

Mechanical loss measurement of sapphire fibers and disks

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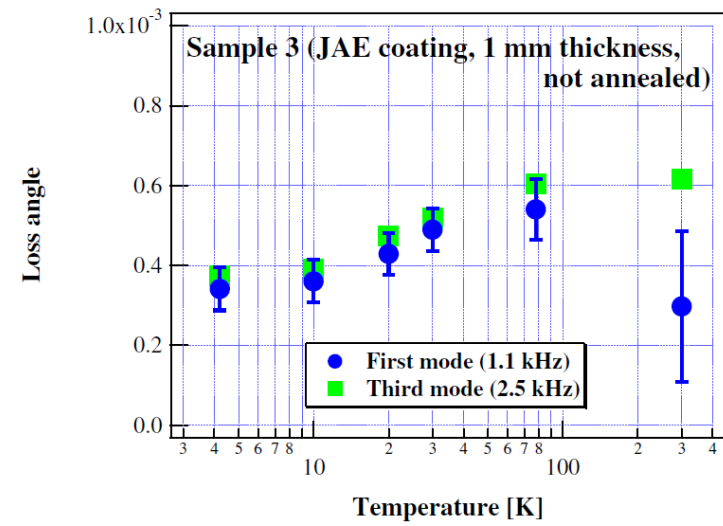
Univ. of Jena

D. Heinert, G. Hofmann, R. Nawrodt, C. Schwarz

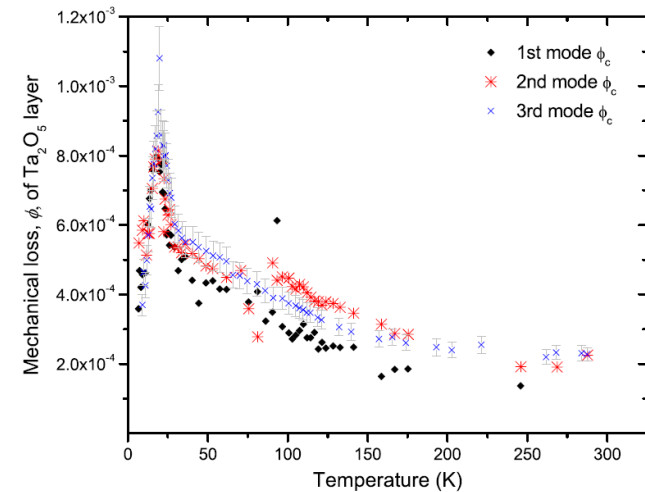
(alphabetical order)

Contents

- I visited Glasgow (1 month) and Jena (1 month) from Japan in ELiTES program
- Mechanical loss measurement in cryogenic temperature
 - Coating on sapphire disks (Glasgow)
 - Results of Japan[1] and Glasgow[2] show difference at ~ 20 K
 - It is necessary to examine the reason
 - It is useful to measure samples of Japan in Glasgow
 - Measured only in room temperature (in future in cryogenic temperature)
 - Sapphire fibers (Glasgow and Jena)
 - It is necessary to evaluate quality of sapphire fibers for KAGRA



[1] K. Yamamoto, et al, Phys. Rev. D **74** (2006) 022002



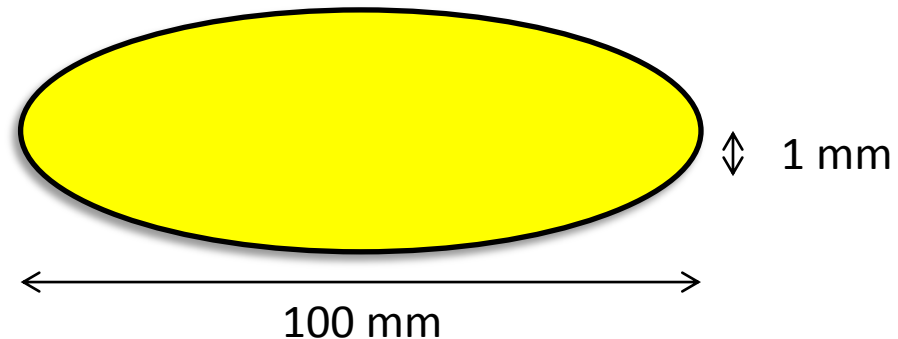
[2] I Martin, et al, Class. Quantum Grav. **25** (2008) 055005

Sapphire disks

Samples

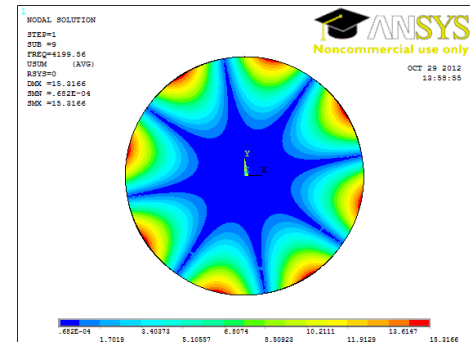
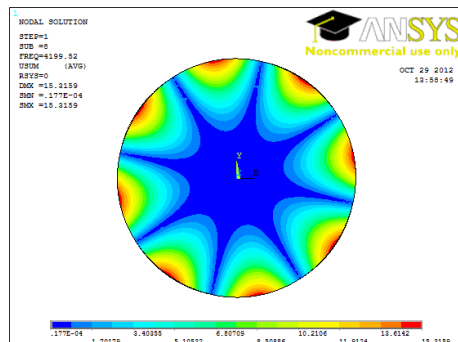
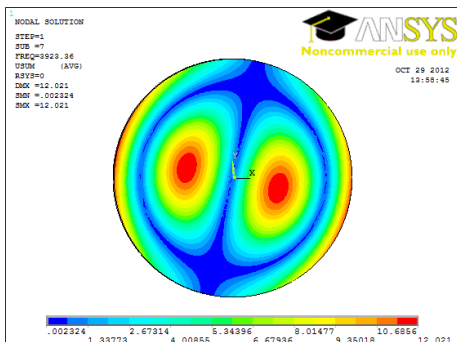
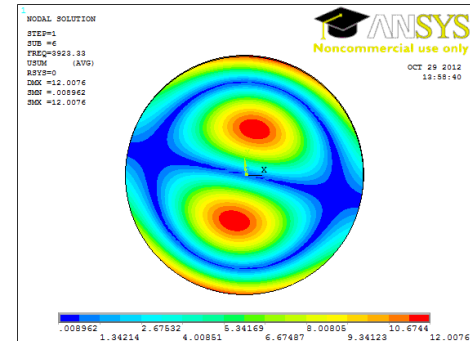
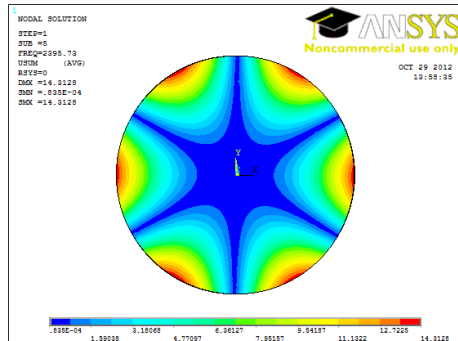
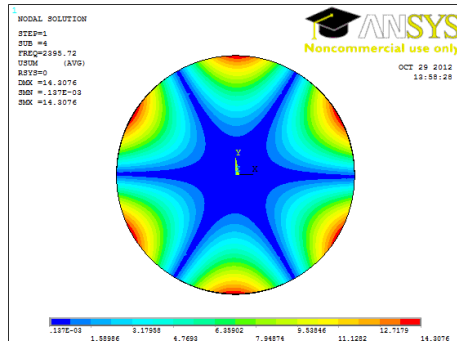
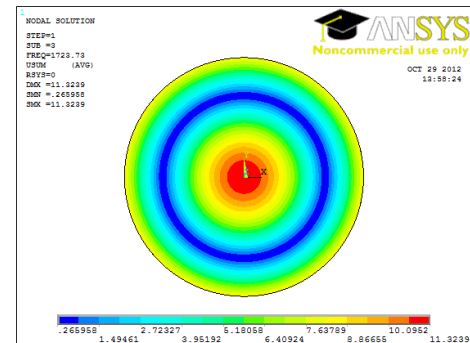
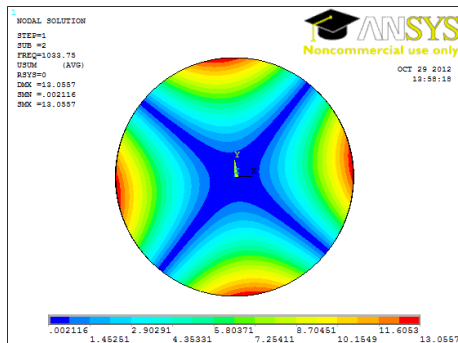
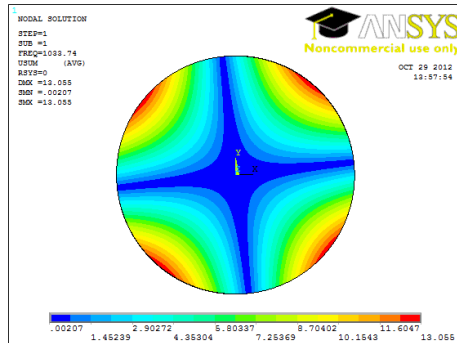
- Sapphire disks
 - Made by SHINKOSHA
 - C-axis is perpendicular to flat surface
 - Micro roughness 0.1 nm
- Coating
 - Made by Japanese Aviation Electronics Industry (JAE)
 - Ion-beam sputtering
 - 31 alternating layers of SiO_2 and Ta_2O_5
 - Total thickness 4.8 μm

