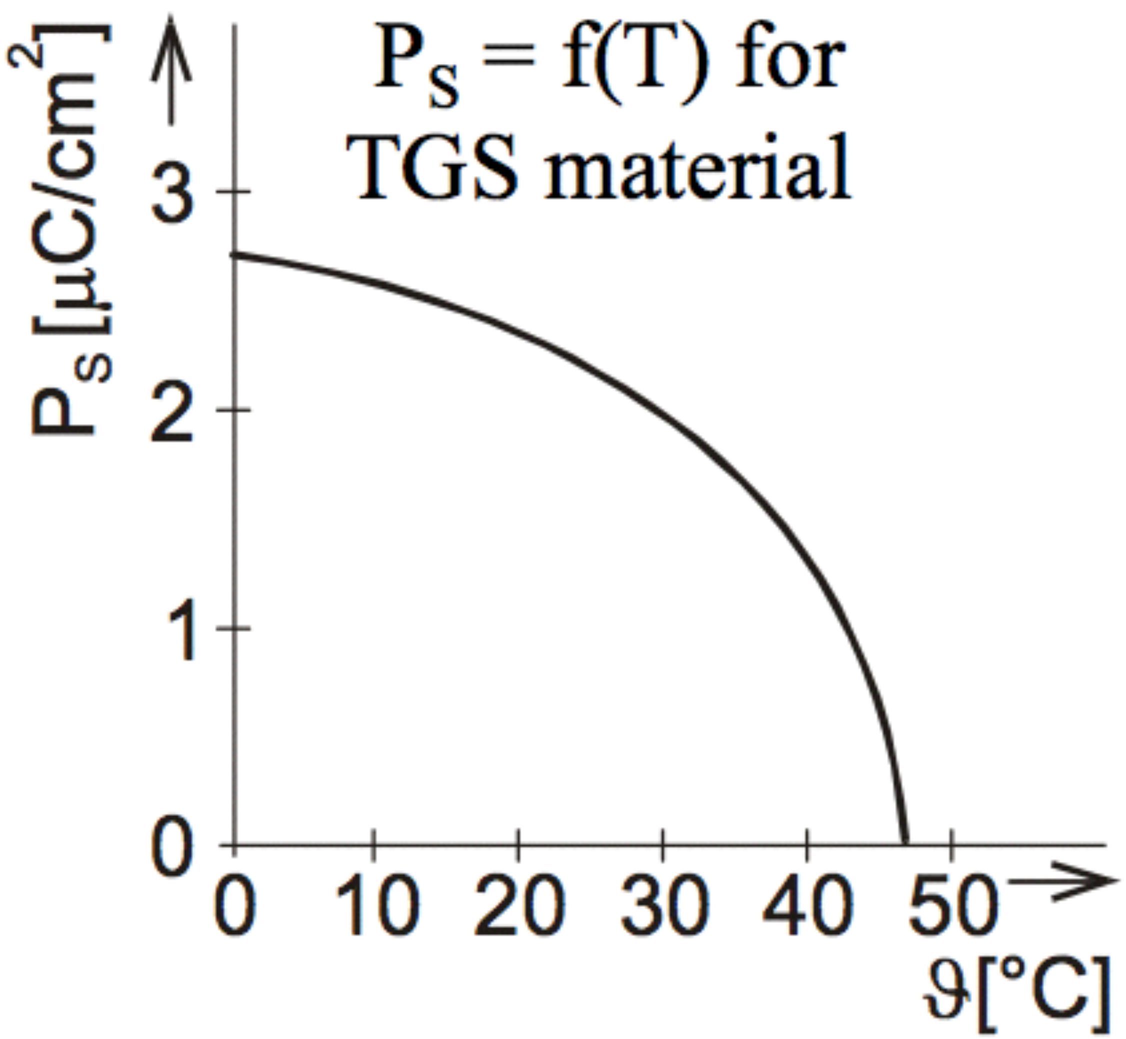
sensitive element suspended in free space

- no heat transfer to substrate
- fast response

How to measure radiation?

