Low Mechanical Dissipation in Fused Silica

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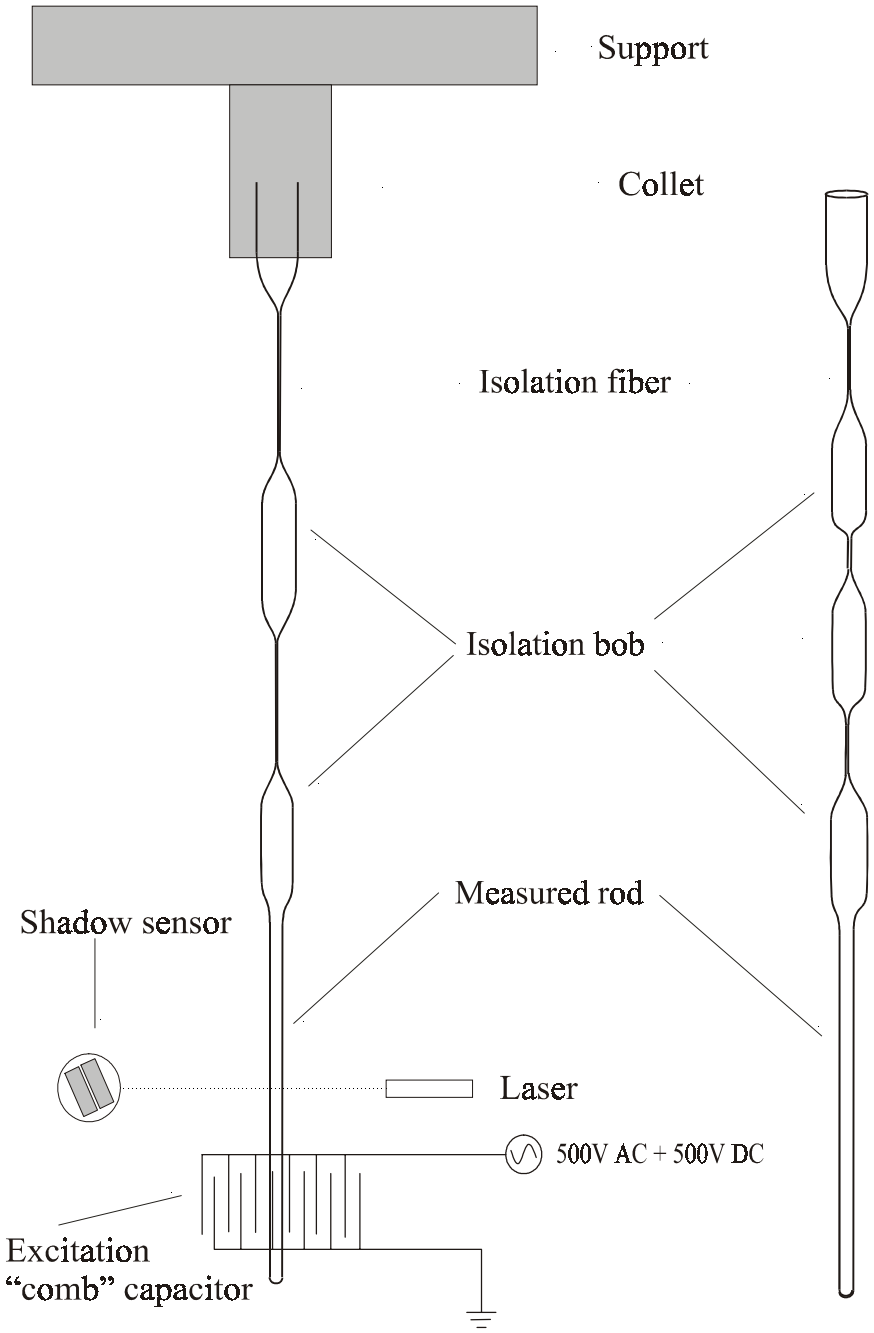
Experimental Apparatus