No	Heat process	Coating
1	Not annealed	Not coated
2	Not annealed	Coated
3	Annealed	Coated



Calculated resonant modes

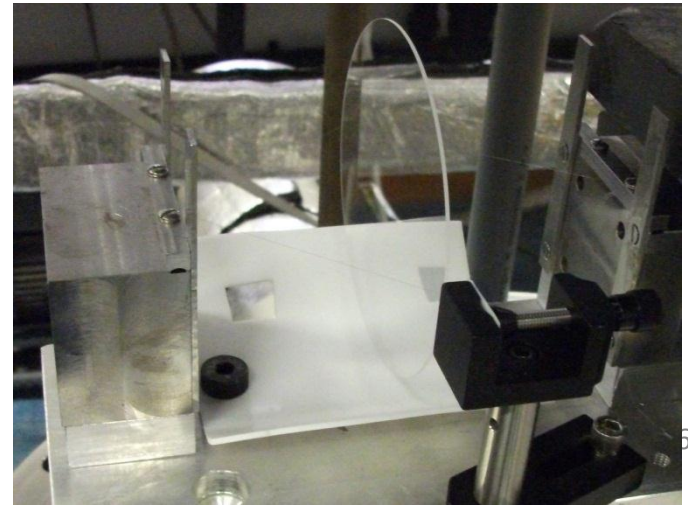
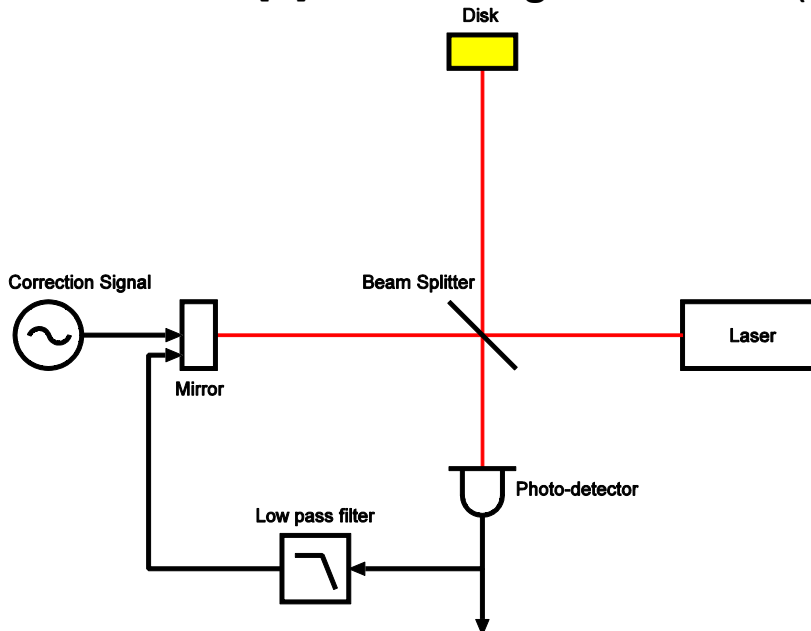
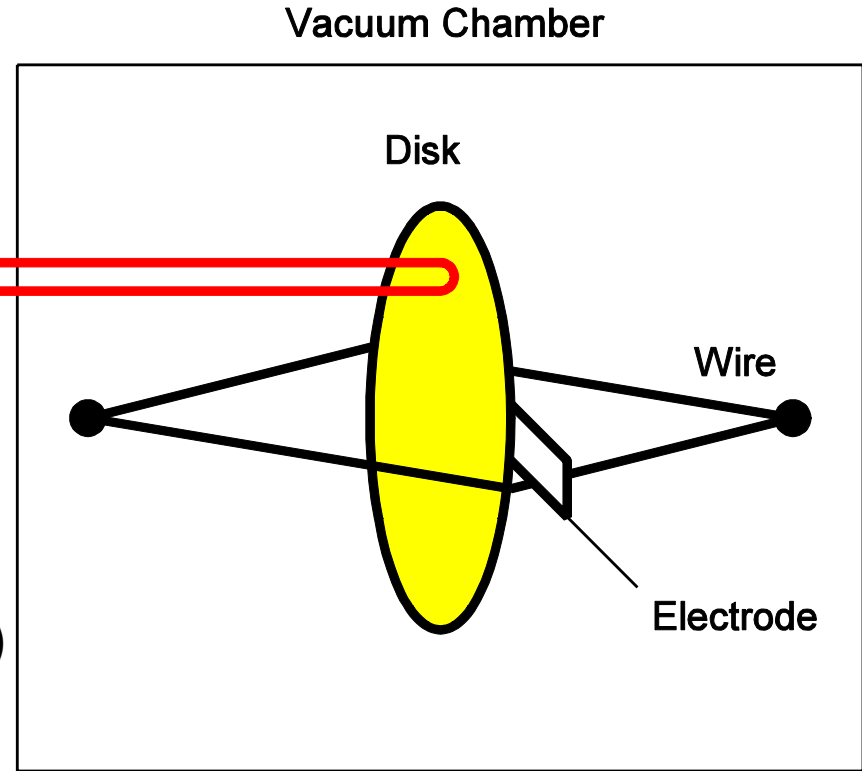
- Calculated by ANSYS
 - Assumption: isotropic material without any constraint



