# Mechanical loss measurements at low temperatures of coating and bulk materials

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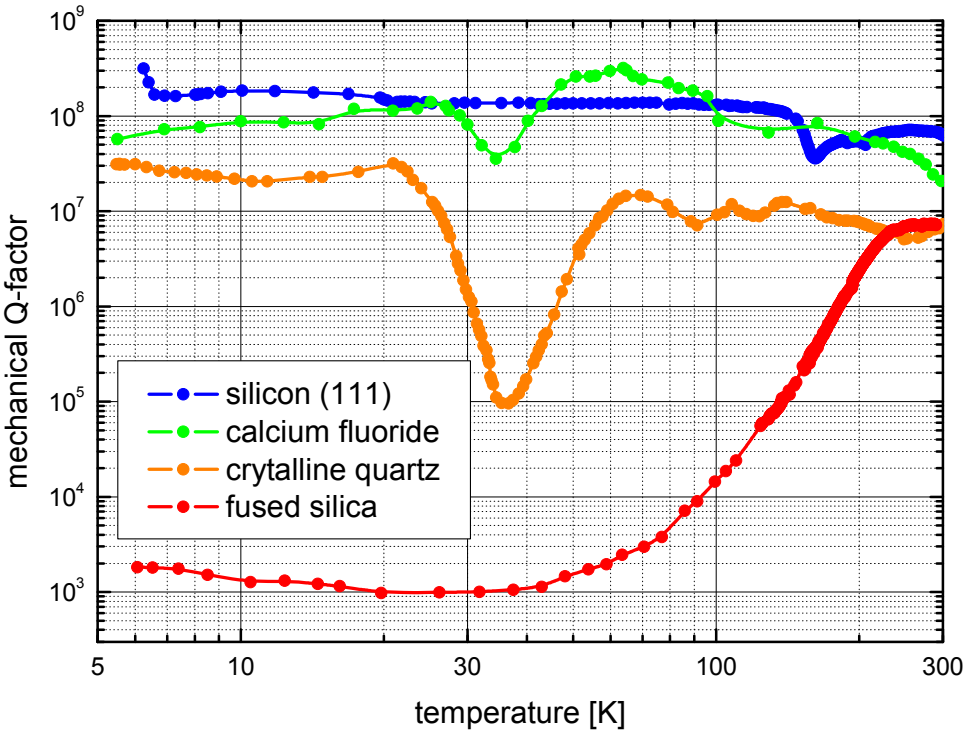
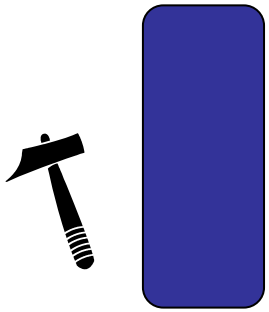
DFG / SFB TR 7

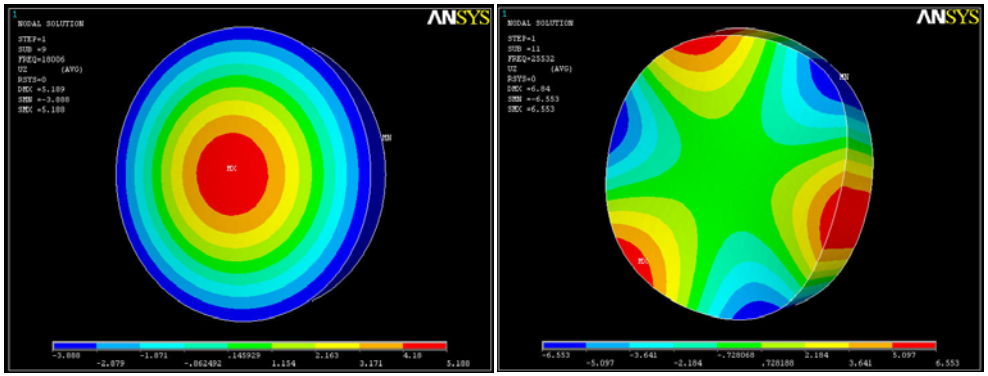
# Overview

- Measuring technique
- Cryogenic loss measurement setup
- Temperature dependence of the Q-factor / loss of bulk materials
- Cantilever setup and coating and suspension investigantions