3. Pyroelectric detectors

Same principle as piezoelectric sensors, but the polarization P_S after changes because of temperature instead of mechanical stress

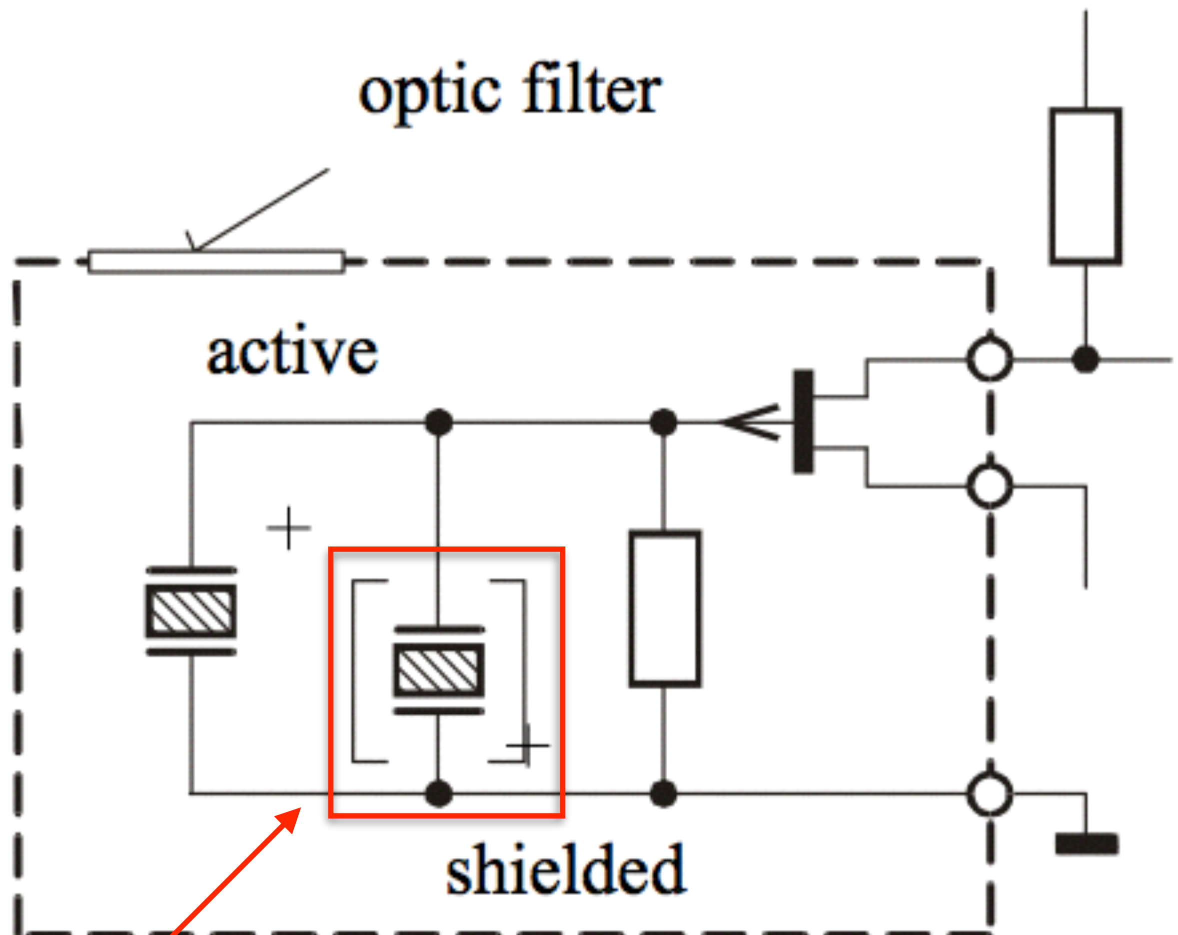


materials: TGS, PZT, $LiTaO_3$, PVDF

Problem: as piezoelectric sensor does only measure variation of temperature rather than constant temperature

Problem: it is affected also by mechanical stress.