Initial Q measurements

- 1998 measurement

  $Q = 21 \times 10^6$ at $f = 732$ Hz

  Measured in smaller bell jar

- post storage measurement

  $Q = 37 \times 10^6$ at $f = 2868$ Hz

  Measured in larger bell jar, after storage and measurement with calipers

- knocked against copper tube

  $Q = 18 \times 10^6$ at $f = 1579$ Hz

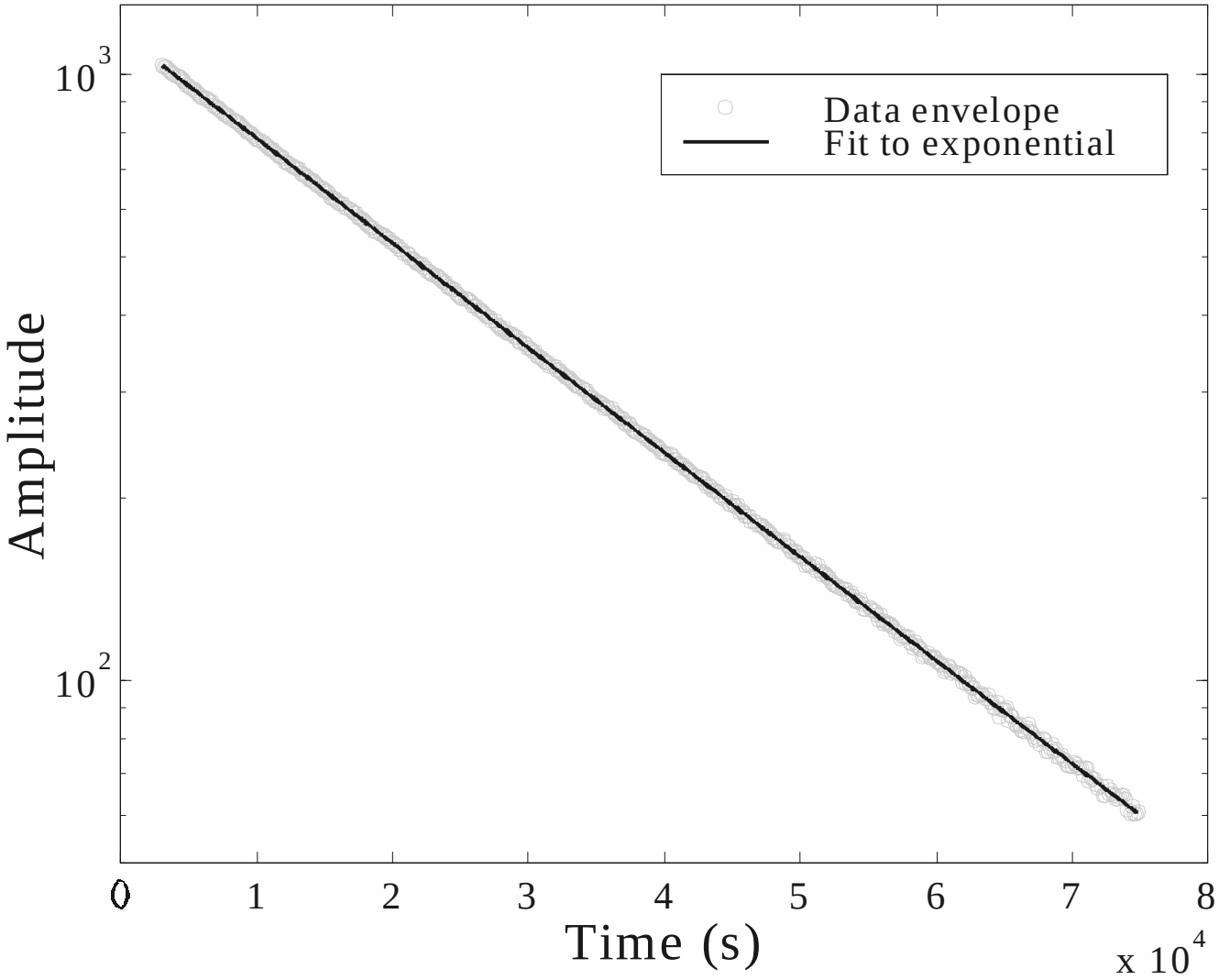
  Measured in larger bell jar, surface hit against copper tube multiple times

Flame polishing

- Natural gas flame polished sample surface
- Surface brought to transition temperature
- Polished for 15 minutes
- Cooled for 15 minutes
- Quickly returned to lab, reattached to suspension, and pumped down to vacuum