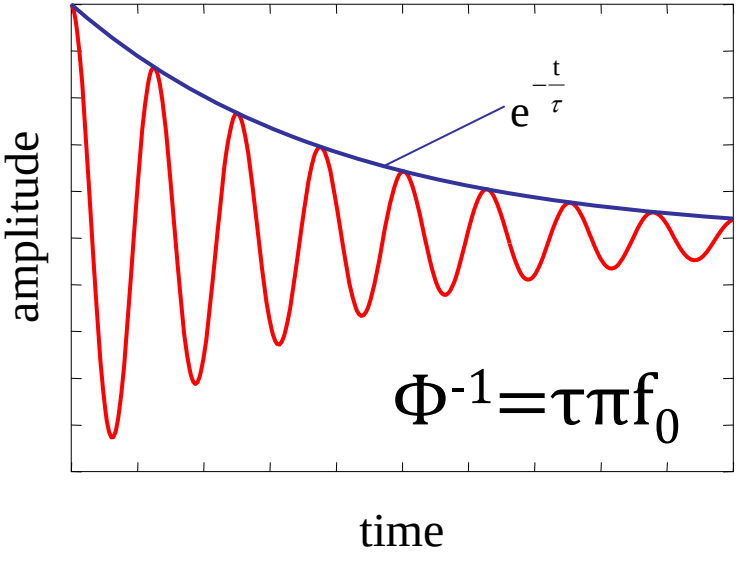


# Measuring Technique

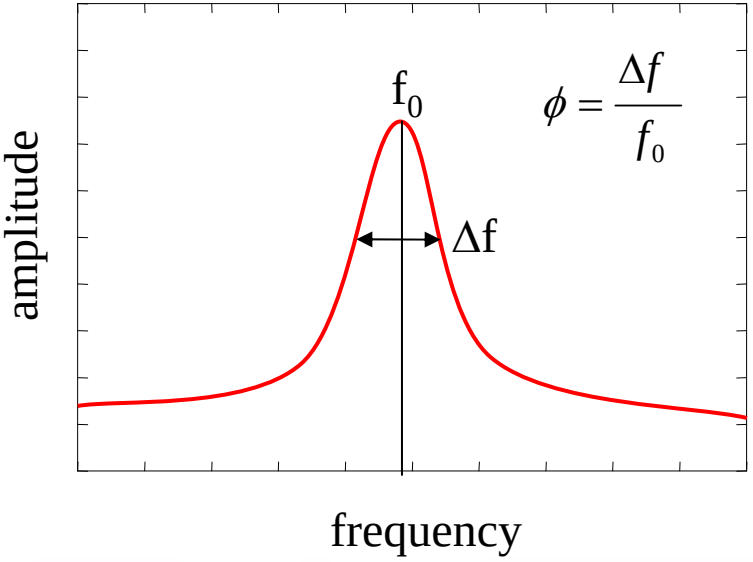




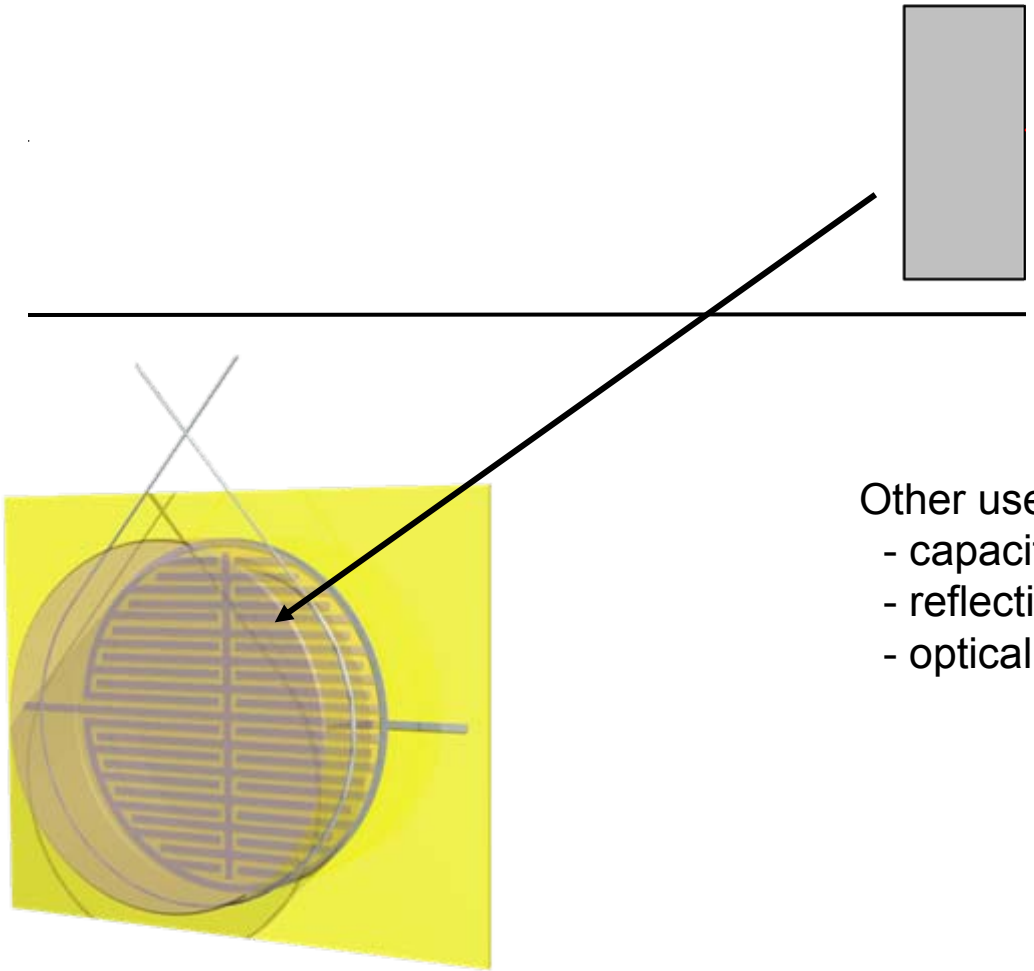

Determination of the mechanical loss via amplitude ringdown




… or bandwidth measurement

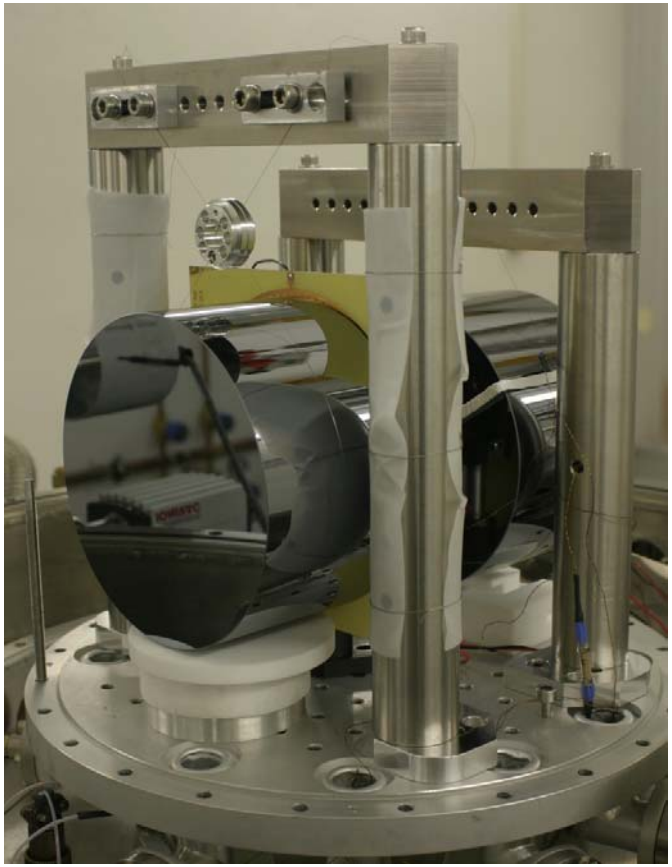


## Measuring Technique

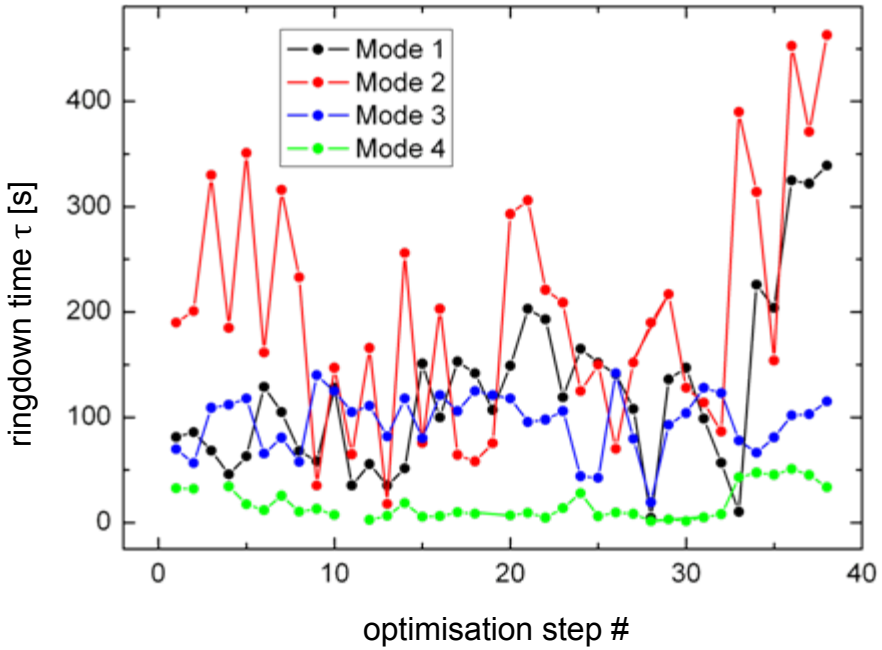


Other used read-out techniques:
- capacitive
- reflective (splitted photodiode)
- optical fiber