Solution: Compensated pyroelectric sensor

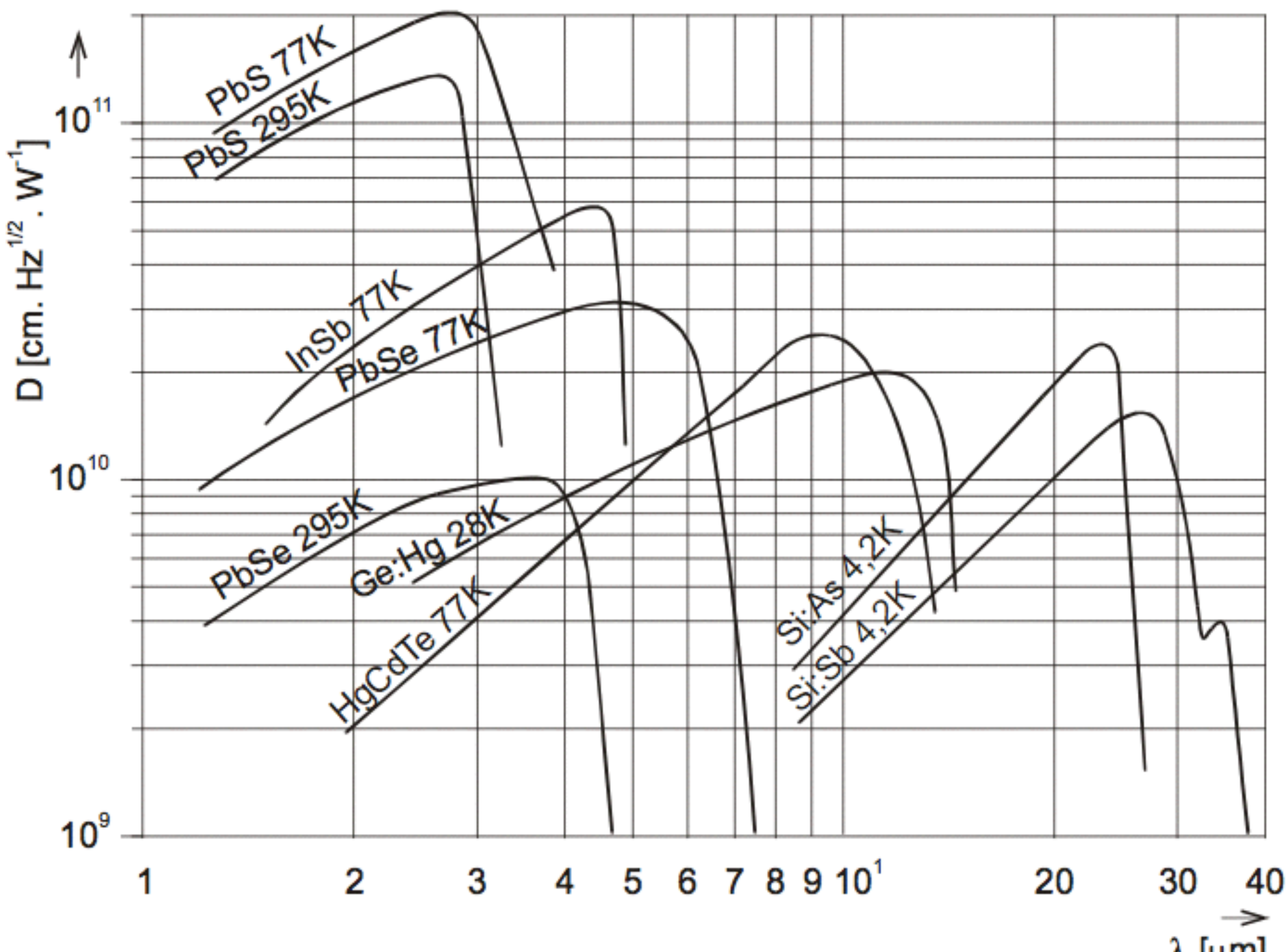


this is not exposed to
temperature but to the