$Q = 57 \times 10^6$ at $f =$ 726 Hz

Ringdow data



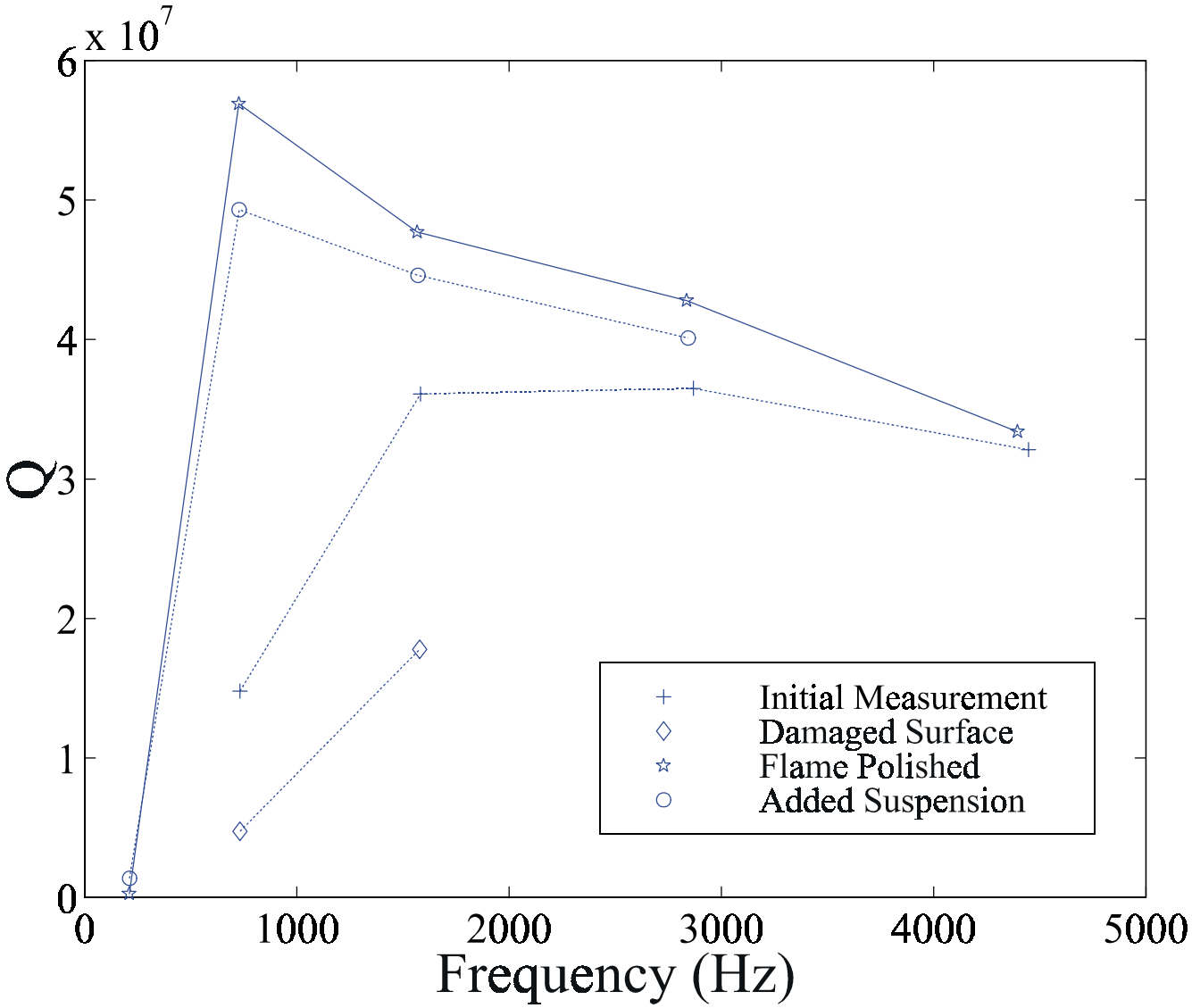
Additional bob in suspension

- Added additional bob to to check for excess suspension loses
- Replaced center bob with two smaller bobs
- Sample carefully handled so surface was never touched