Measurement

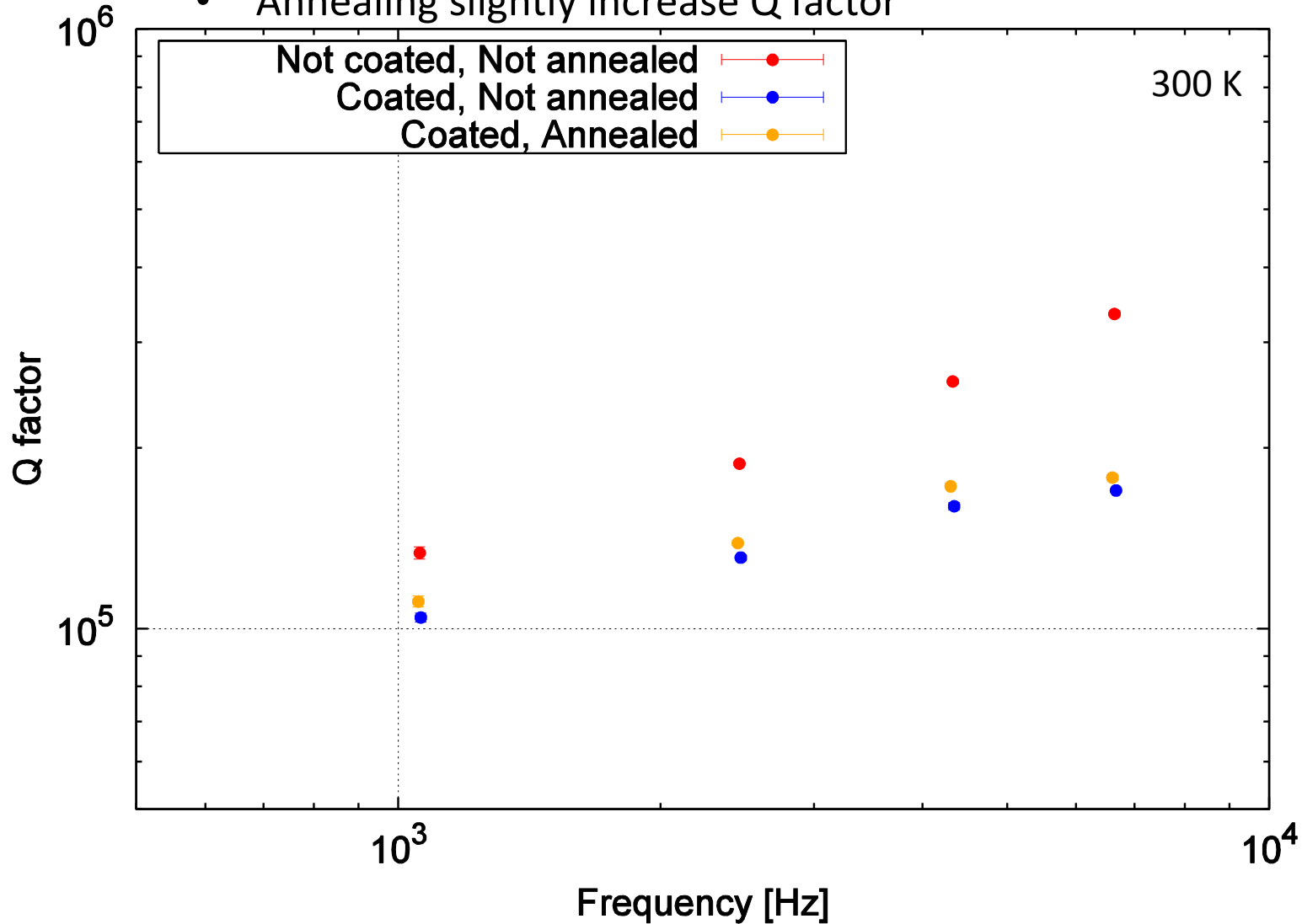
- Disk held by tension of tungsten wires[3] (50 μm in diameter)
- Pressure 10^{-4} Pa to 10^{-3} Pa
- Electrode (~ 750 V) excited vibration
- Locked Michelson interferometer detects vibration
- Decay time measured

[3]A. Cumming Ph.D Thesis (2008)



