A new facility for thermal conductivity measurements

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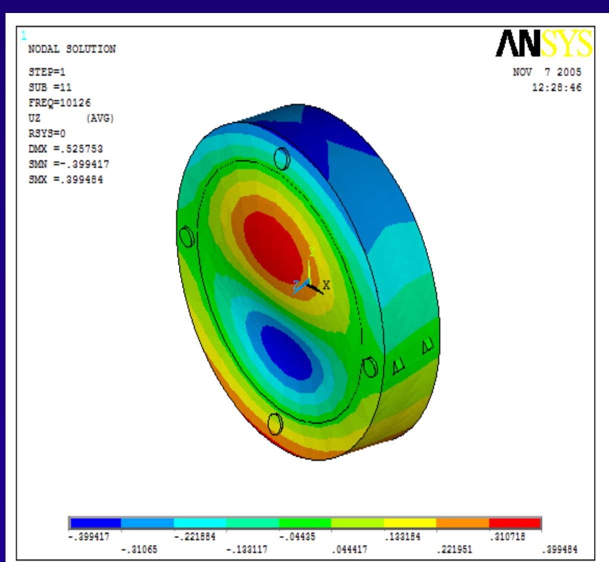
Activities on thermal noise in Florence

- Modelling of thermal noise for Virgo optics and suspensions
- Measurements on crystalline silicon fibres
- Study of new materials for 3rd generation interferometric GW detectors (JRA3-STREGA collaboration)



Cryogenic facility

Study of the t  es of materials

Thermal conductivity

Thermal expansion coefficient

Thermoelastic properties

Amplitude of thermoelastic peak

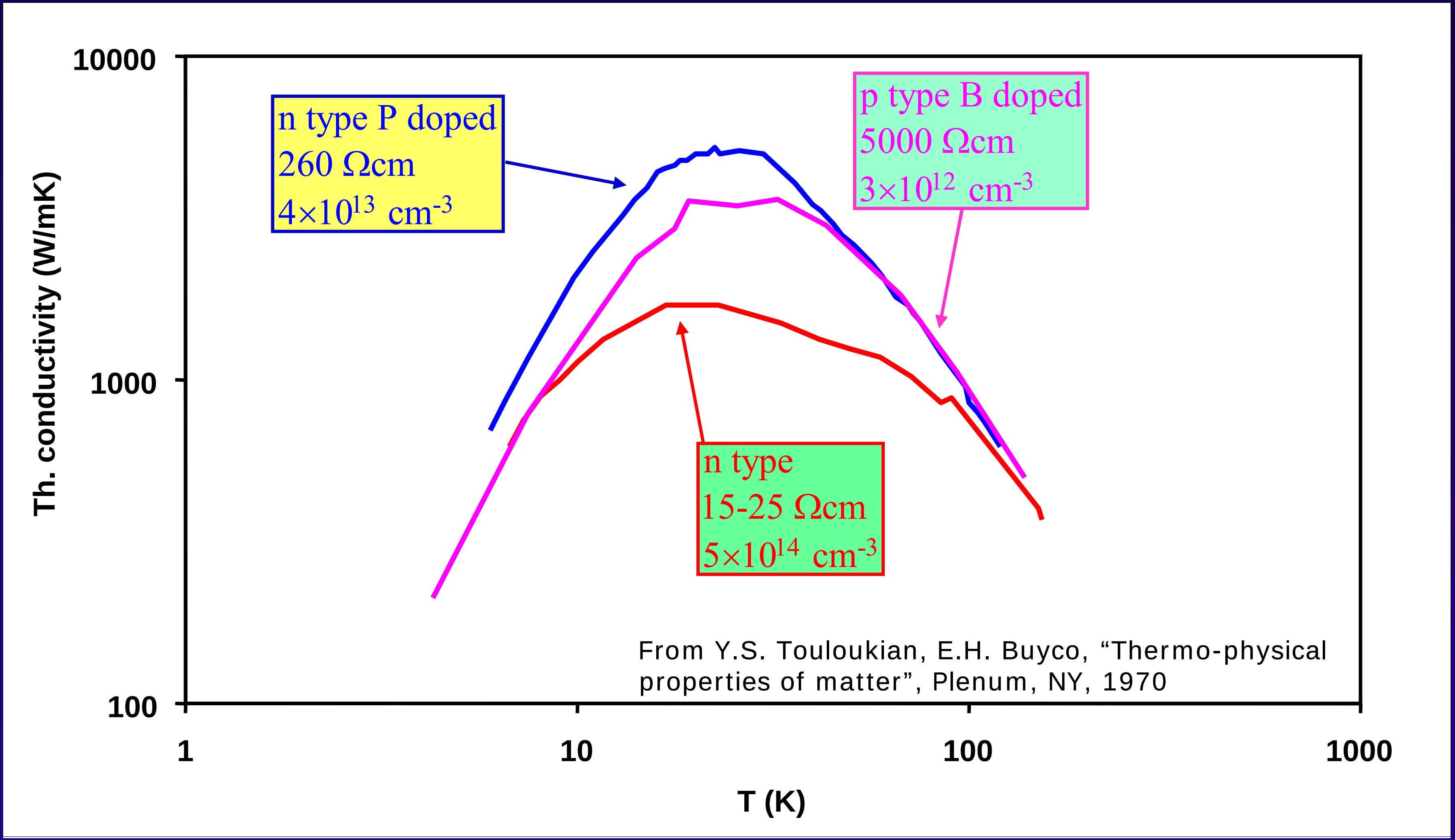
$$\Delta = \frac{E\alpha^2 T}{c_V}$$

Position (cylindrical sample)

$$\frac{1}{f_p} = \frac{1}{2.16}\frac{c_V d^2}{\kappa}$$

- **Knowledge of the thermoelastic peak is important for identification of the various contribution to the loss angle (study of bulk, surface, clamp....losses)**
- **Knowledge of thermal conductivity is crucial for suspensions to be used in cryogenic detectors (heat extraction)**