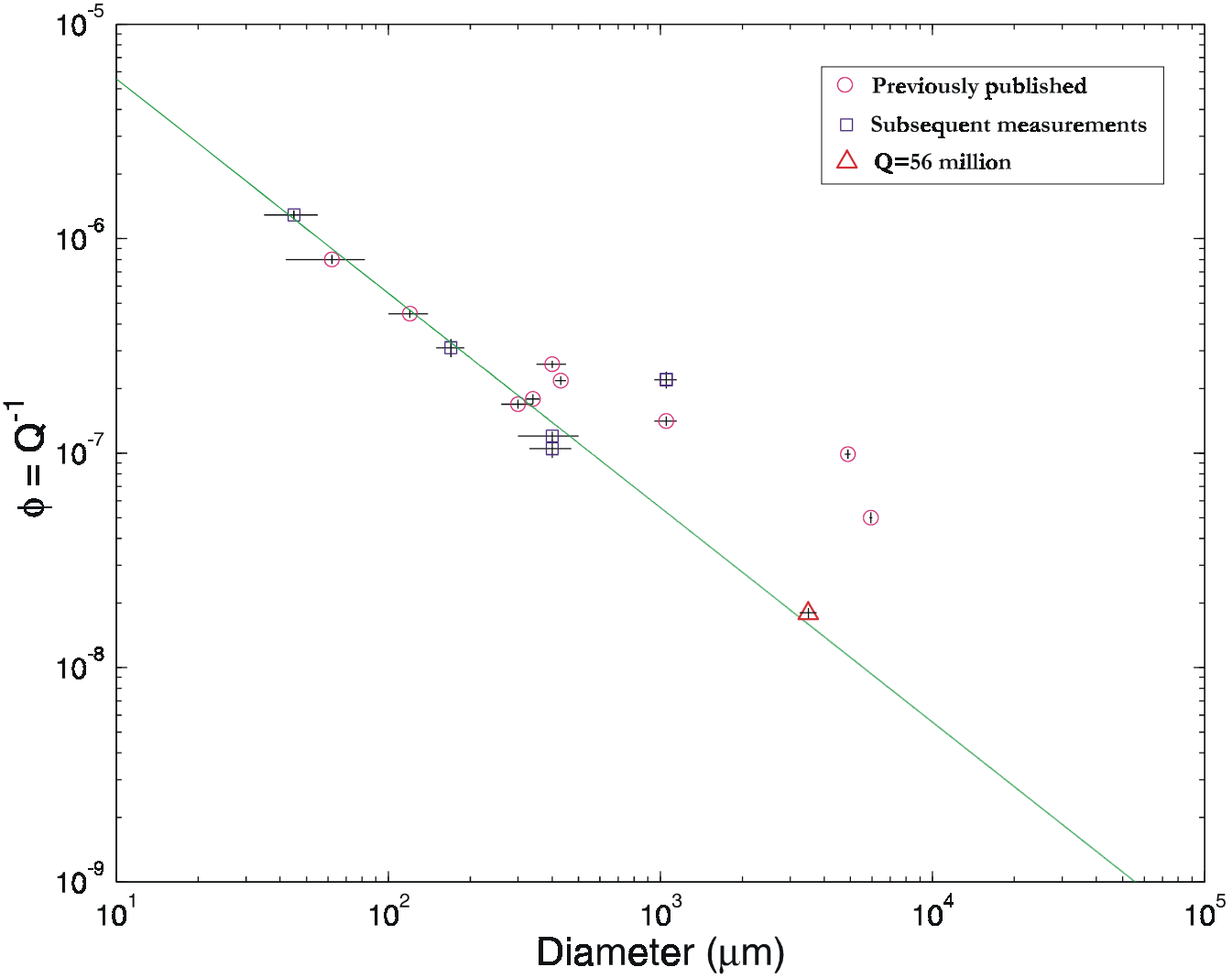
$$Q = 49 \square 10^6$$

at f = 726 Hz

Graph of Q for all modes