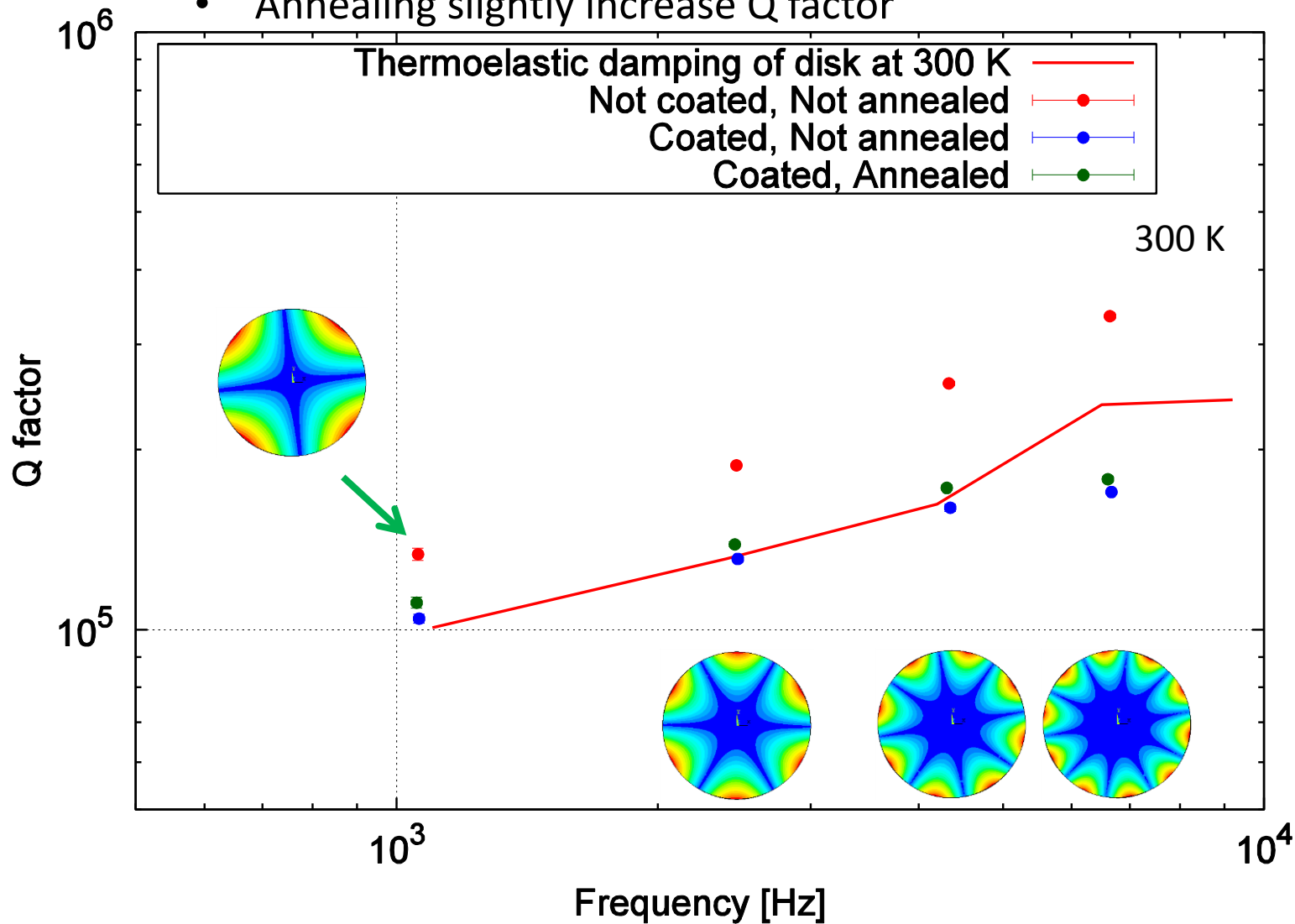
Result

- Each dot is average value over several measurements
- Each error bar is standard deviation of several measurements
- Result without coating is limited by thermoelastic damping
- Coating decrease Q factor
- Annealing slightly increase Q factor



Result

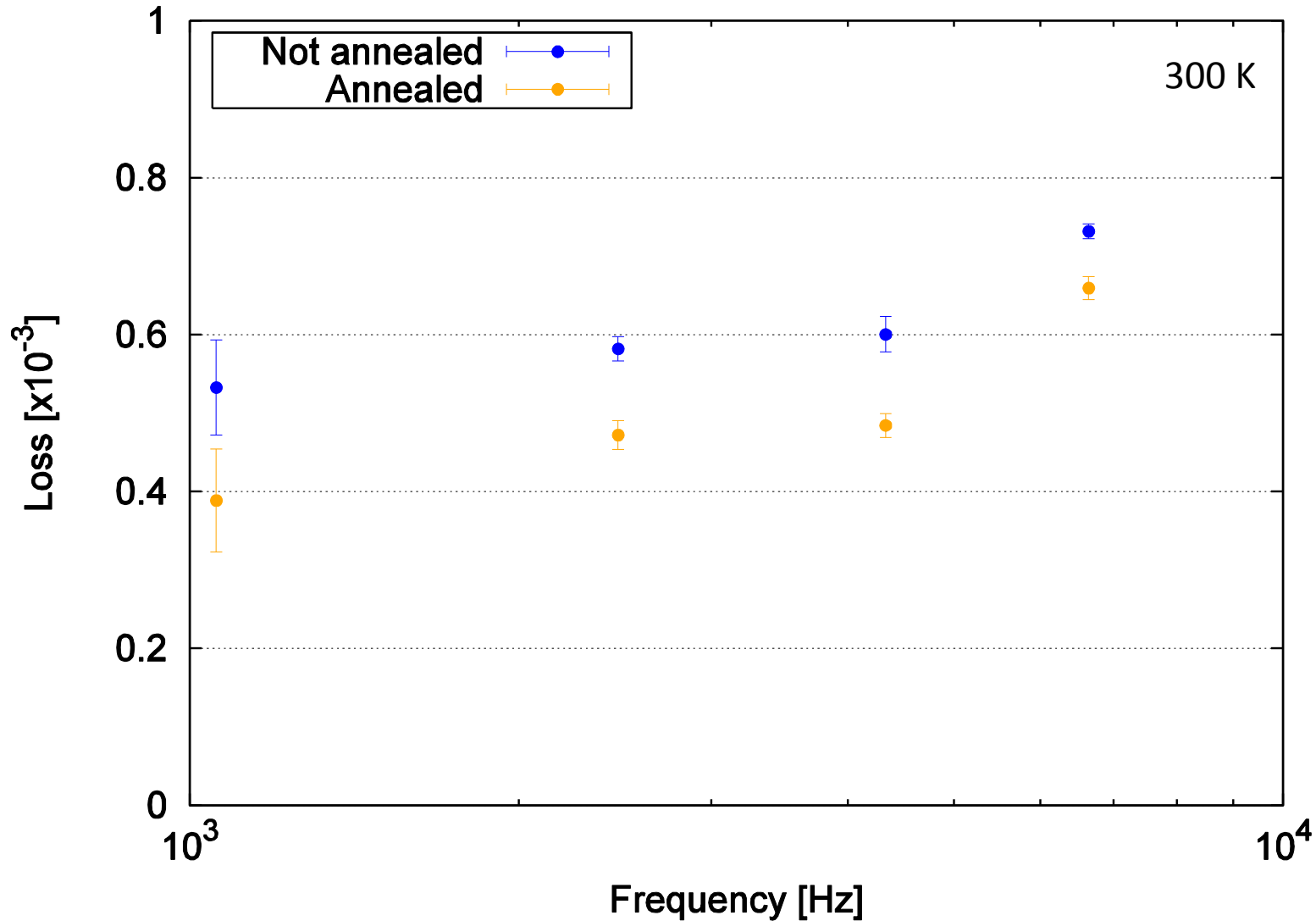
- Each dot is average value over several measurements
- Each error bar is standard deviation of several measurements
- Result without coating is limited by thermoelastic damping
- Coating decrease Q factor
- Annealing slightly increase Q factor