## Optimisation of the crystals orientation

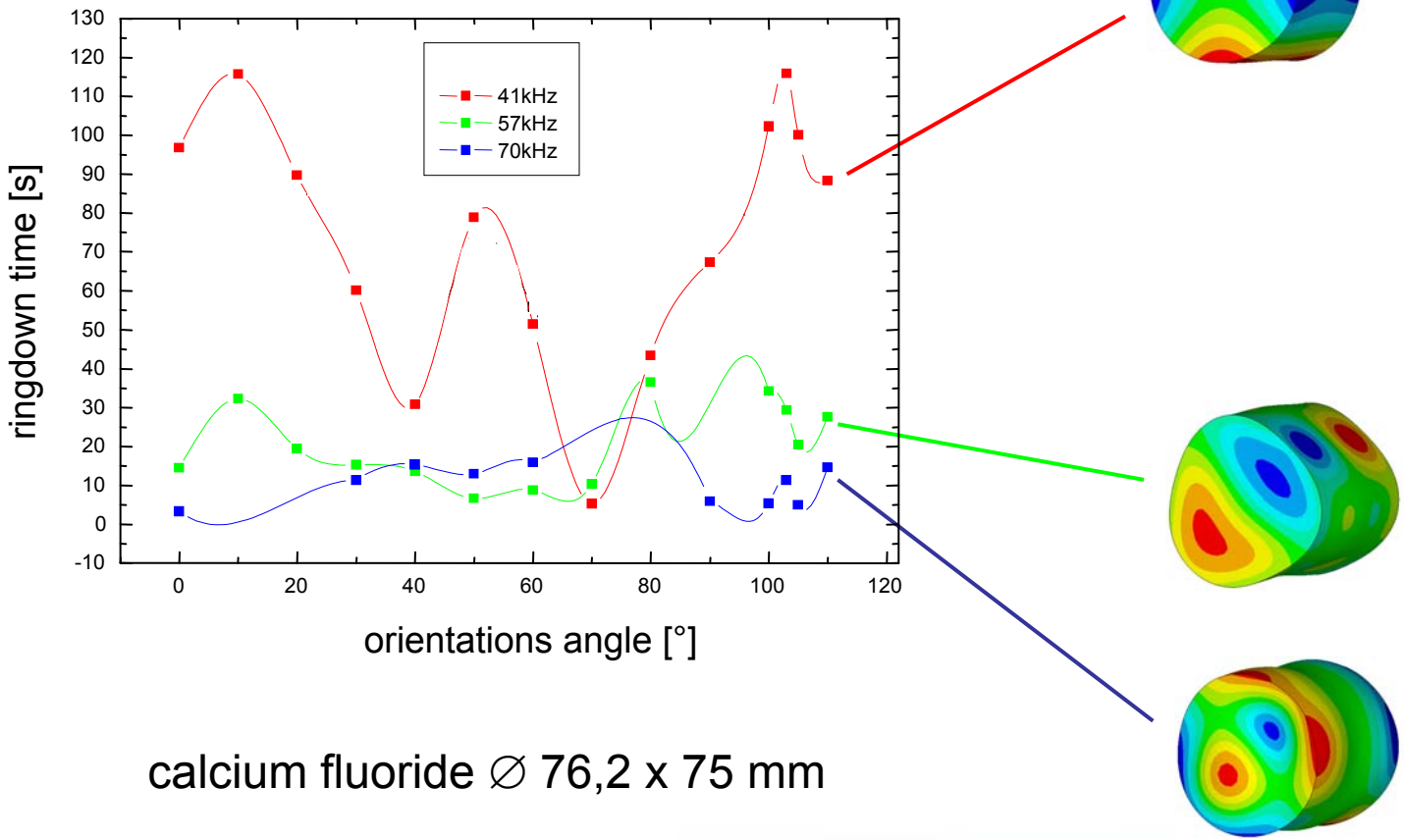


silicon (111)
∅ 150 x 96 mm (~ 4.1 kg)



## Optimisation of the crystals orientation

Ringdown time dependence of the modeshapes orientation angle within the the suspension wire loop



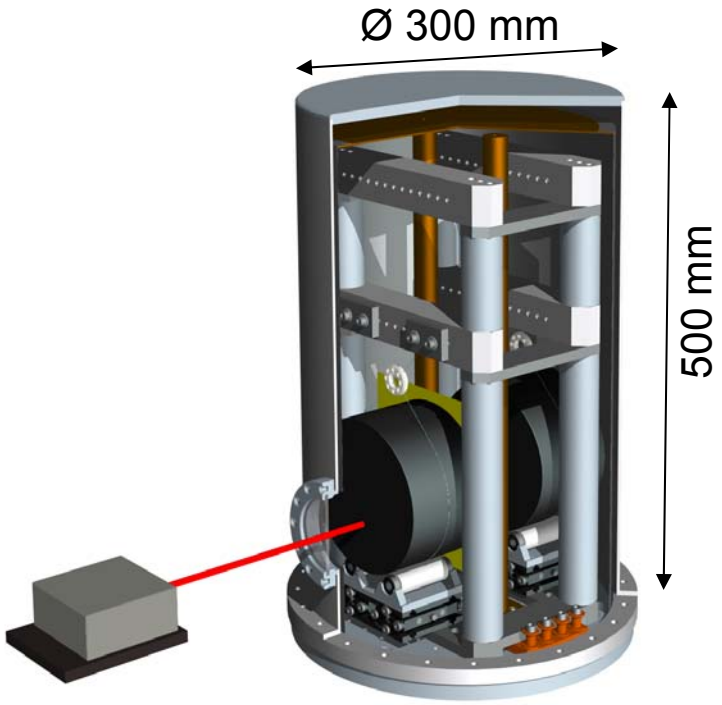

calcium fluoride ∅ 76,2 x 75 mm

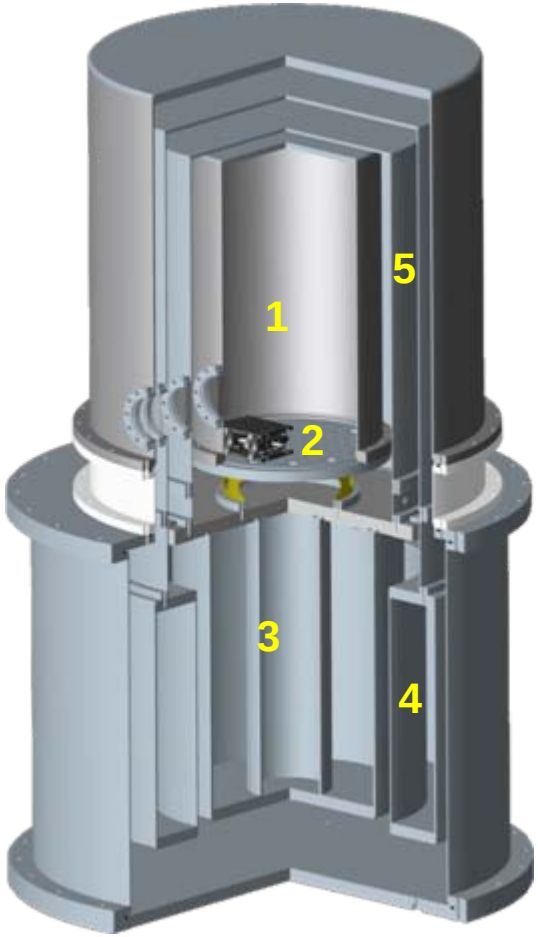
## Requirements for cryogenic loss measurements

- low pressure to avoid pressure damping
- wide temperature range
- long term stability in:
  - > temperature (± 0.2 K for hours)
  - > seismic isolation
- low external damping due to the suspension

# Environment for Bulk Material Research

## Experimental Setup




## Cryostat

1 probe chamber
2 experimental platform
3 LHe tank (49 l)
4 LN2 tank (62 l)
5 heat radiation shields

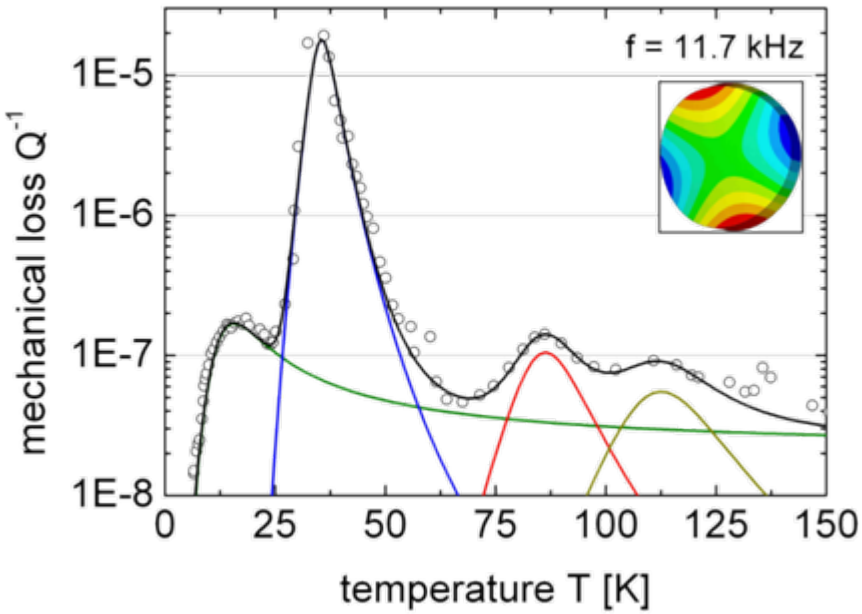
> T = 5…325 K
ΔT = ± 0.1 K

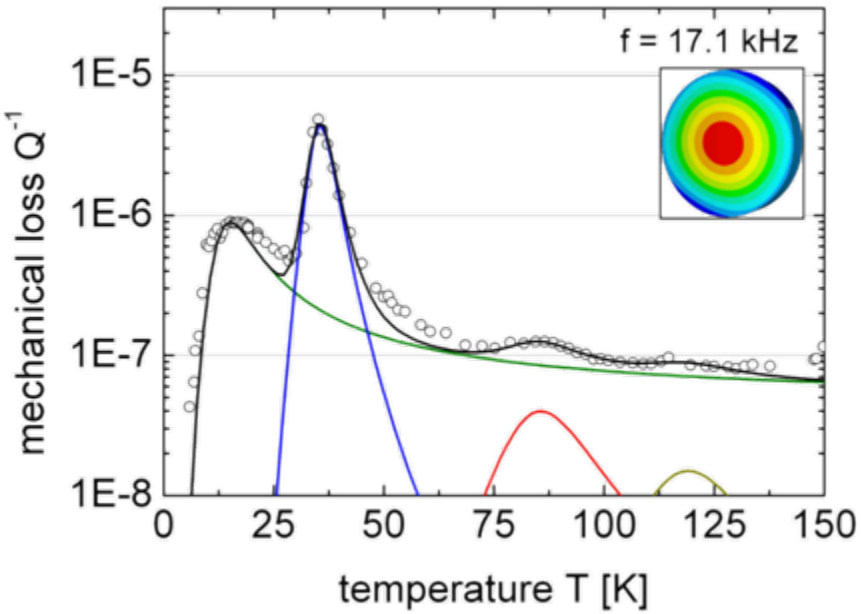
> $p < 3 \times 10^{-6}$ mbar

> LHe hold time of 36 h

→ Suitable for loss measurements on bulk material !!!