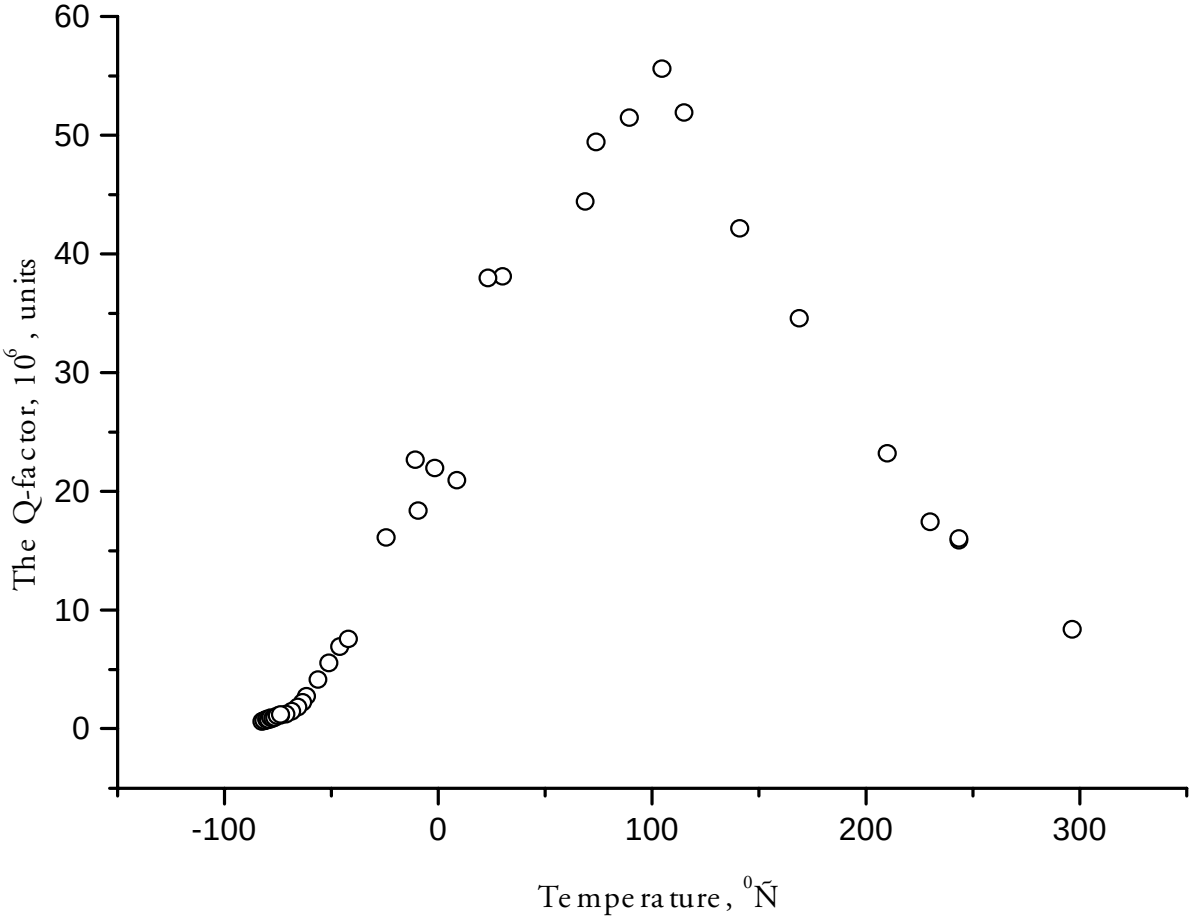
Dissipation vs diameter in fused silica fibers