Result

Coating loss

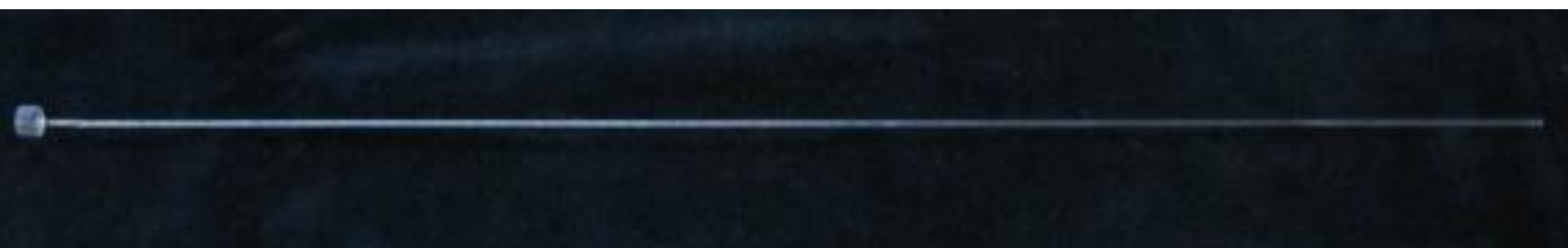
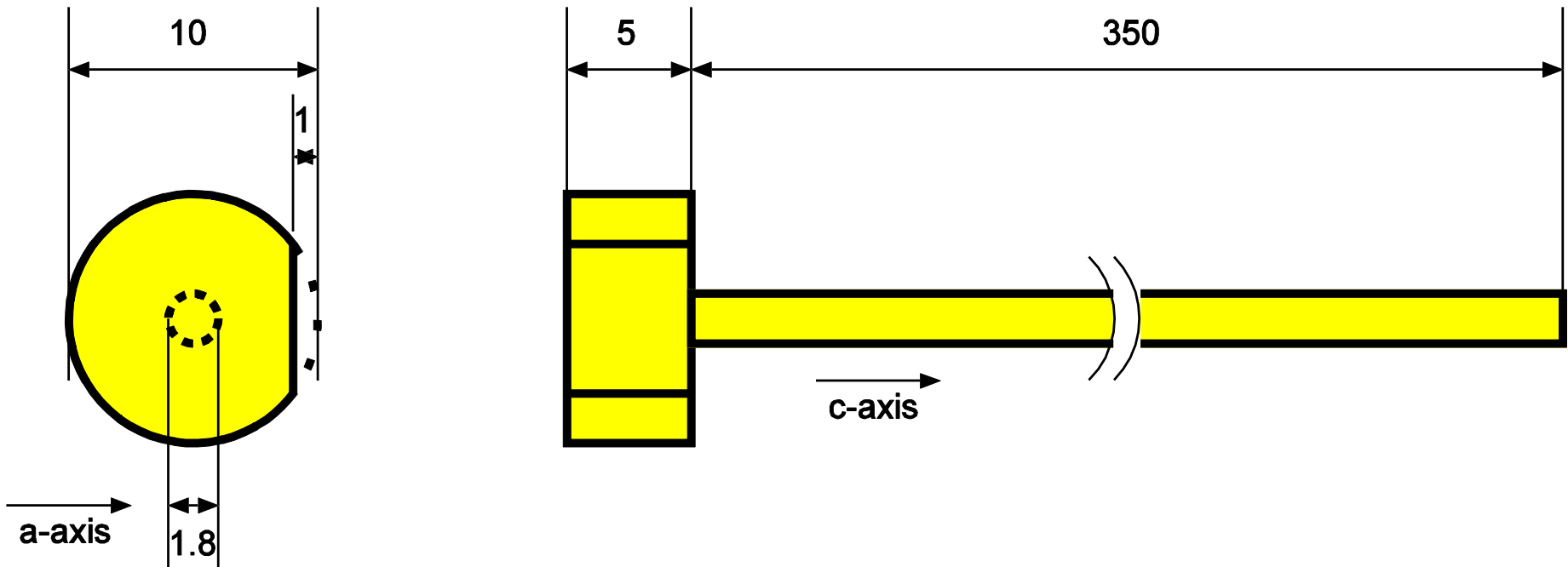
- Comparable to result of K. Yamamoto et al.
- Annealing decreases loss of coating
- Measurement in cryogenic temperature will be conducted in future