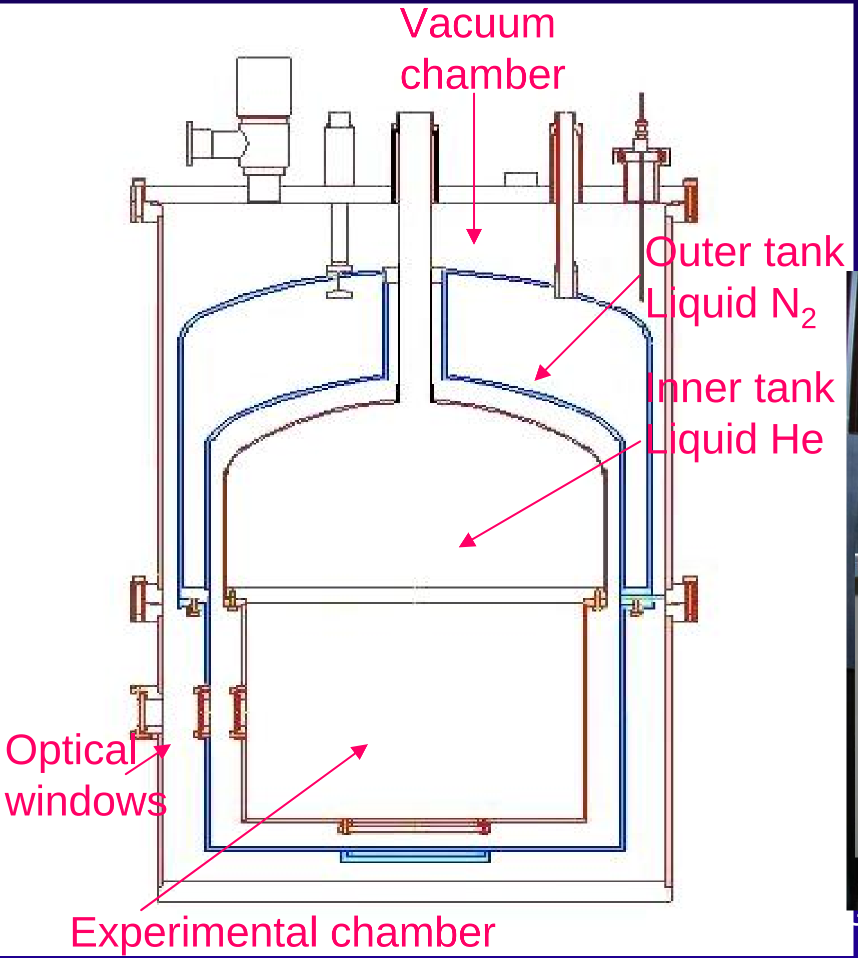
Thermal conductivity of Si



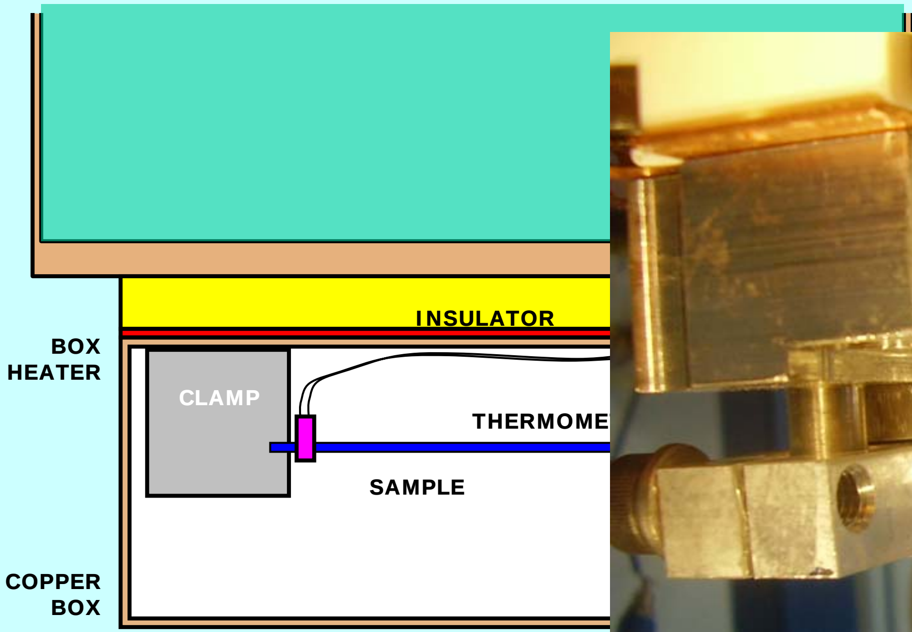
The cryostat

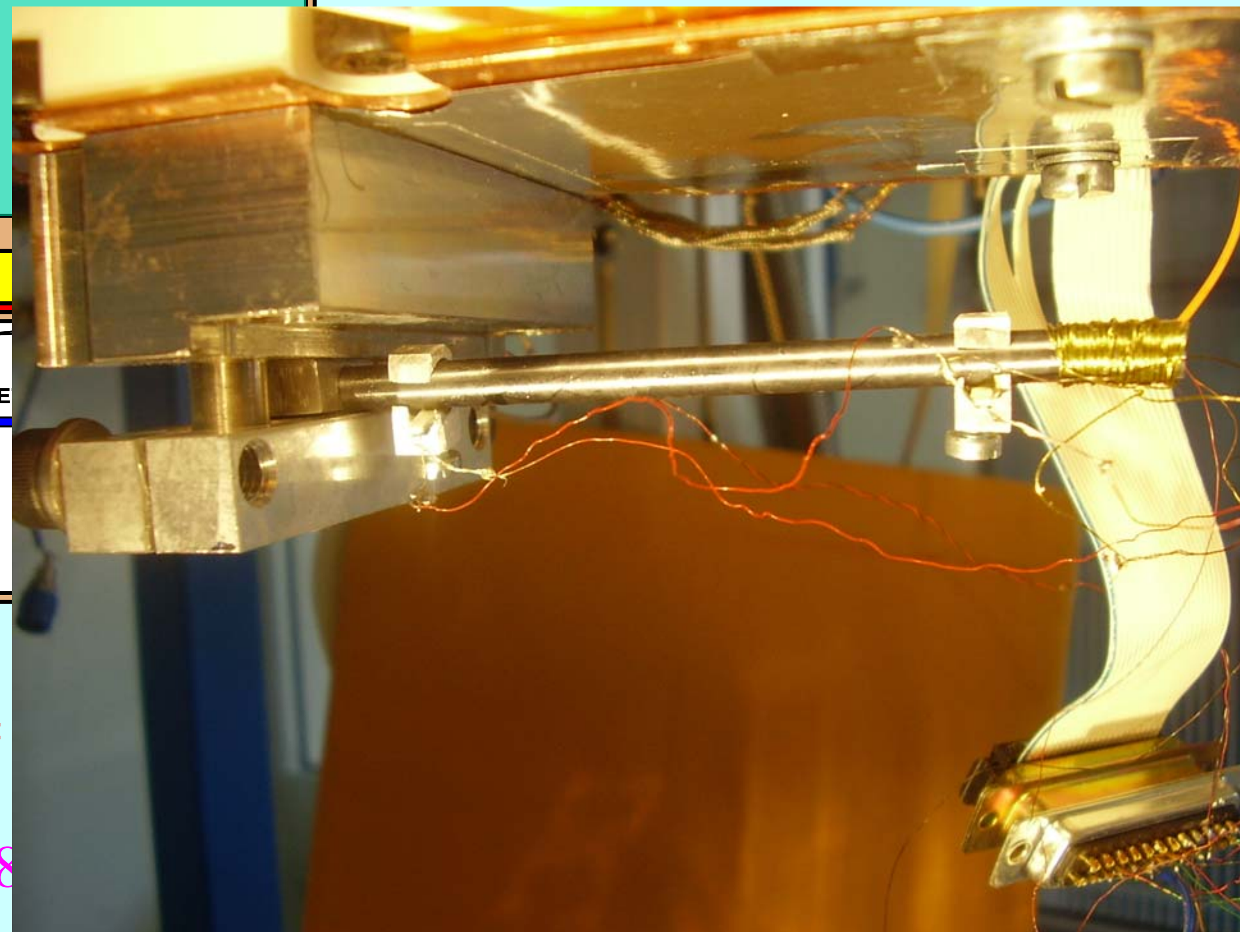
A.S. Scientific cryostat