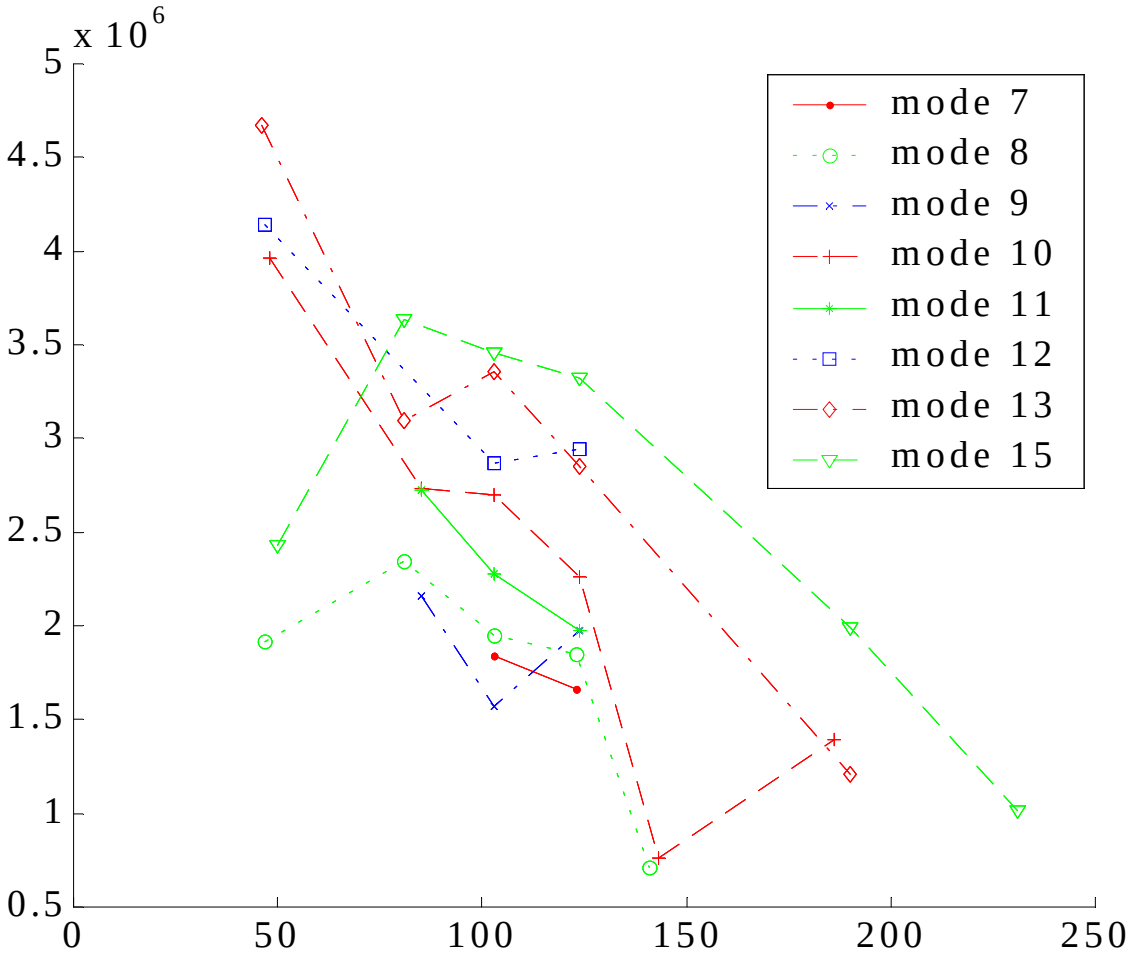
Flame polish of rod stock sample

- Repeated experiment with 3 mm rod stock straight from Heraeus rather than drawn from larger bob
- Flame polished in same way, but only on surface
- Surface contained visible flaws even after flame polish
- Found $Q = 20.4 \square\square 10^6$ at 113 Hz

B. Lunin's data on fused silica



Syracuse temperature data



Possible indication of cause of dissipation

$$\log\left(\frac{f_1}{f_2}\right) = \frac{E_a}{k_B}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

(Nowick and Berry, p. 59)