Sapphire fibers

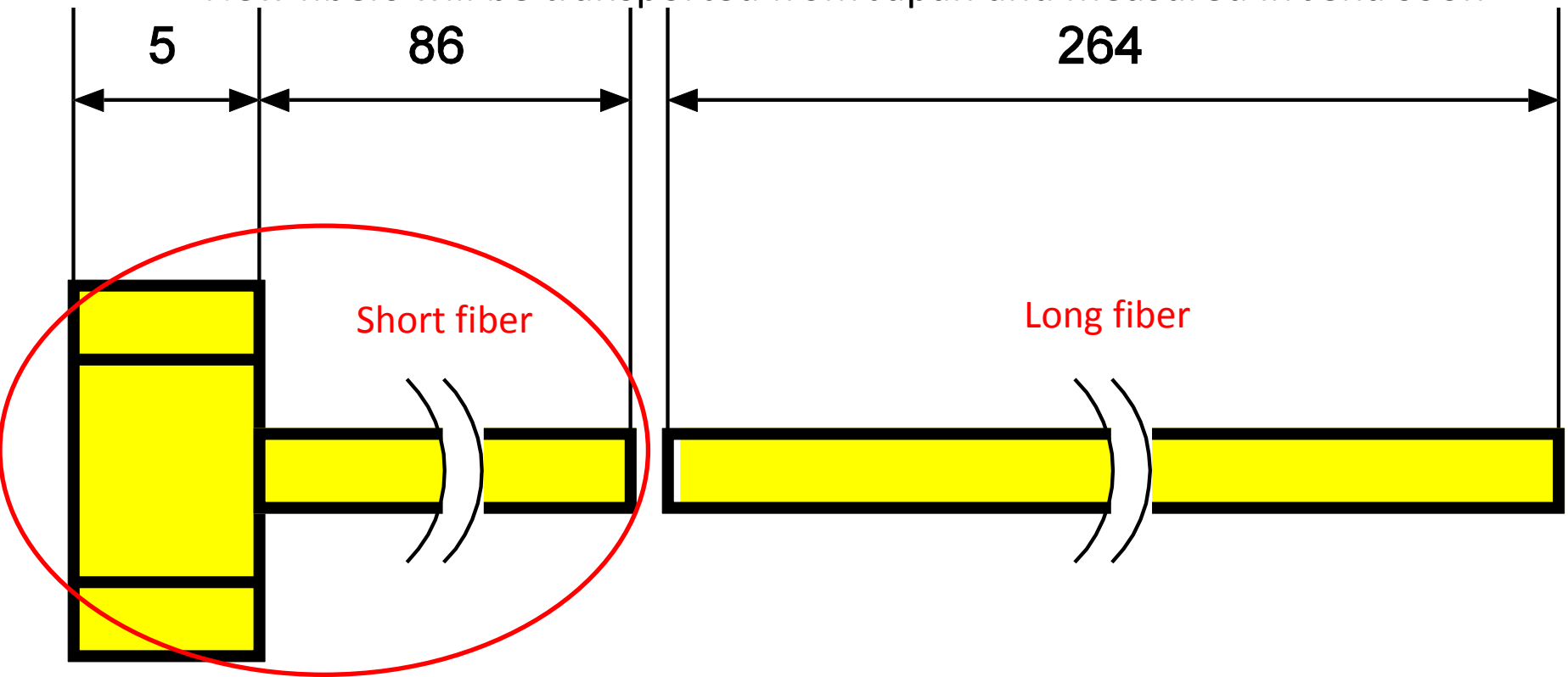
Sample

- Sapphire fiber from Moltech
- Grown along c-axis



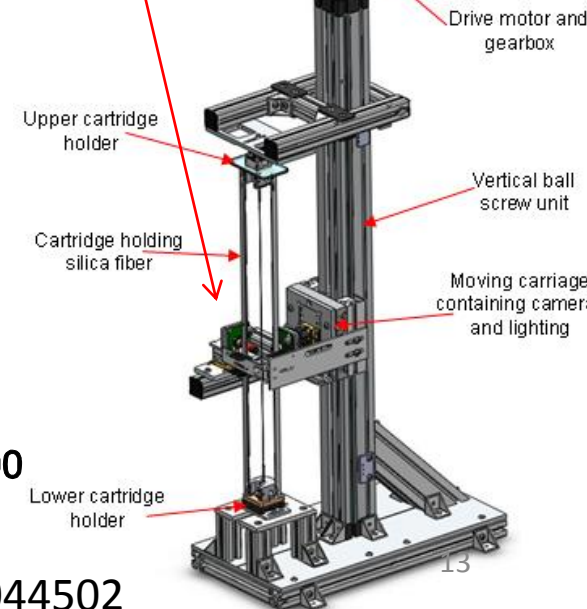
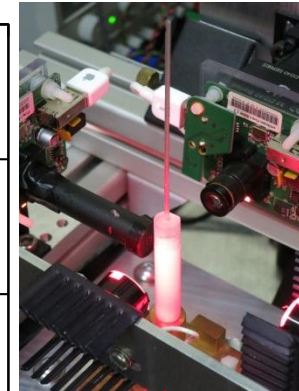
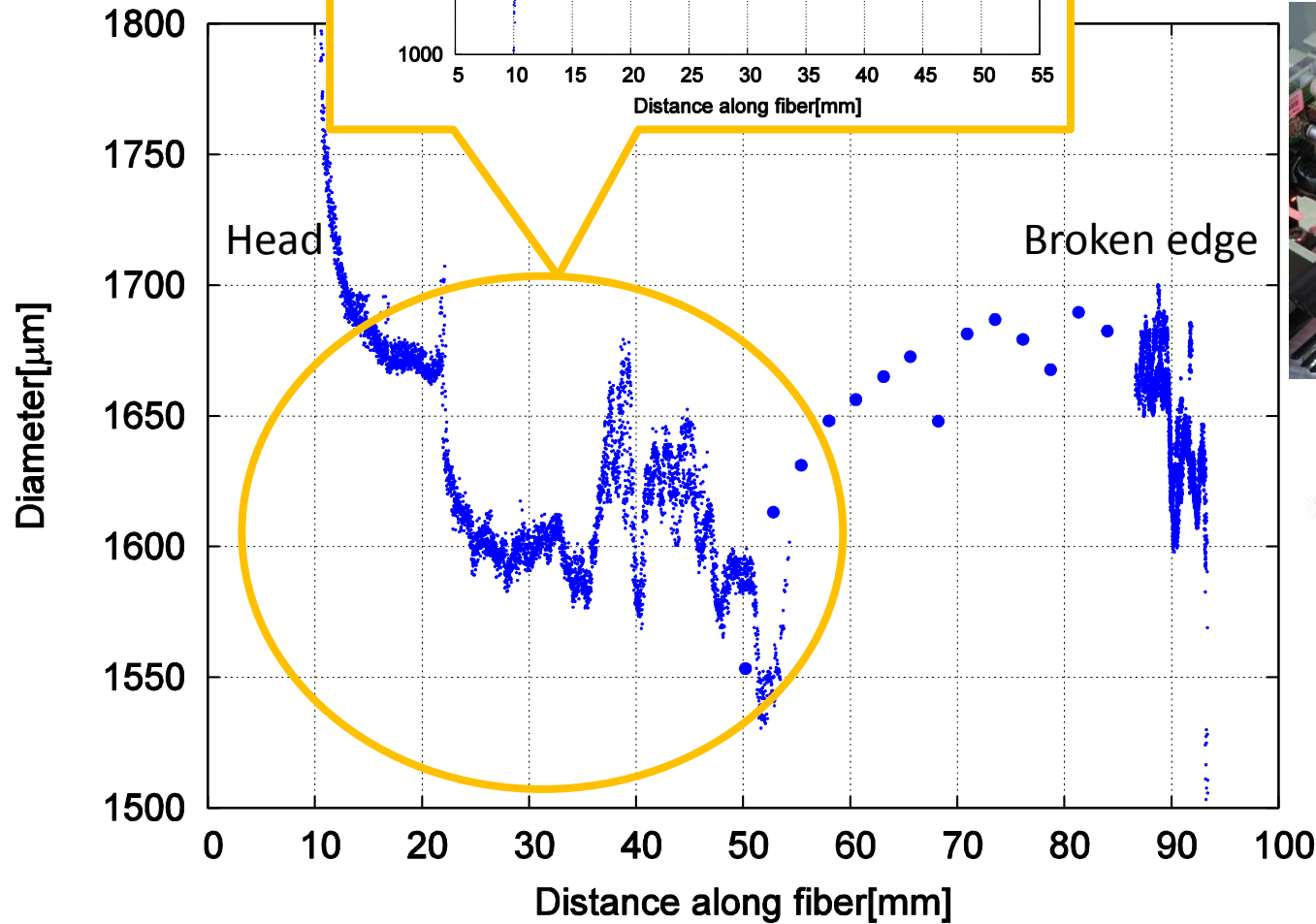
Sample broken during transportation

- Broken fiber
 - It had double enclosures during transportation
 - Packing more securely was necessary
 - Some force during transportation?
 - New fibers will be transported from Japan and measured in Jena soon