Experimental volume:
about 14 dm^3



Thermal conductivity measurement





$$\Delta T = 100\ \mathrm{mK} \qquad P =$$

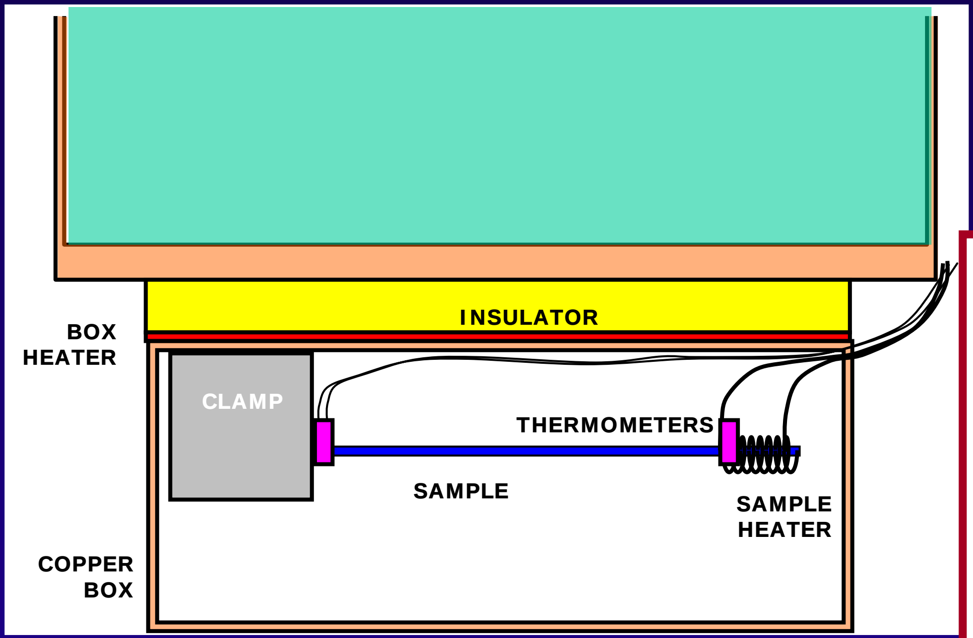
$$\kappa = P \frac{L}{S_{tr} \Delta T}$$