## Results for the mechanical loss of crystalline quartz



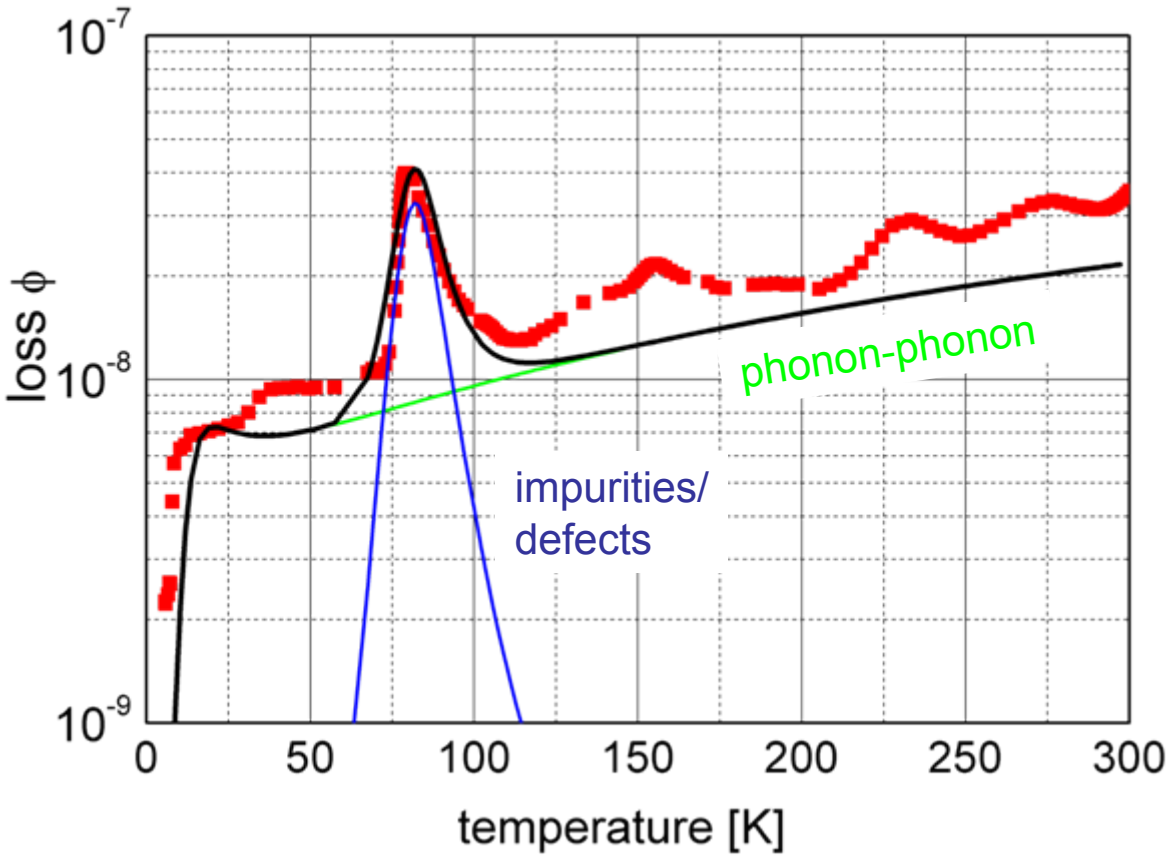




- blue, red and yellow peaks identified as result of impurity atoms (aluminium and alkali atoms)

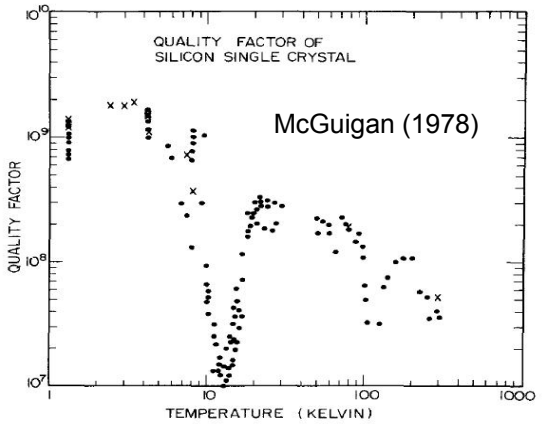
  [Martin 1984, Fraser 1964, …]

- green peak explained by thermoelastic and phonon-phonon damping

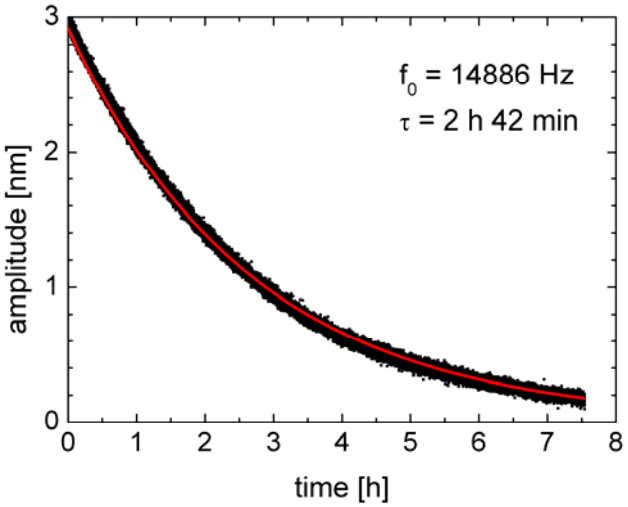
# Dissipation peaks due to impurities in silicon bulk materials

