Update on Thermal Noise Experments at Syracuse University

S. *D. Penn, G. M. Harry*,
A. M. Gretarsson, S. E. Kittleberger,
P. R. Saulson, J. J. Schiller, J. R. Smith,
S. O. Swords

Syracuse University

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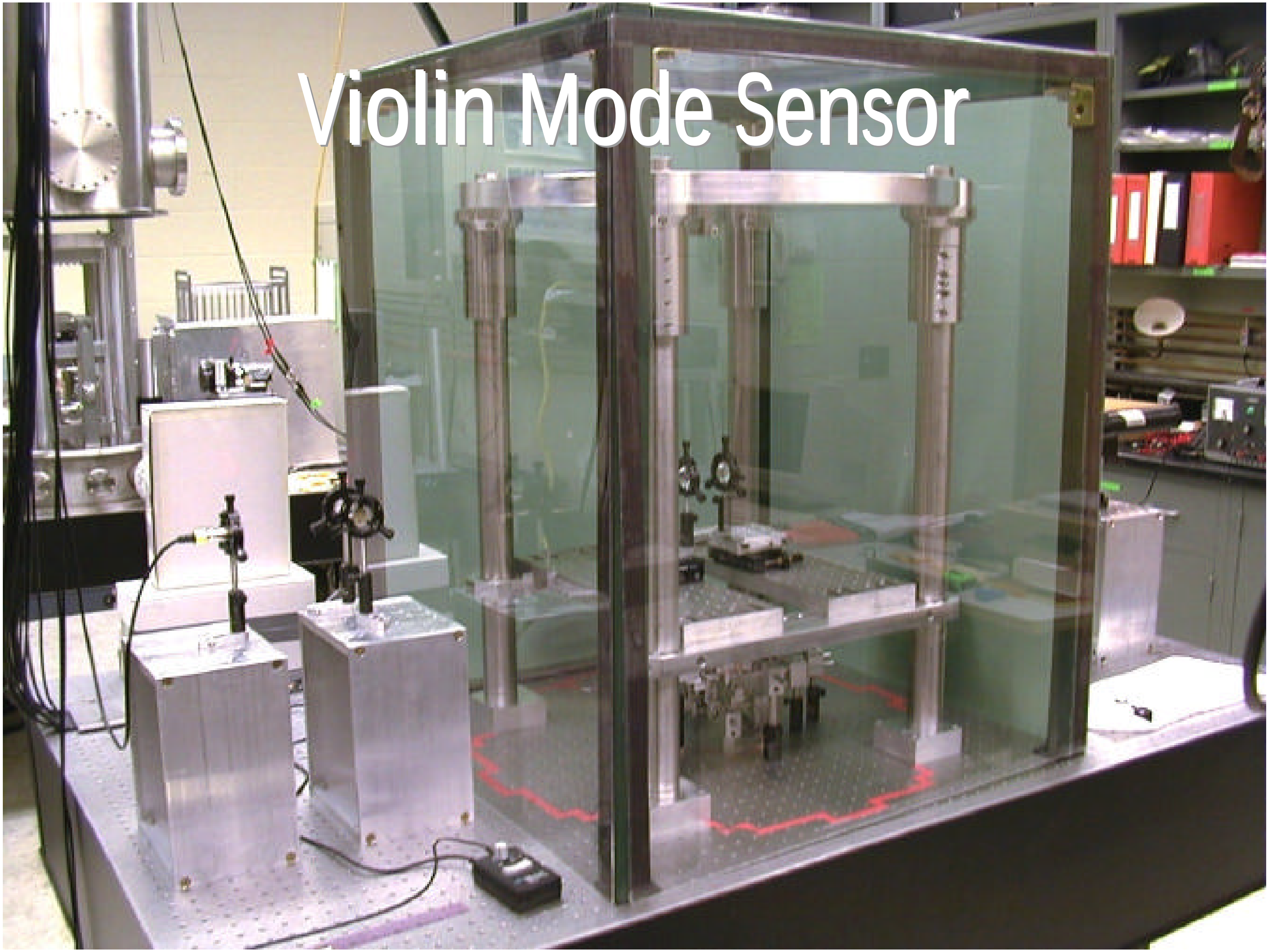
Coating Experiment

- Measured uncoated *Q* on a 16.5 cm diameter, 2 cm thick disk. $Q = 3.5 \times 10^6$
- Disk was coated at REO just prior to LSC
- 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