L=5.8

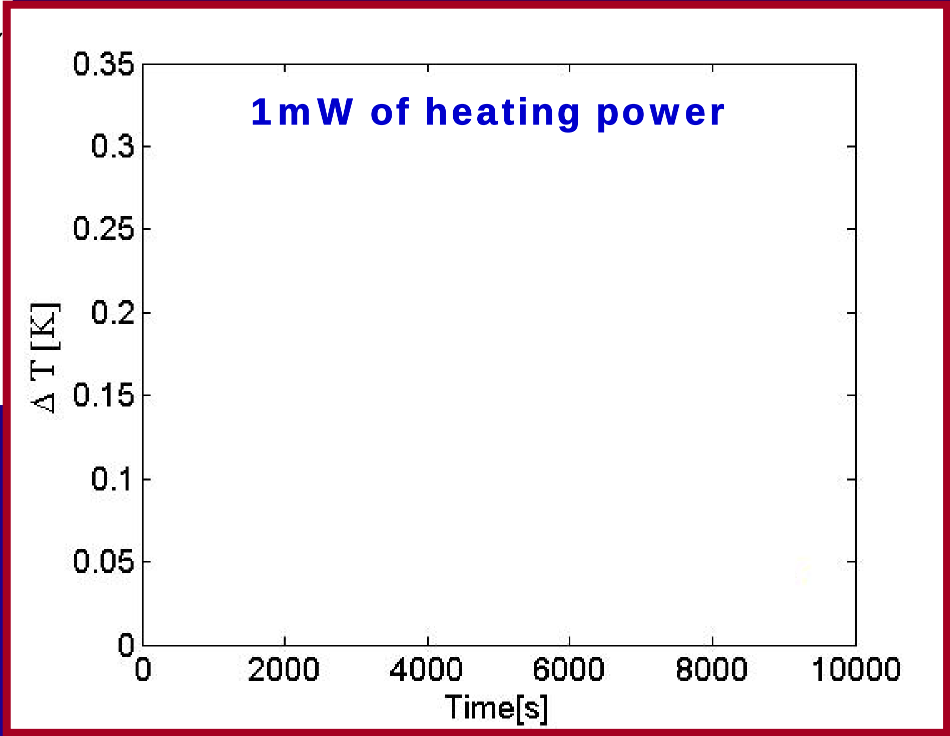
D=5 mm

Evaluation of the power loss

Heat loss is due mainly to radiation (small contribution by wire conduction)



Conductive losses through wires are negligible (0.1 % of radiative losses at room temperature)