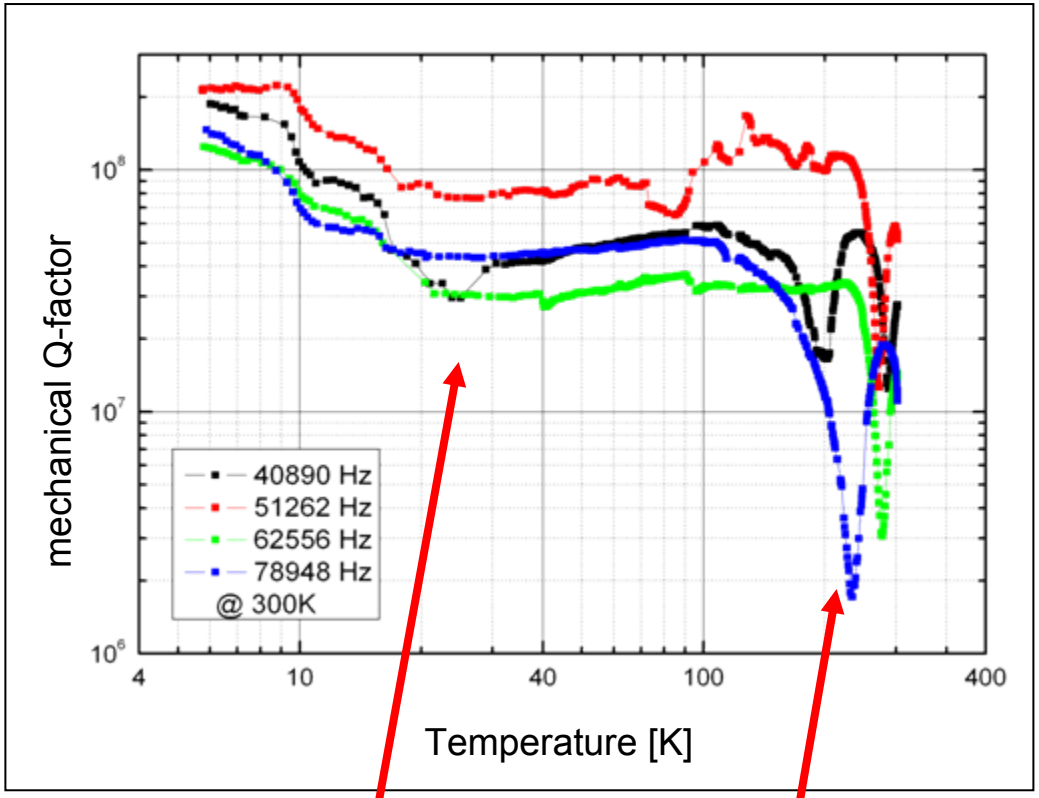



Silicon, Ø 3” x 12 mm



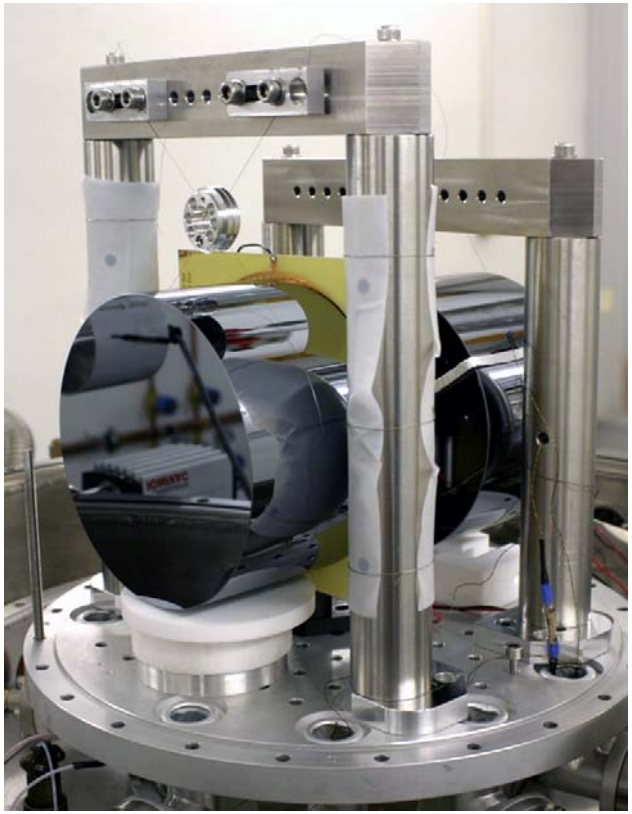

$\Phi_{min} = 2.2 \times 10^{-9}$ @ 5.8 K





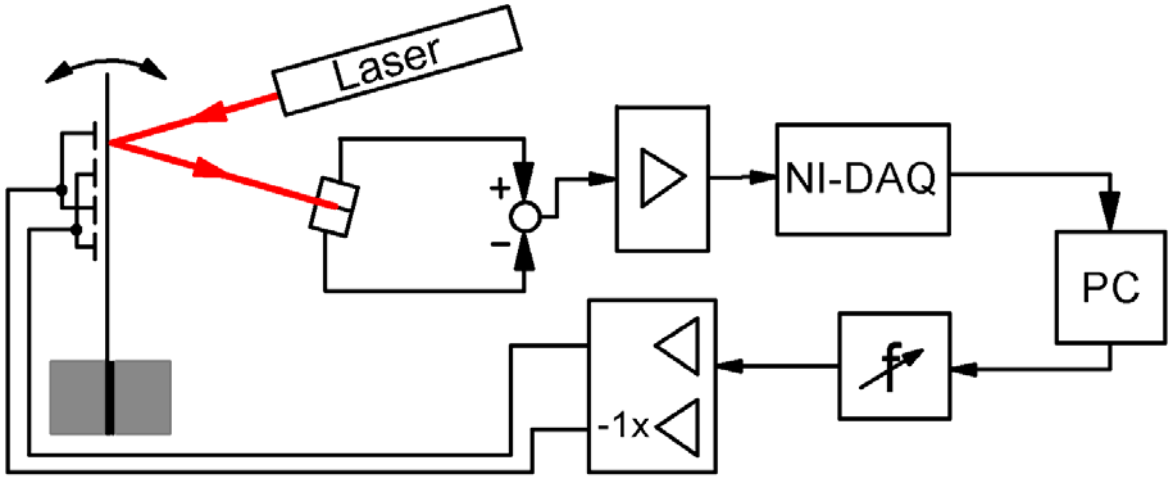

"flat" profile at low temperatures

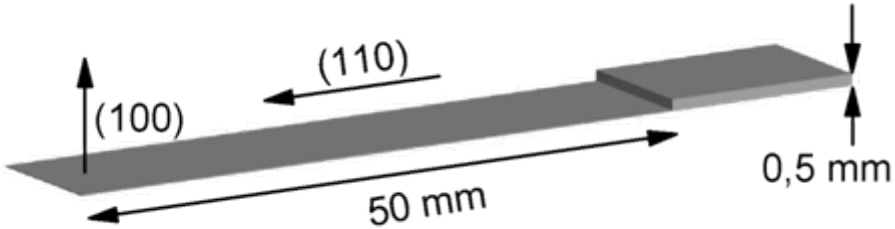
dips between 100 and 300K

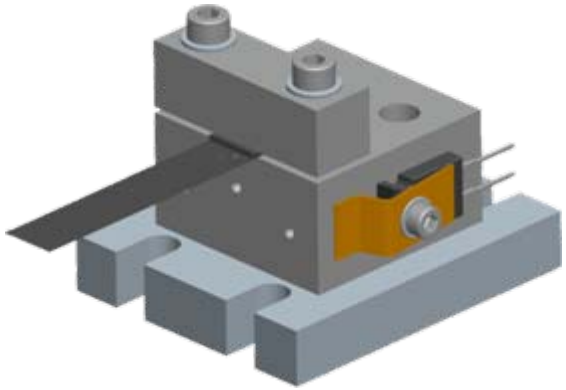


silicon (FZ), Ø 6" x 96 mm

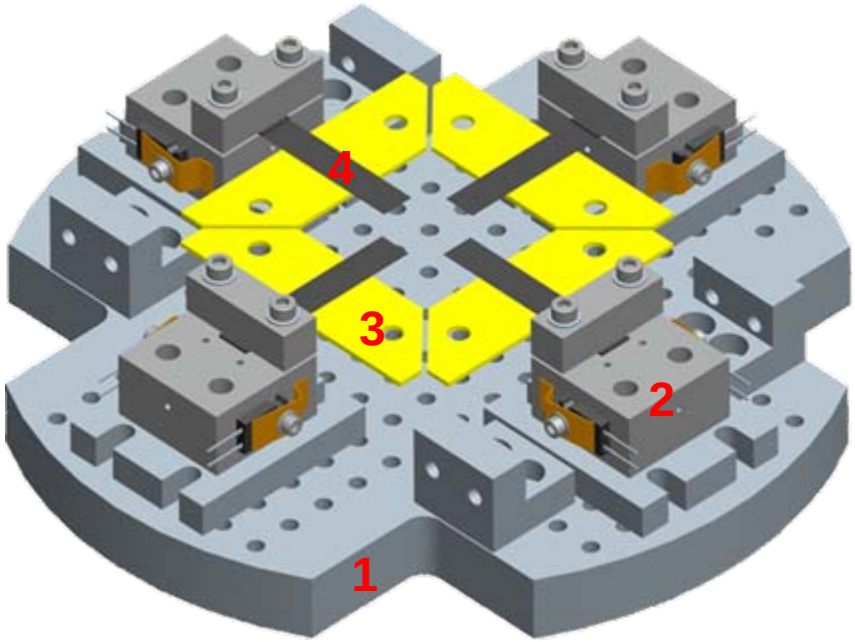