same mechanical stress

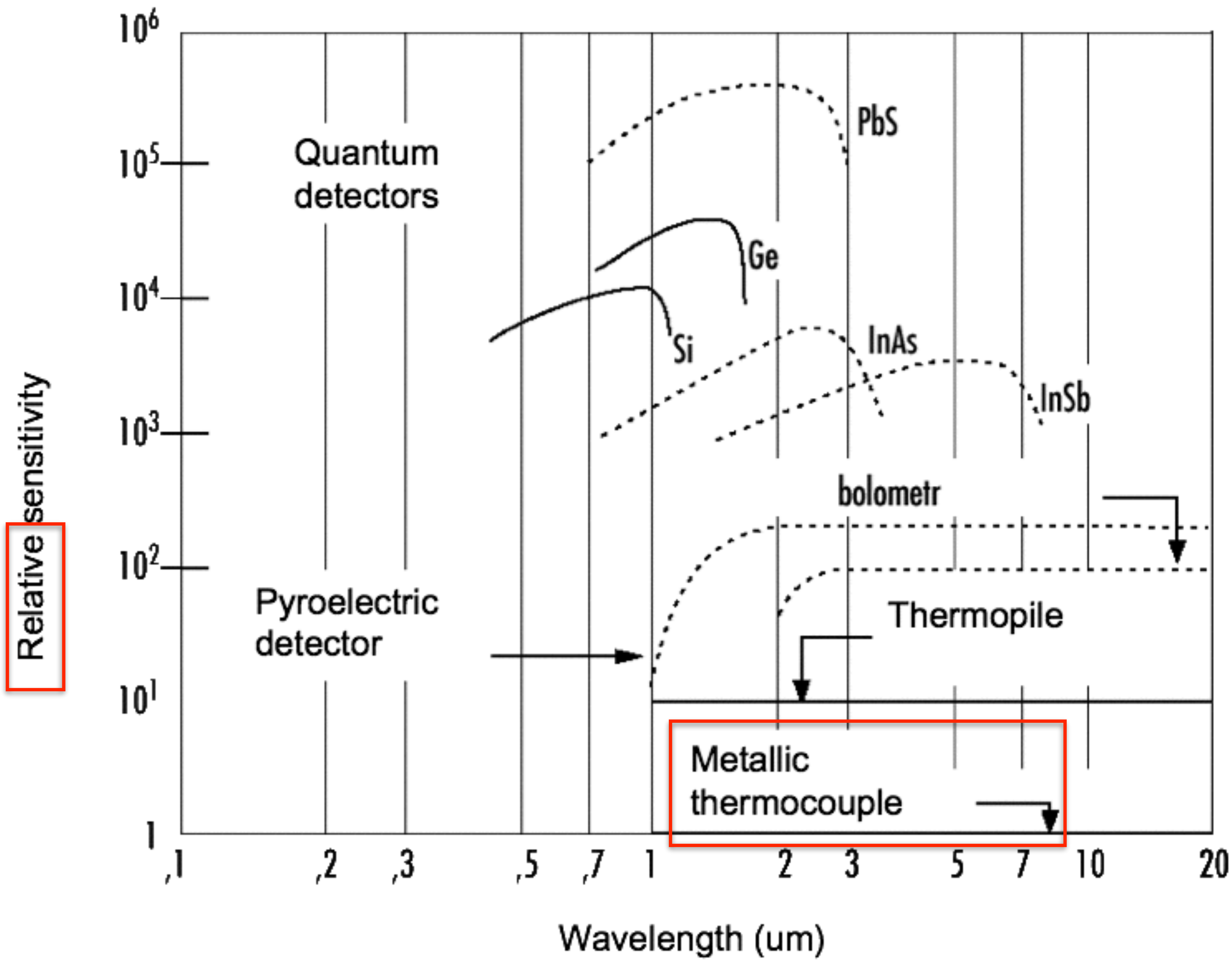
Quantum (photoelectric) detectors

Basically as photodiodes.