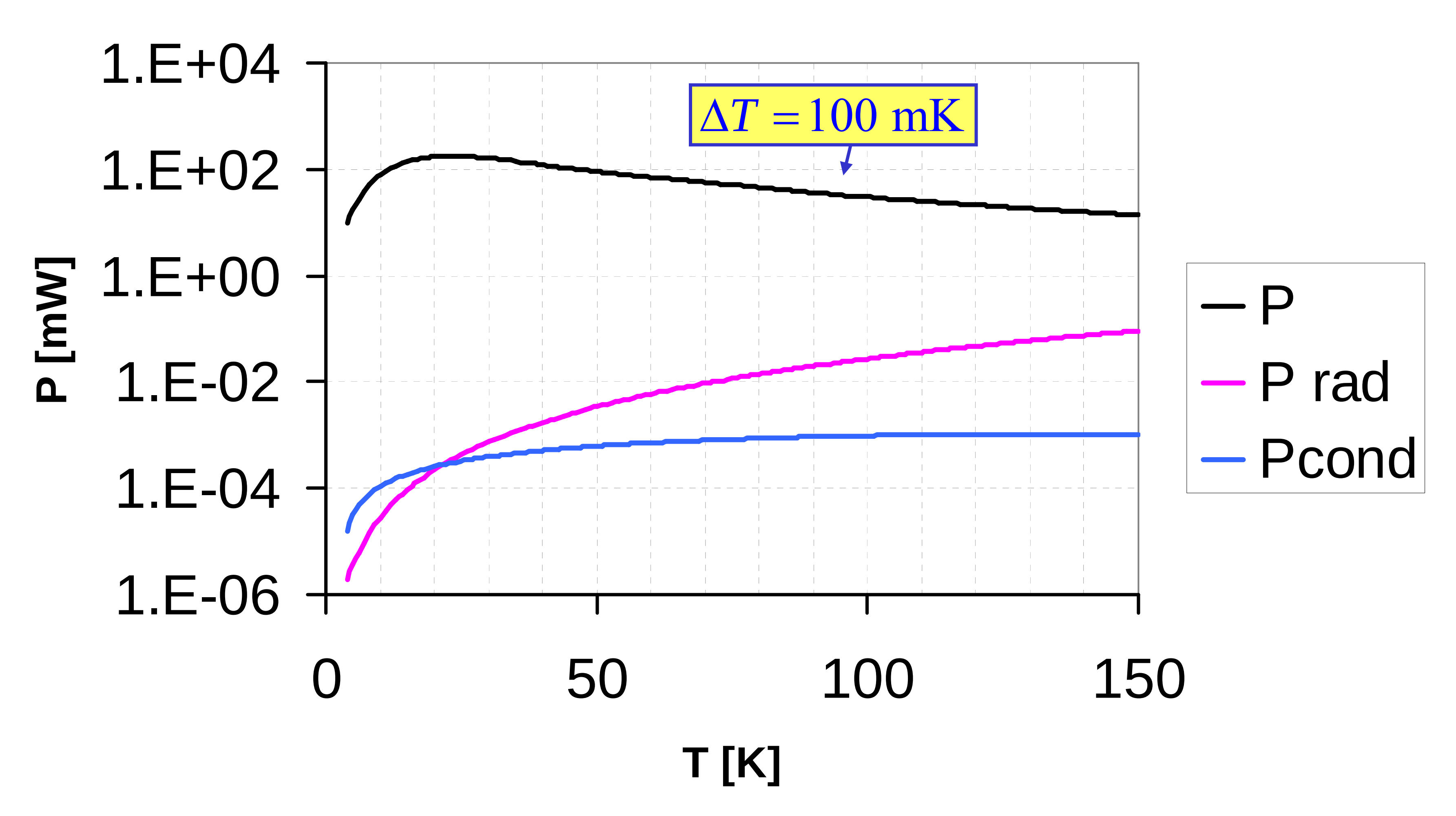


From the heating-cooling cycle at room T

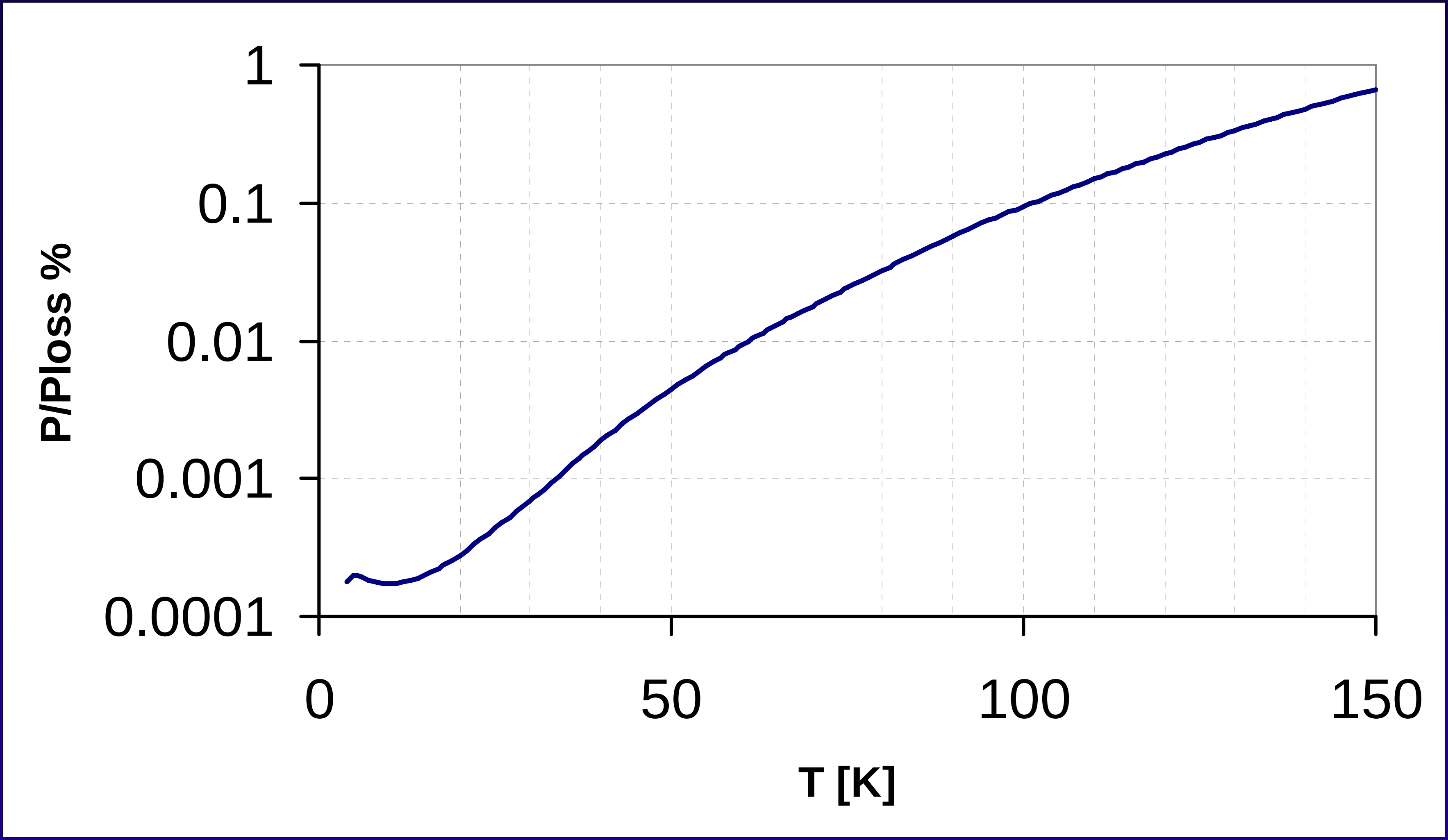
we evaluate the unknown parameter in radiative losses