# Cantilever Coating Research

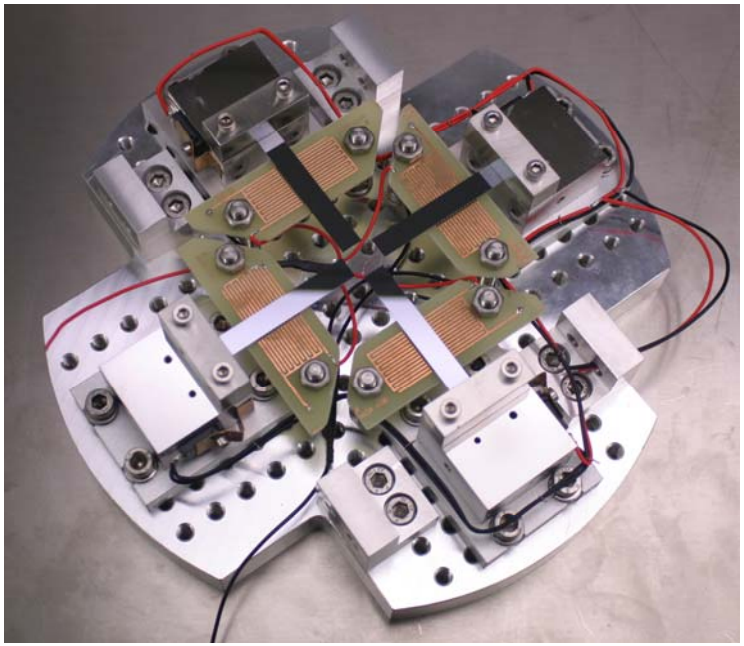


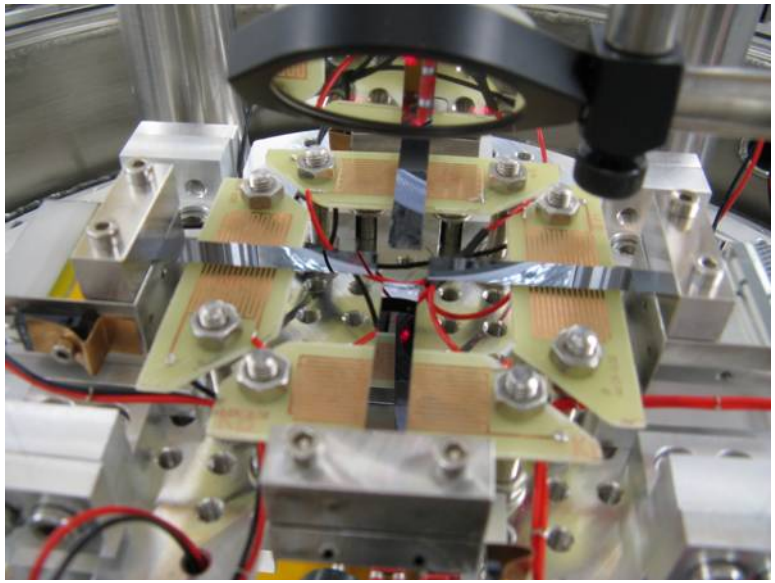



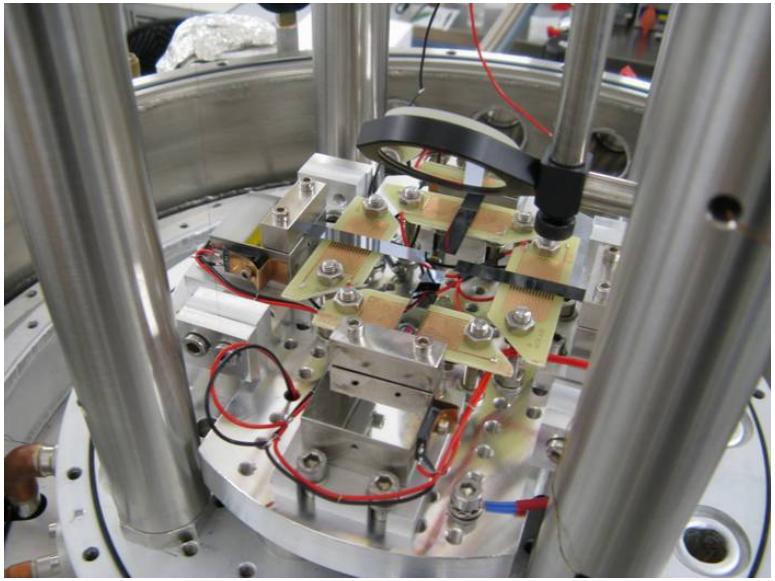
# Cantilever setup for the “large” cryostat



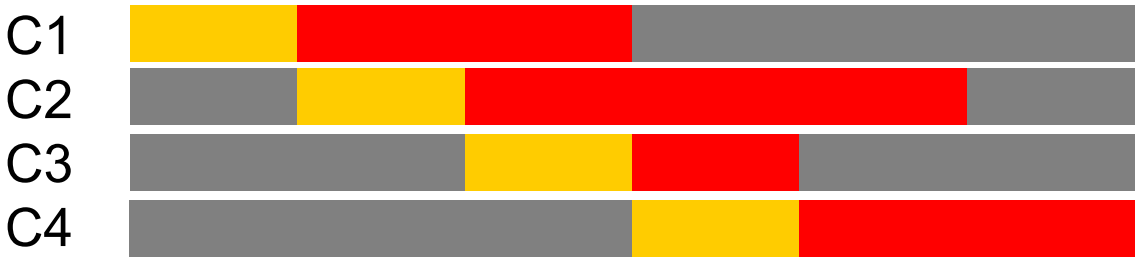



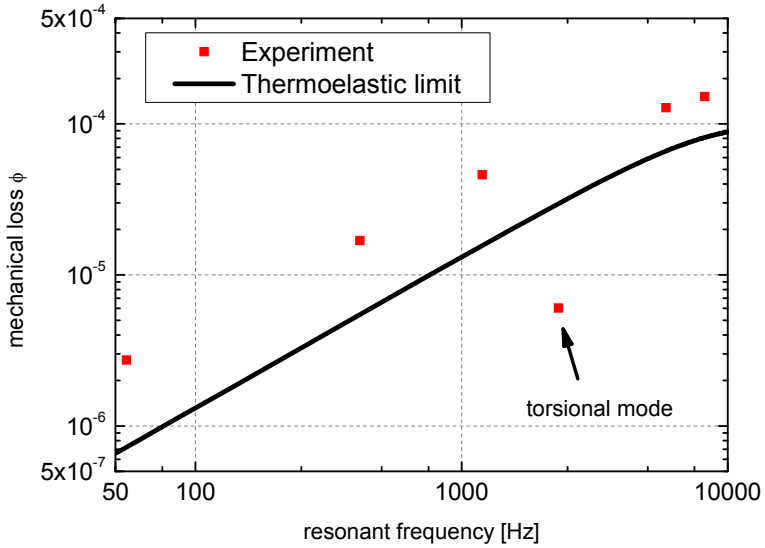
1 massive base plate
2 cantilever clamping blocks
3 excitation structure mount
4 cantilever