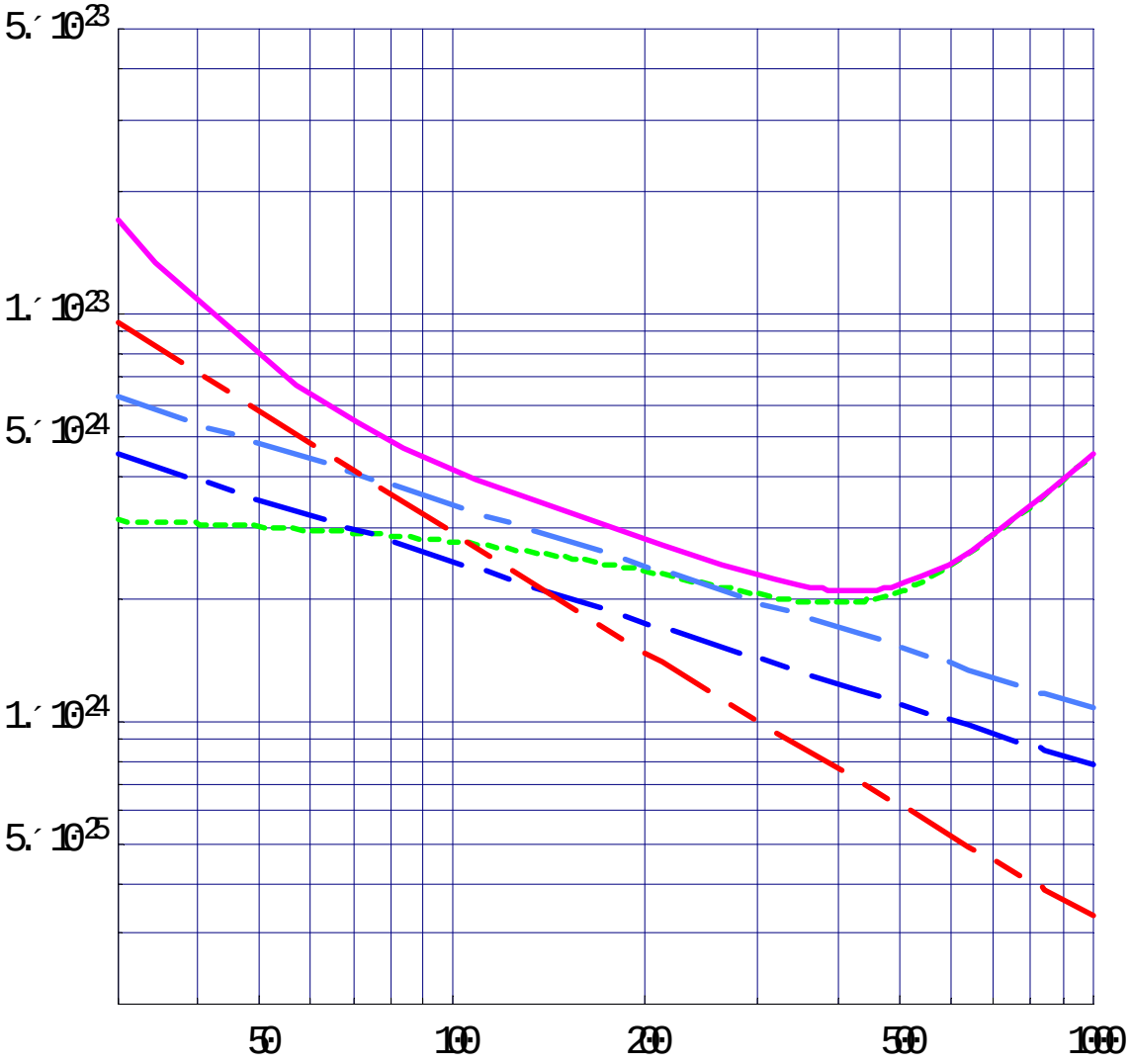
f_1 = 8400 Hz
T_1 = 105 C

f_2 = 726 Hz
T_1 = 25 C

E_a = 0.31 eV

A plausible value for activation energy

Implications for LIGO II



NS Binary Inspiral range

- Sapphire 202 Mpc
- 30 million silica 166 Mpc
- 57 million silica 193 Mpc

Implications for LIGO II

- Low dissipation may be unobtainable with polished mirrors
- Optical coatings may greatly increase thermal noise
- Even obtaining 30 million Q may be challenging
- Further experiments are needed and some underway at Syracuse