Detectivity of quantum IR radiation detectors:

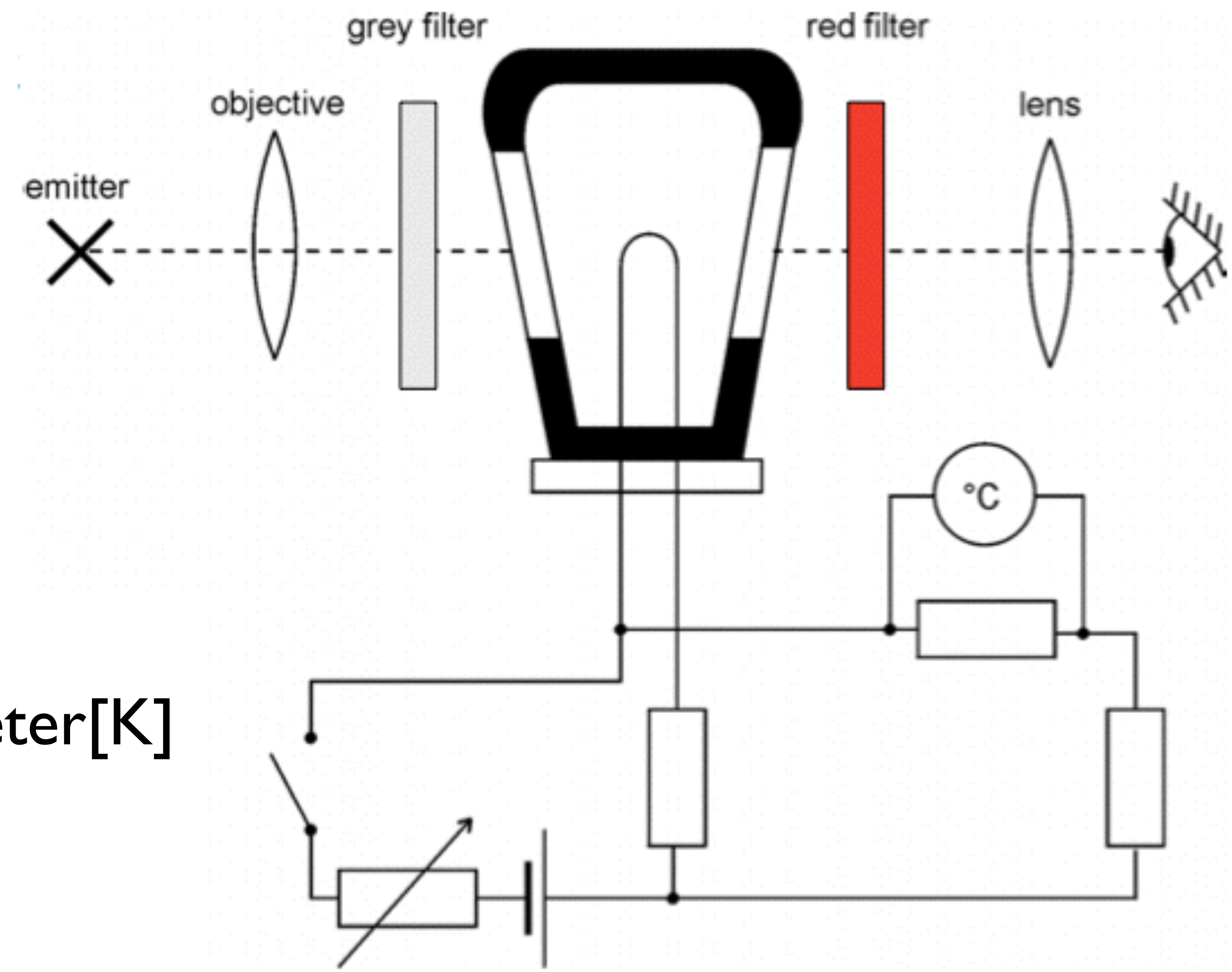


Comparison of sensitivity



Disappearing filament pyrometer
(optical narowband pyrometer)

$$\frac{1}{T_S} = \frac{1}{T_0} + \frac{\lambda}{c_2} \ln(\varepsilon_\lambda \tau_\lambda)$$