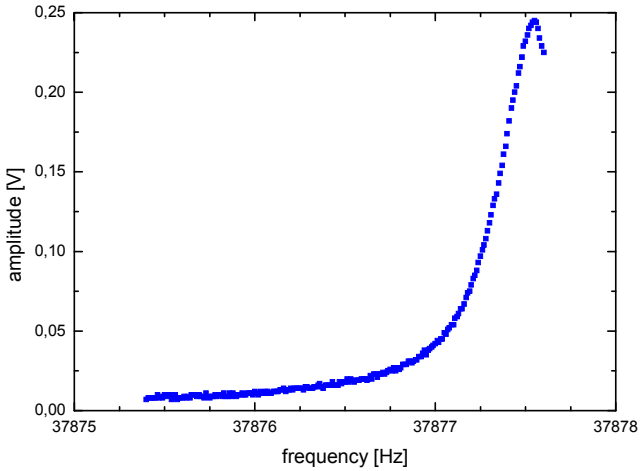


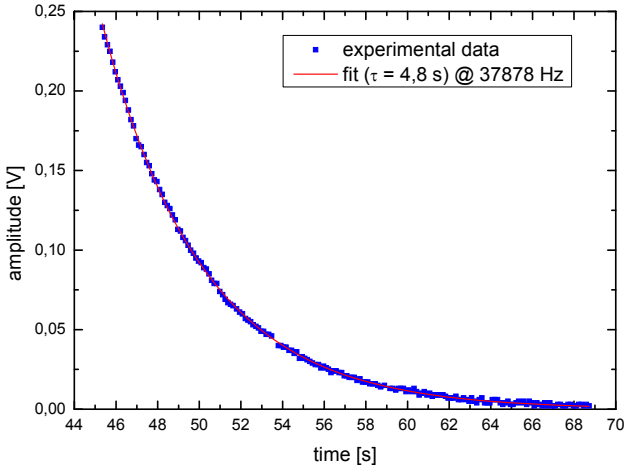


Measurement procedure: Excitation Wait Ringdown

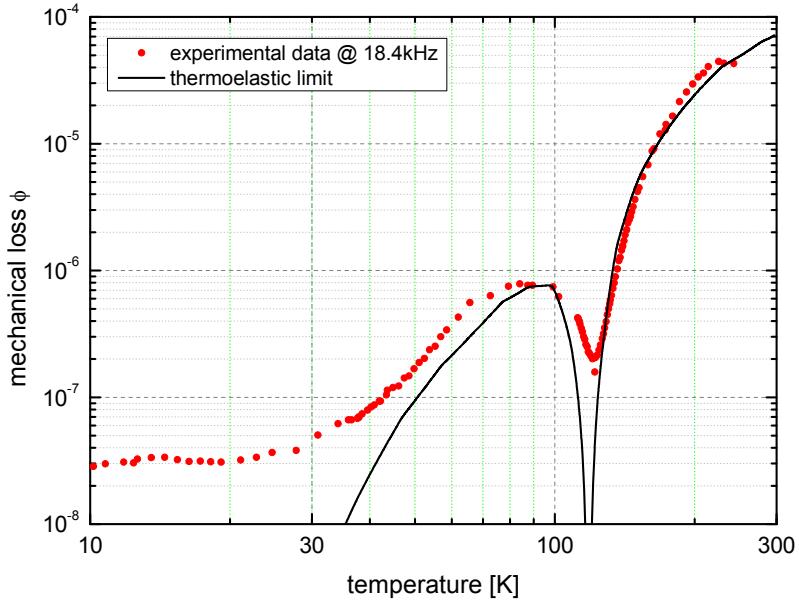


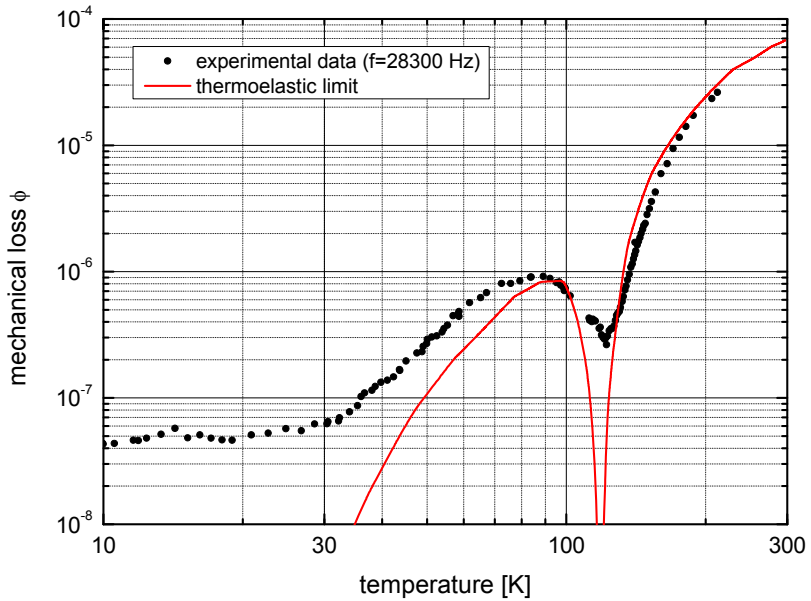


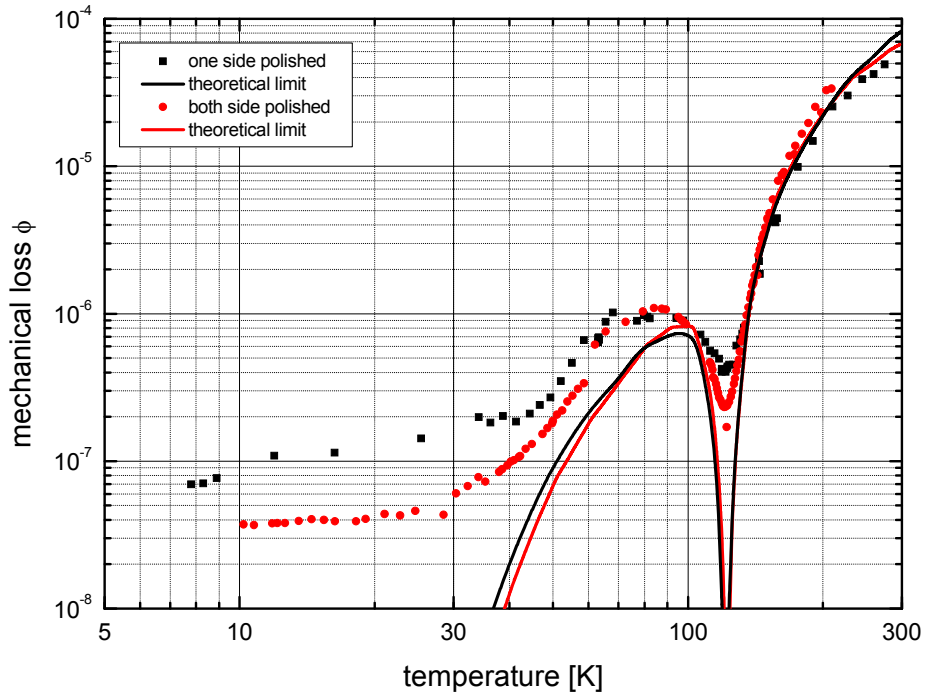

- available frequency range:
  20 Hz …. 90 kHz



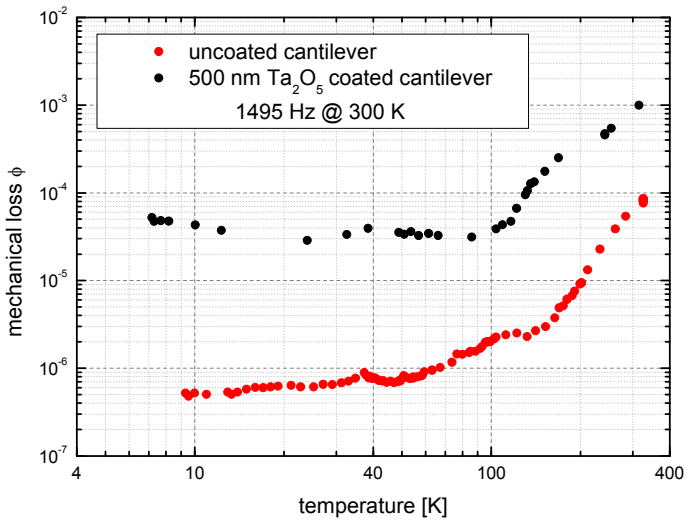



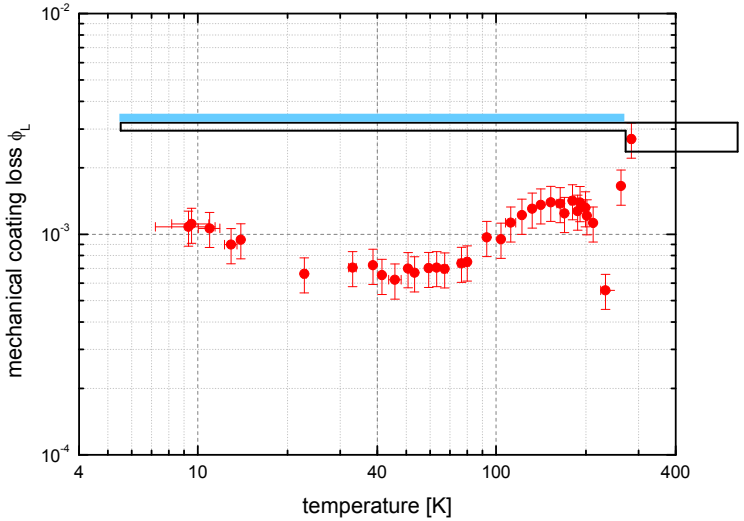

• losses at the thermoelastic limit

comparison between an one side polished and a two side polished cantilever

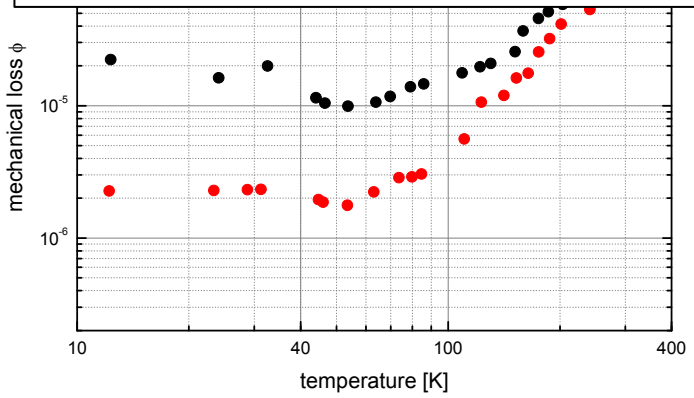


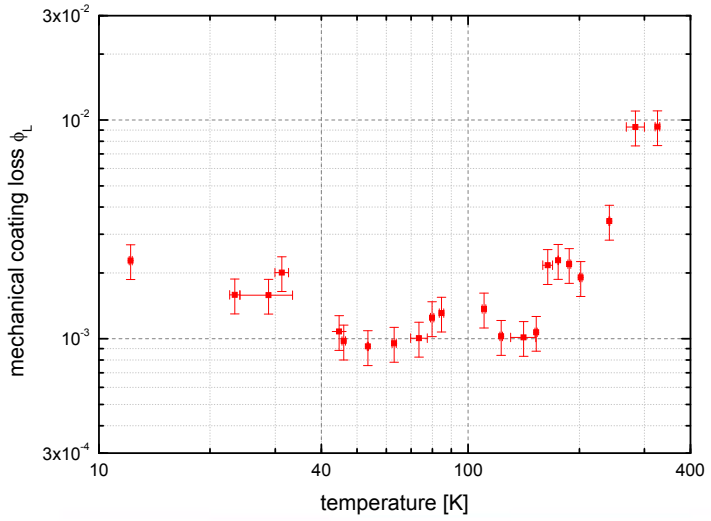
# 1st results of (e-beam) tantala coated cantilevers



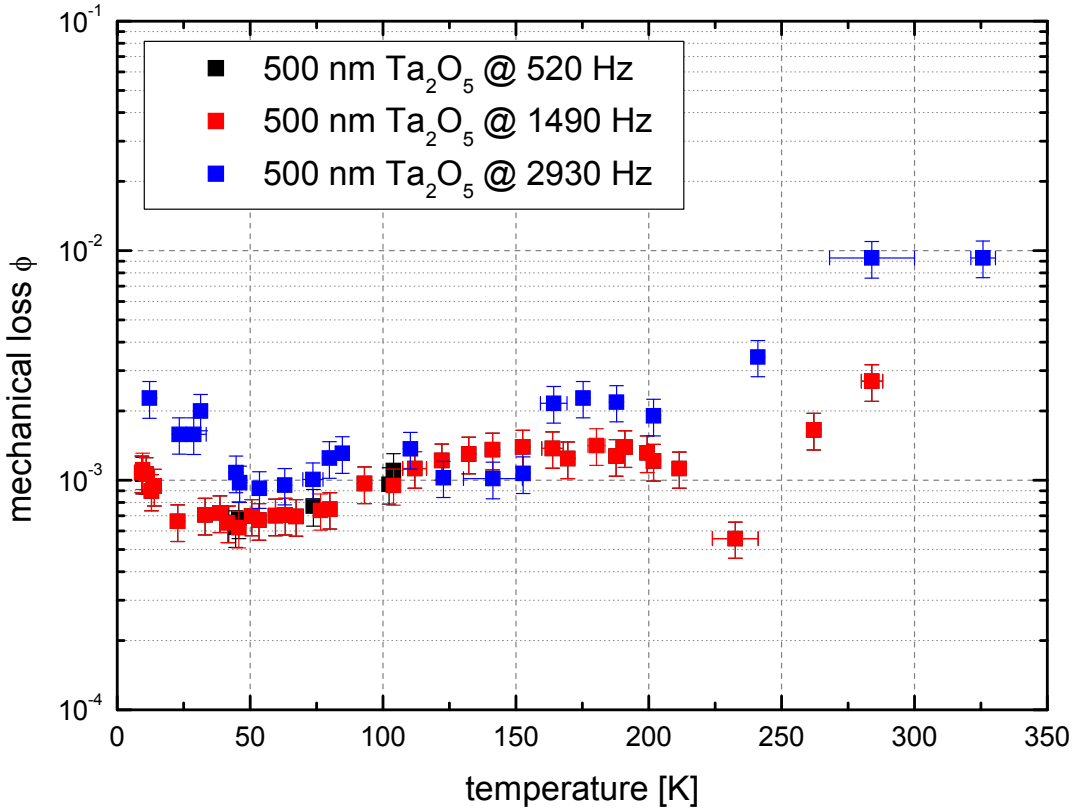

$$\phi(\omega,T) \approx \phi_c(\omega,T) + \frac{E_L}{E_c} \cdot \phi_L(\omega,T)$$



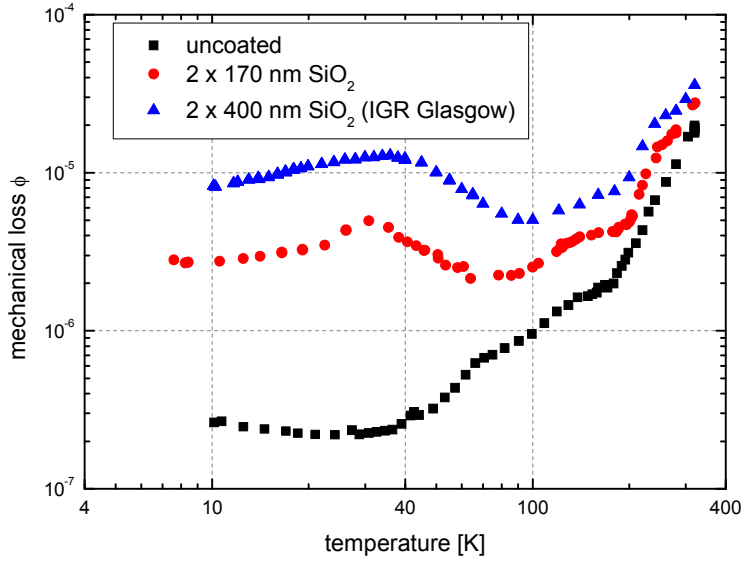