$$P_{\mathrm{rad}} = 4\sigma\varepsilon T^3 \Delta T$$

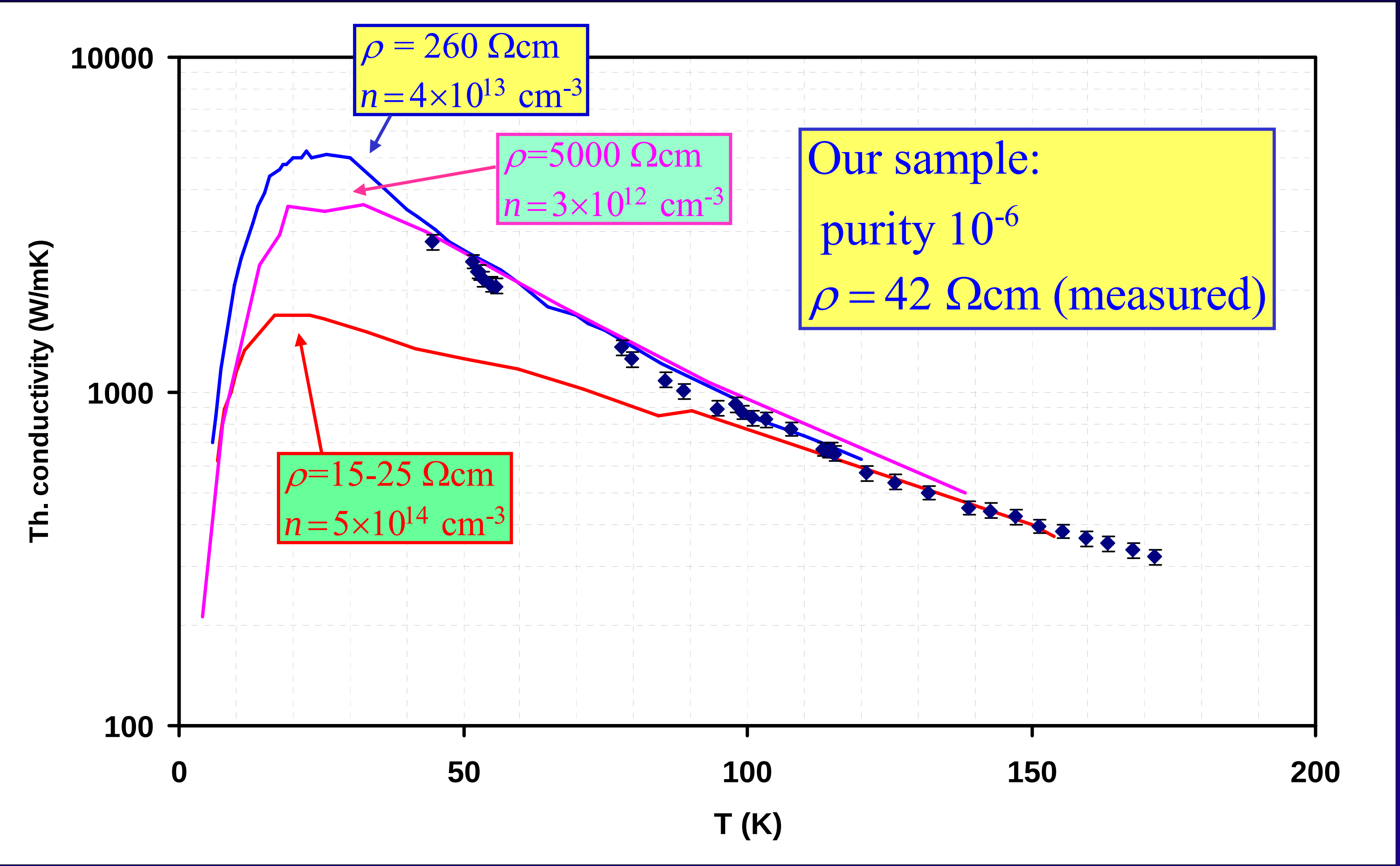
Power loss estimation



Power loss estimation



Results


ρ = 260 Ωcm
n = 4×10^13 cm^-3
ρ=5000 Ωcm
n = 3×10^12 cm^-3
Our sample:
purity 10^-6
ρ = 42 Ωcm (measured)
ρ=15-25 Ωcm
n = 5×10^14 cm^-3
10000
1000
100
0
50
100
150
200
Th. conductivity (W/mK)
T (K)

Thermal expansion measurement facility

$$\alpha = 10^{-7}\ \mathrm{K}^{-1} \pm 10\% \quad \Rightarrow \quad \frac{\Delta L}{L} = 10^{-8}$$

$$\text{if } L = 10\ \mathrm{cm} \quad \Rightarrow \quad \Delta L = 10^{-9}\ \mathrm{m}$$