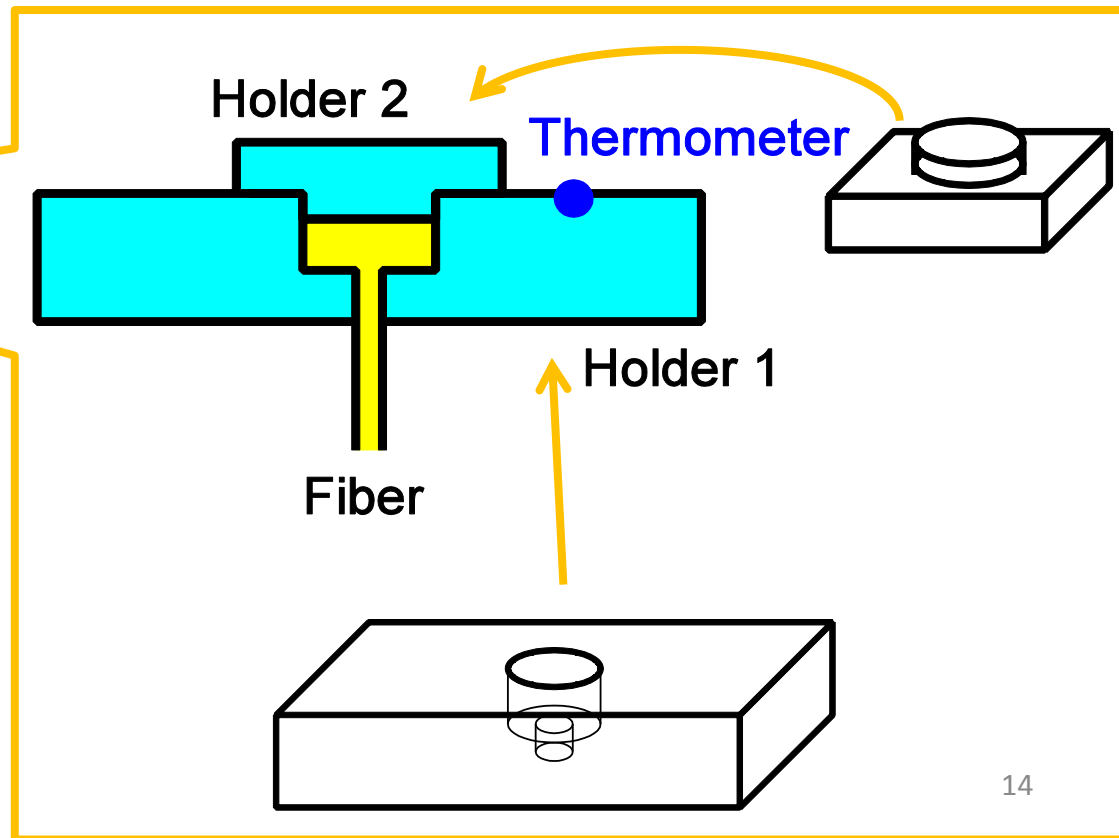
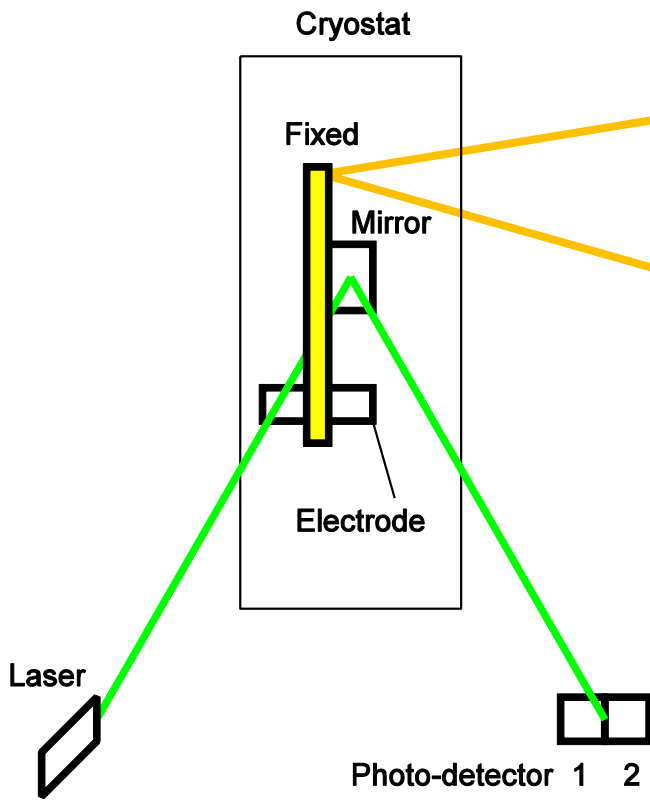
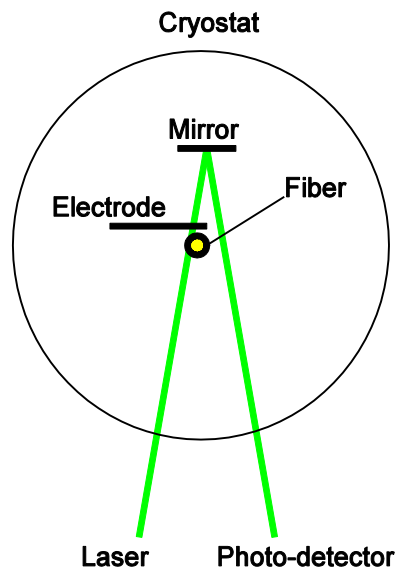
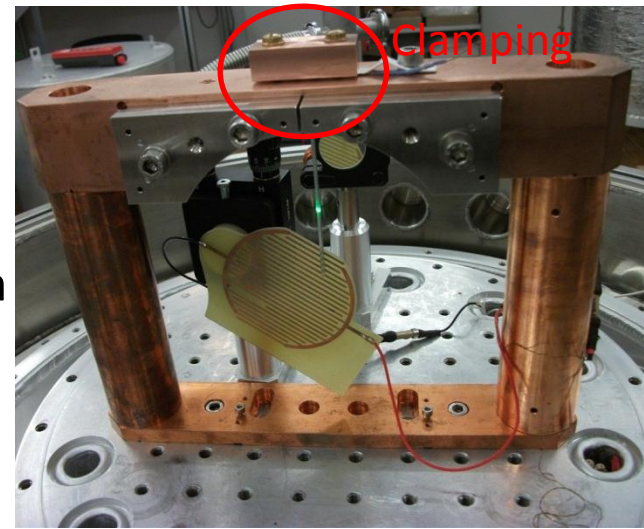
Fiber profiles

- Profiles taken by fiber profiler
- High magnification cameras measure diameter of fiber
- Surface roughness 0.1 mm