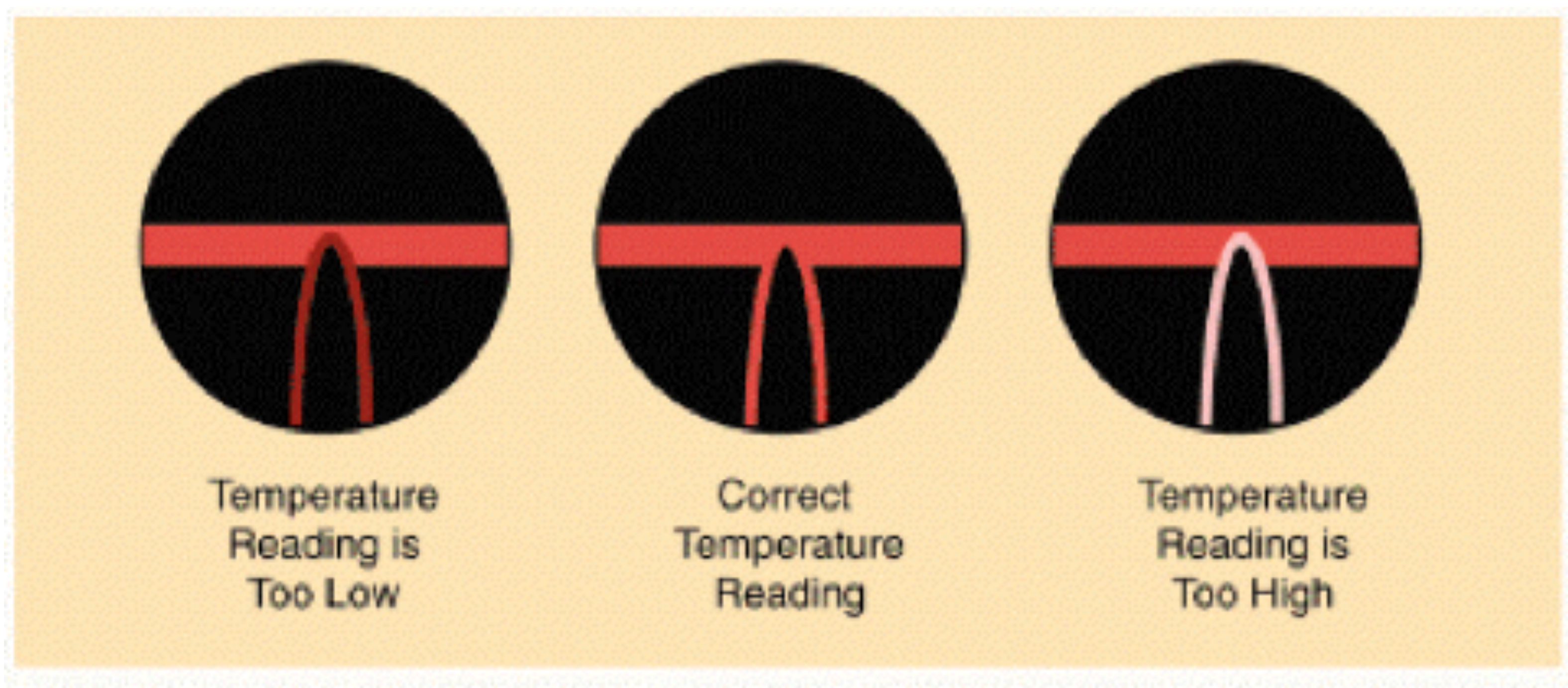


T_s =true temperature[K]
T_0 =temp. measured by pyrometer[K]
λ = wavelength[μm]
constant c_2=1.44 10^{-2} [m.K]
ε_λ=emissivity
τ_λ=spectral transparency

Disappearing filament pyrometer

(optical narowband pyrometer)

working principle



you change the current in the filament will is becomes of the same color as the background. If so, it means the color is the same, thus also the temperature. From the setting of the current we derive the temperature of the filament.