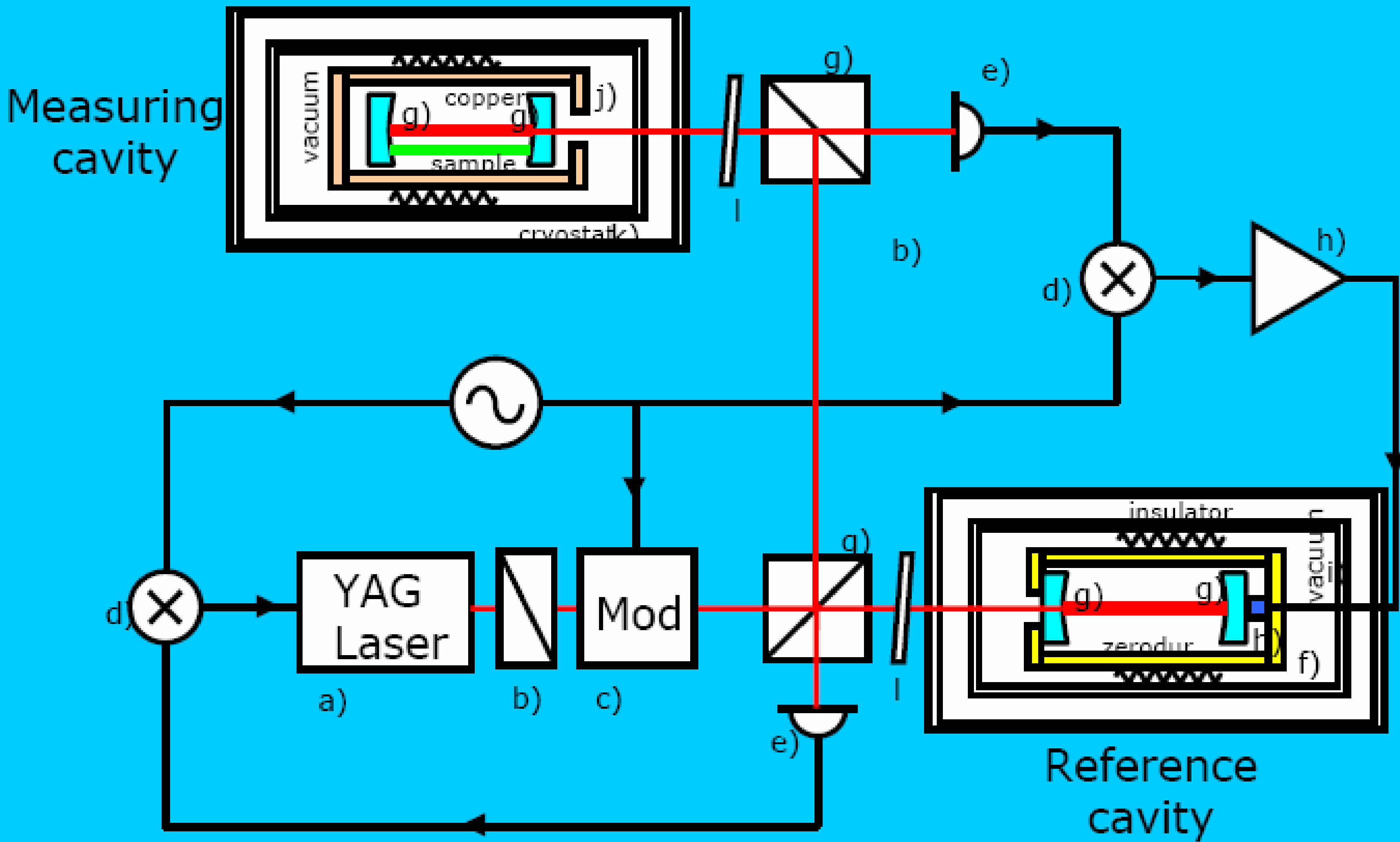
No hope with a simple Michelson !