Measurement

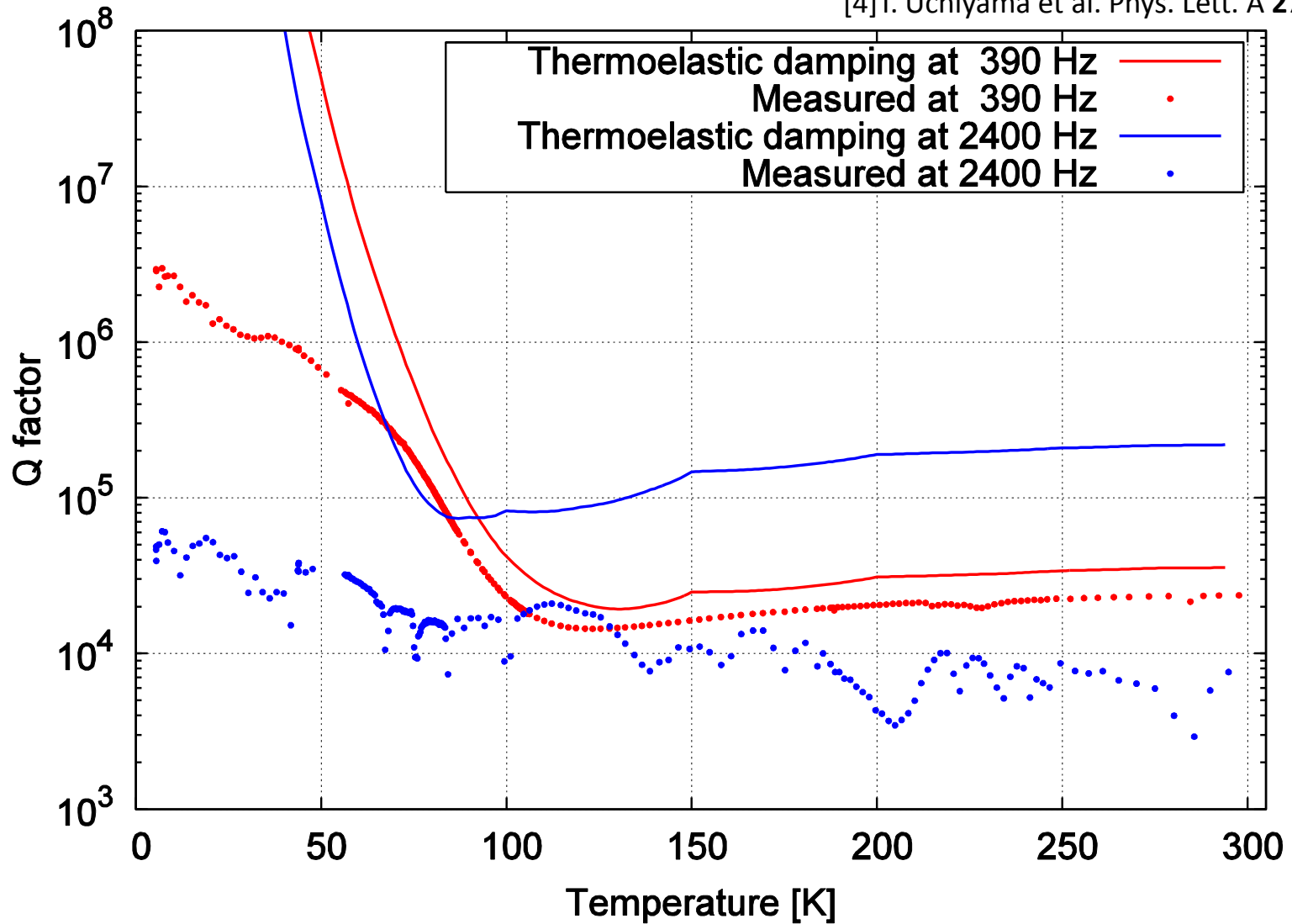
- Fiber clamped by copper holder
- Pressure 10^{-4} Pa to 10^{-3} Pa
- Electrode (~ 1000 V) excited vibration
- Shadow sensor detected vibration
 - Differential signal between two photo-detectors



Result

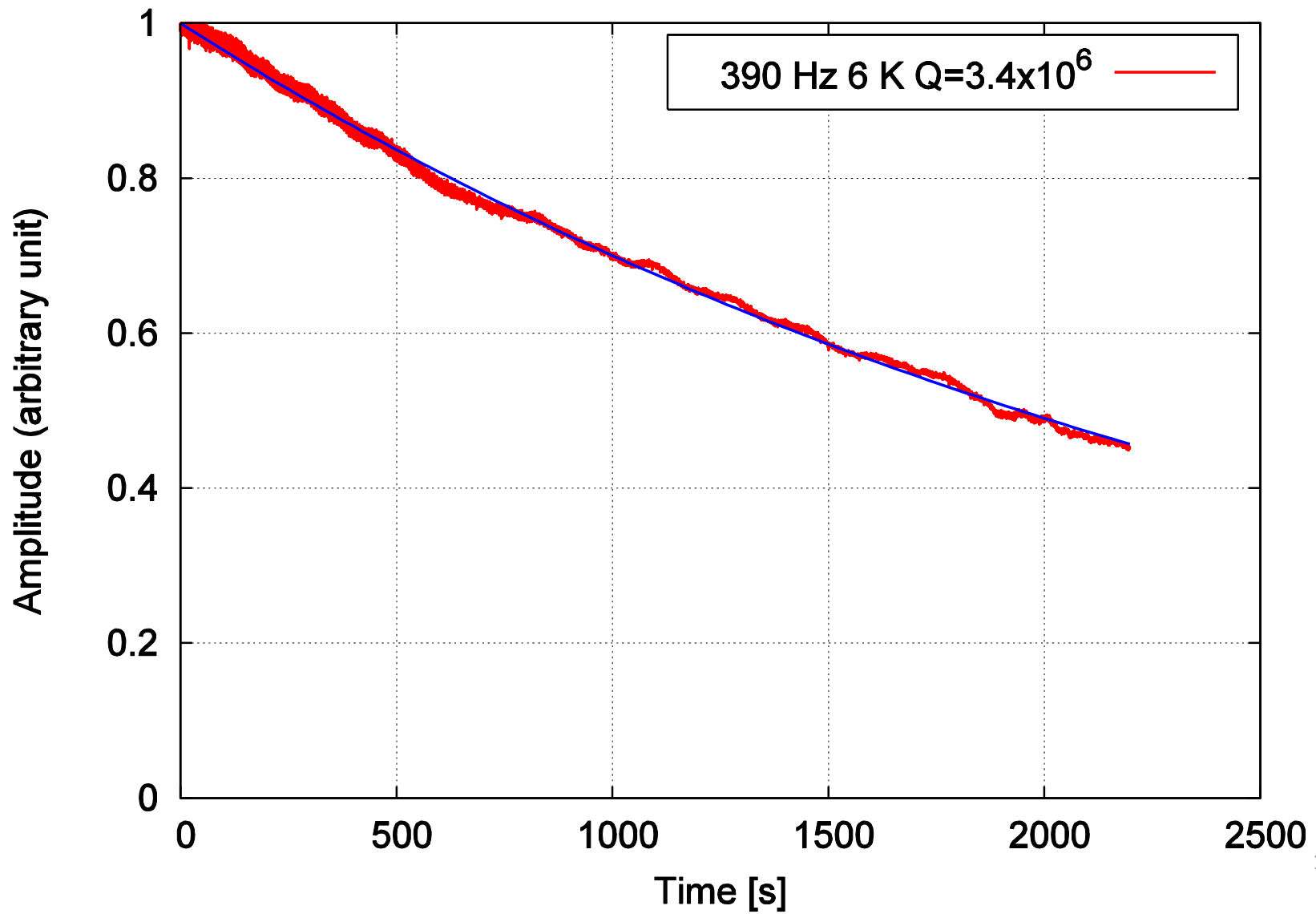
- Result of first mode (390 Hz) above 100 K is consistent with thermoelastic damping
- Second mode (2400 Hz) has higher loss than thermoelastic damping
- Comparable with result of another sapphire fiber made by Saphikon
 - 6.5×10^6 at 374 Hz and 6K[4]

[4]T. Uchiyama et al. Phys. Lett. A **273** (2000) 310



Summary

- Mechanical loss of sapphire fibers and disks has been measured
- Disks
 - Result at room temperature is comparable to result of K. Yamamoto et al.
 - Measurement in cryogenic temperature will be conducted in future
- Fibers
 - Q value 3.4×10^6 was measured at 390 Hz and 6 K
 - Loss in other frequency will be measured by using long fibers



Calculated resonant modes

Bar with the one edge clamped and the other edge free