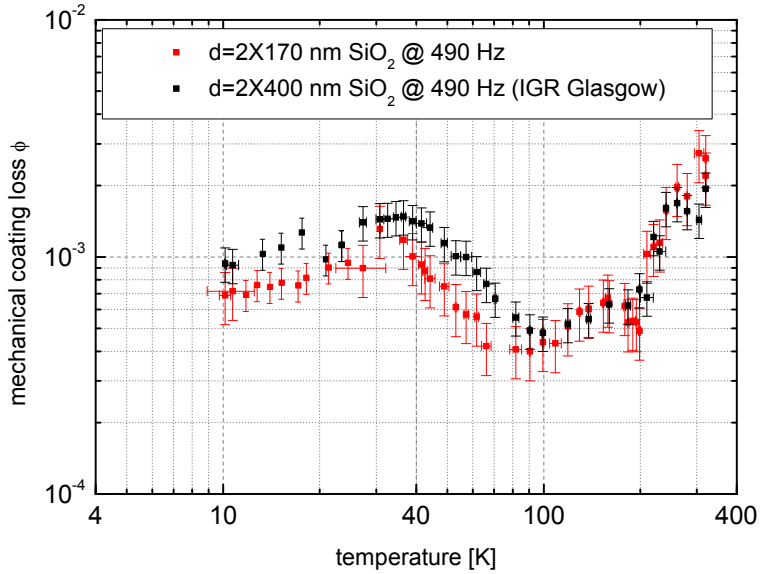
# 1st results of tantala coated cantilevers

500 nm tantala deposited by e-beam evaporation



## results of silica coated cantilevers




Mechanical loss comparision of two thermal oxide layers (170nm and 400 nm)

# Conclusions

- 2 experimental setups for loss measurements on bulk materials and cantilever
- results for the temperature dependence of the mechanical loss of various bulk materials
- Significant difference between optimized and sligthly deadjusted bulk suspension setups
- for silicon further investigations on doping levels and crystalls orientation are needed but take a long time
- cantilever setup allows measurements at the thermoelastic limit
- further measurements with changed surface paramters are needed

fused silica
Dia. 3“ x 12mm