Simple Fabry-Perot cavity

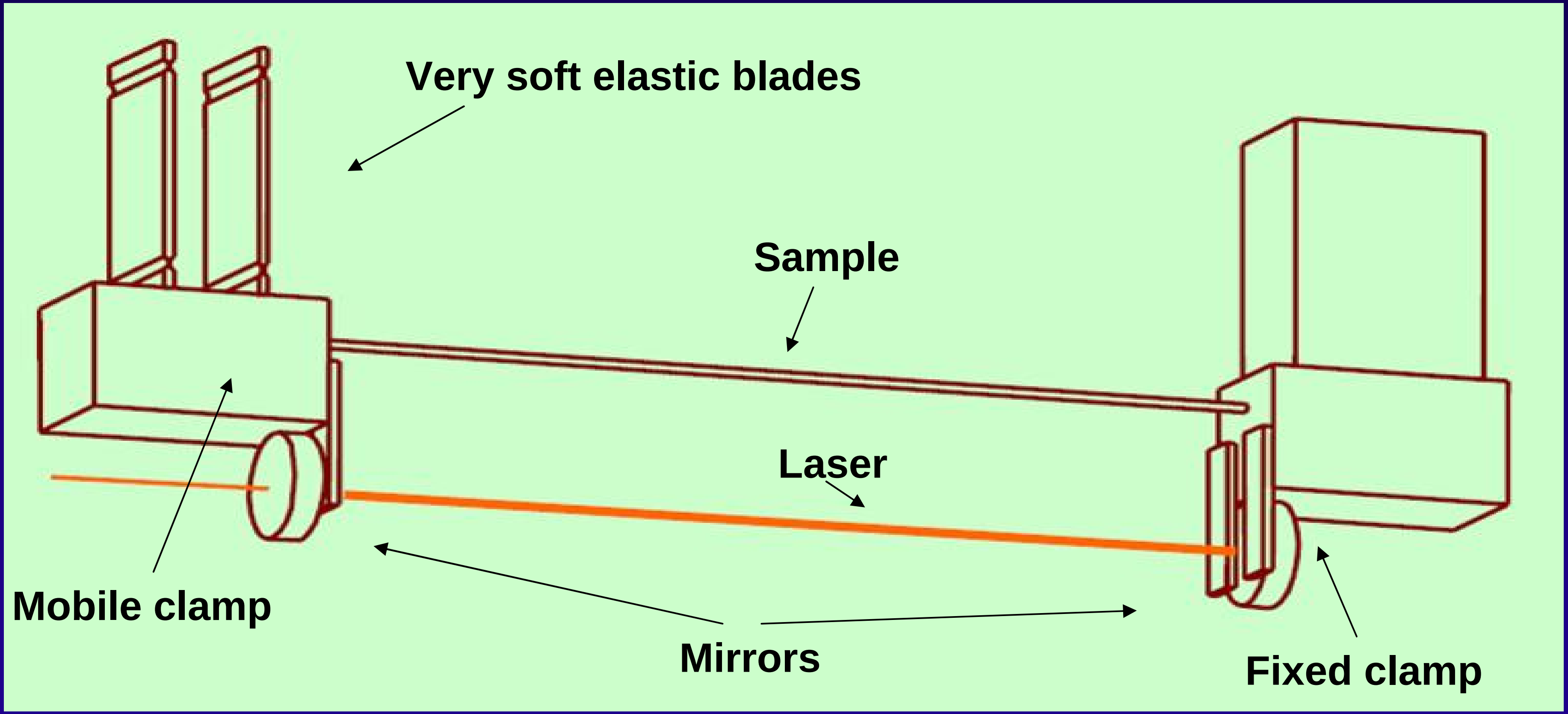
⇓

Problems from frequency stability !

Thermal expansion measurement facility



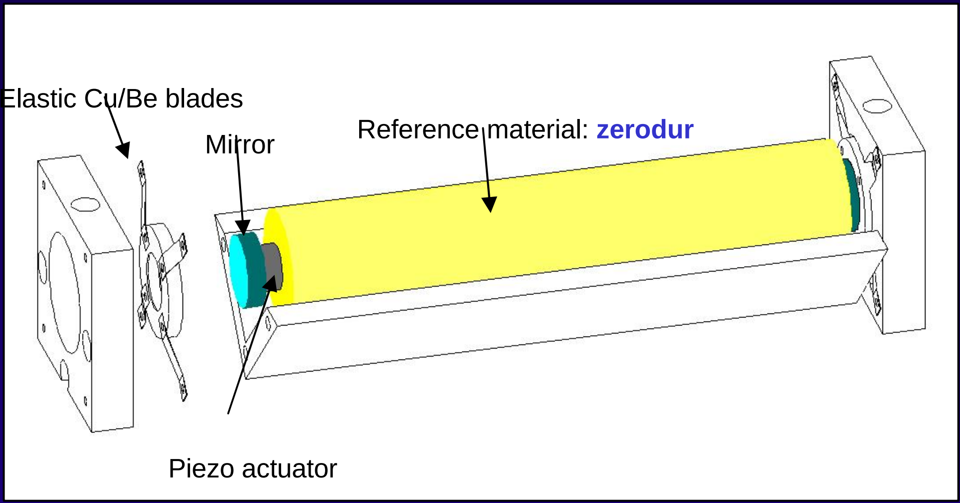
Measuring cavity

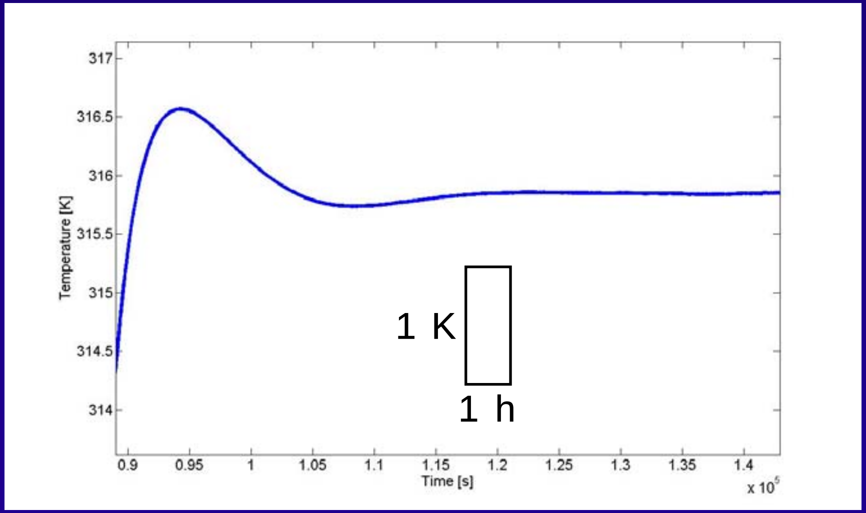


The reference cavity

Vacuum chamber hosting reference cavity

Heating wires for RC temperature control





Result of the temperature stabilization (Matteo Lorenzini)

T fluctuations must stay below 0.01 K

We now have a few mK stability

Conclusions

- We have a facility for direct measurements of thermal conductivity in samples shorter than 20 cm from 4 K up to room temperature
- First measurements on a Si sample down to 40 K show that the instrument is properly working (we need a better calibration)
- The setup for LHe should still be optimized
- We are studying the possibility of measuring the thermal expansion coefficient as well