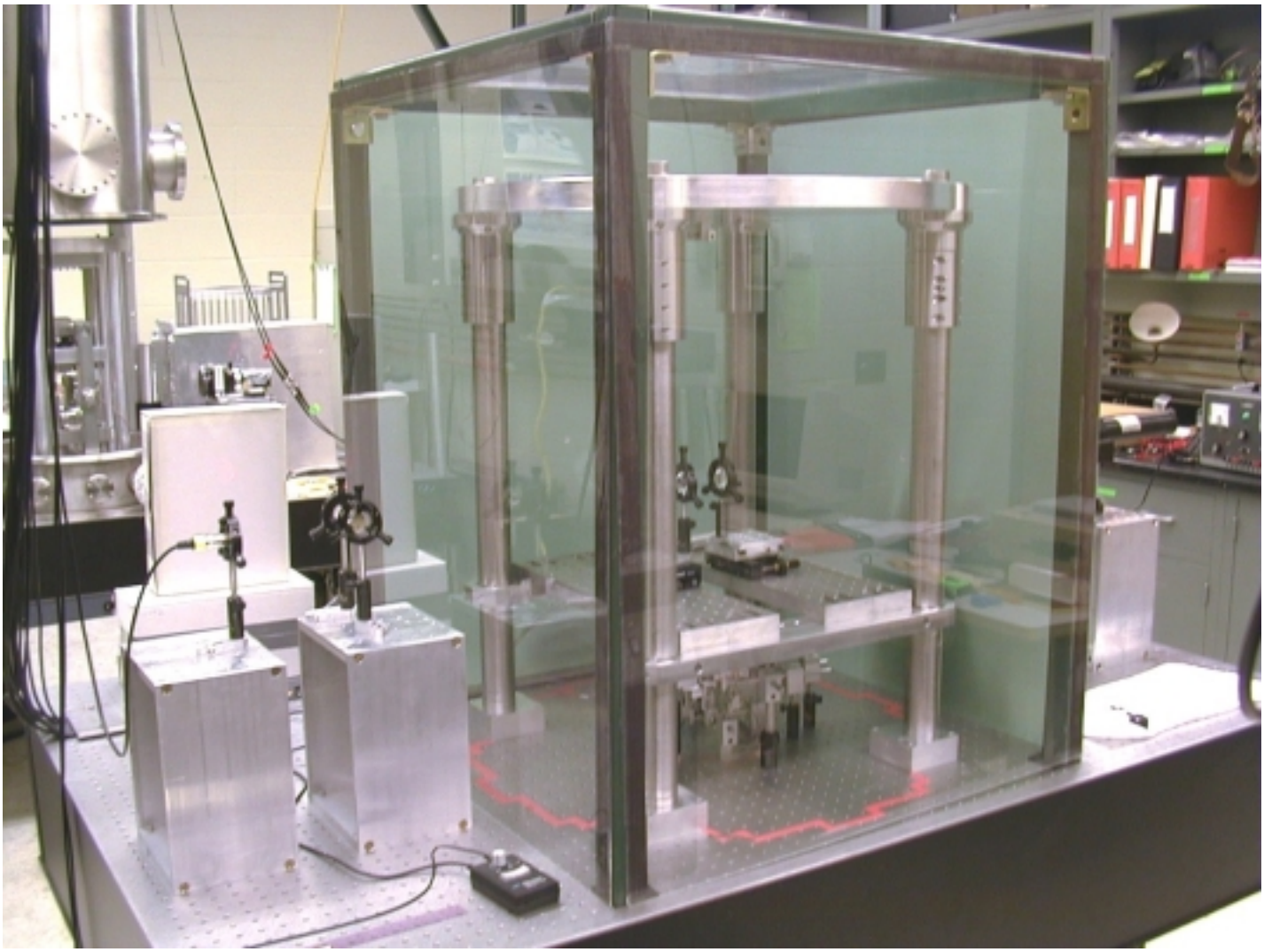
Suggestions for further research

- Thick flame polished drawn rods
  - 6 mm in vacuum, 10 mm planned
  - can we flame polish mirror-like geometries?
- Get further Q vs T data
  - 25-500 C oven built
- Explore alternatives/additions to physical polishing
  - chemical treatments
  - learn more about Russian experience (B Lunin)
  - other possibilities?

Coating experiment update

- Measured uncoated Q on 16.5 cm diameter, 2 cm thick disk
  - $Q = 3.5 \times 10^6$
- Disk being coated at REO
- Using smaller, 7.5 cm diameter, 2.5 mm thick, polished but not flat, disks
  - 1st welded directly to suspension
  - 2nd connect by bonded ear

Violin mode sensor



Violin mode sensor

- Non vacuum mock up made with stainless steel fiber
- Feedback controls for all pendulum modes
- Laser noise eater working
- Seismic noise seen
  - may have to build isolation
- Preliminary results: thermal noise measured in one violin mode, in air, with steel wire

Anelastic aftereffect experiment

Future plans

- Ringdown experiment with silicate bonded fused silica rods (with J. Hough and S. Rowan)
- Ellipsometry experiment to measure coating ϕ on excess 40 m mirror
- Anelastic aftereffect measurements on sapphire including thermoelastic damping
- Further ϕ vs temperature work