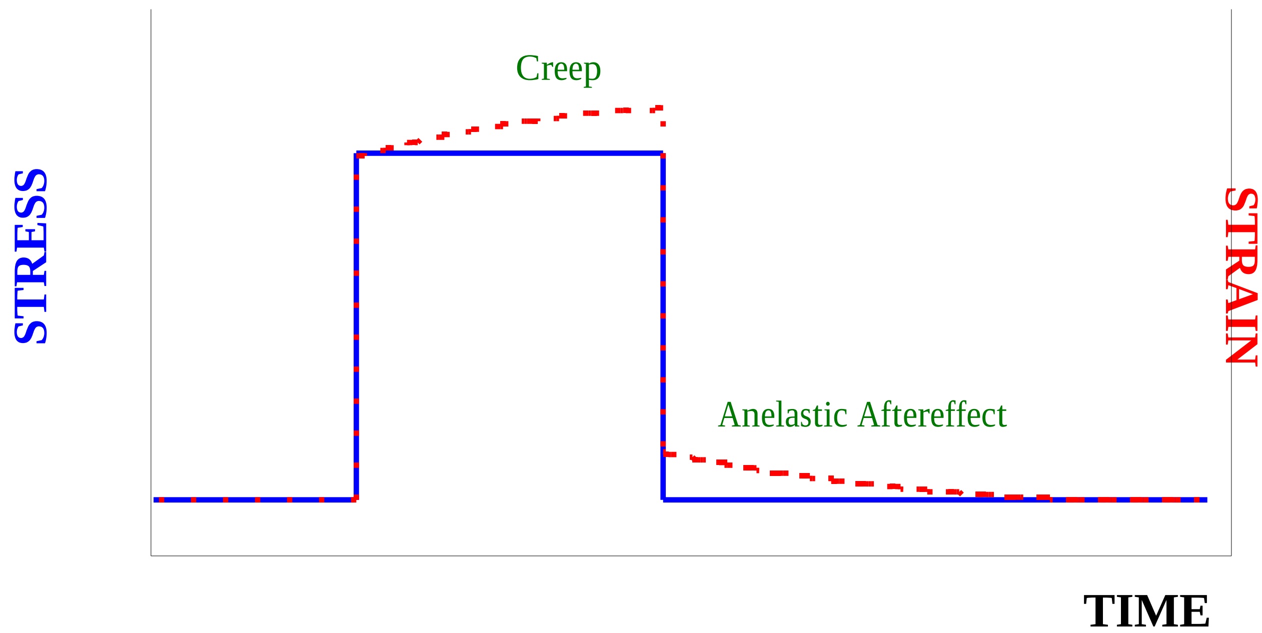
Violin mode sensor

- 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

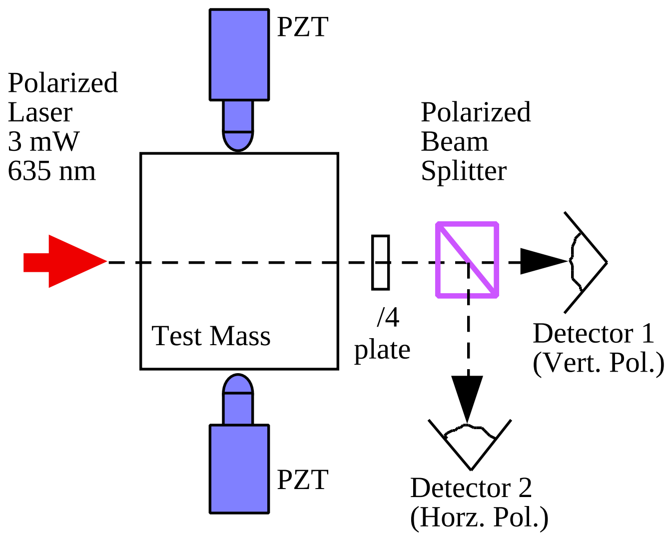
- Anelastic Aftereffect is a function of Dissipation in Bulk Mass in the 1 Hz – 1 kHz Frequency Range
- Provides a Direct Measure of $\phi(f)$ in contrast to at Resonance: $\phi = 1/Q$
- Tests our Assumptions for Structural Damping, and Thermoelastic Damping
- For Glass Test Masses, Anelastic Aftereffect can be Measured using the Stress-Induced Birefringence (see *RSI* paper by M. Beilby, P. Saulson and A. Abramovici)

We measure the Anelastic Aftereffect in Optically Transparent Test Masses via Stress-Induced Birefringence.

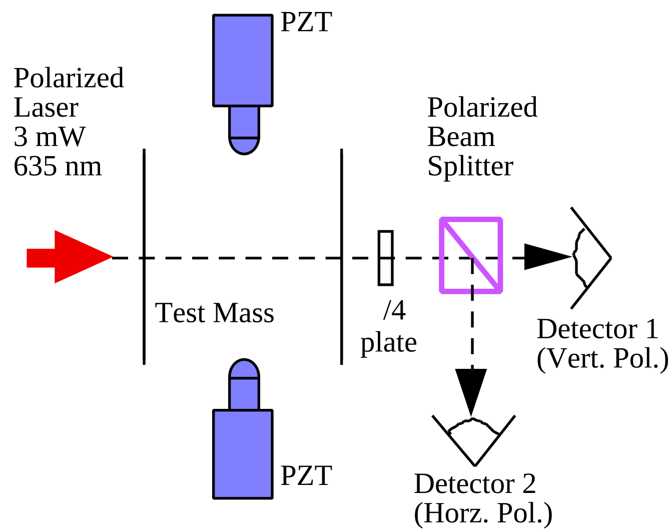


$$\phi\left(f = \frac{1}{2\pi\tau}\right) \approx \frac{\pi}{2}\,\frac{d\,J(\tau)}{d\ln\tau}$$

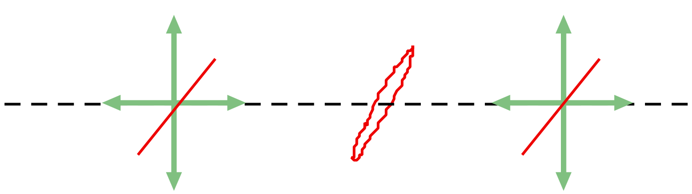
UN-SQUEEZED STATE



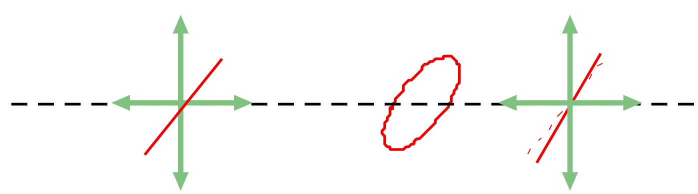
SQUEEZED STATE



Polarization (looking downstream)

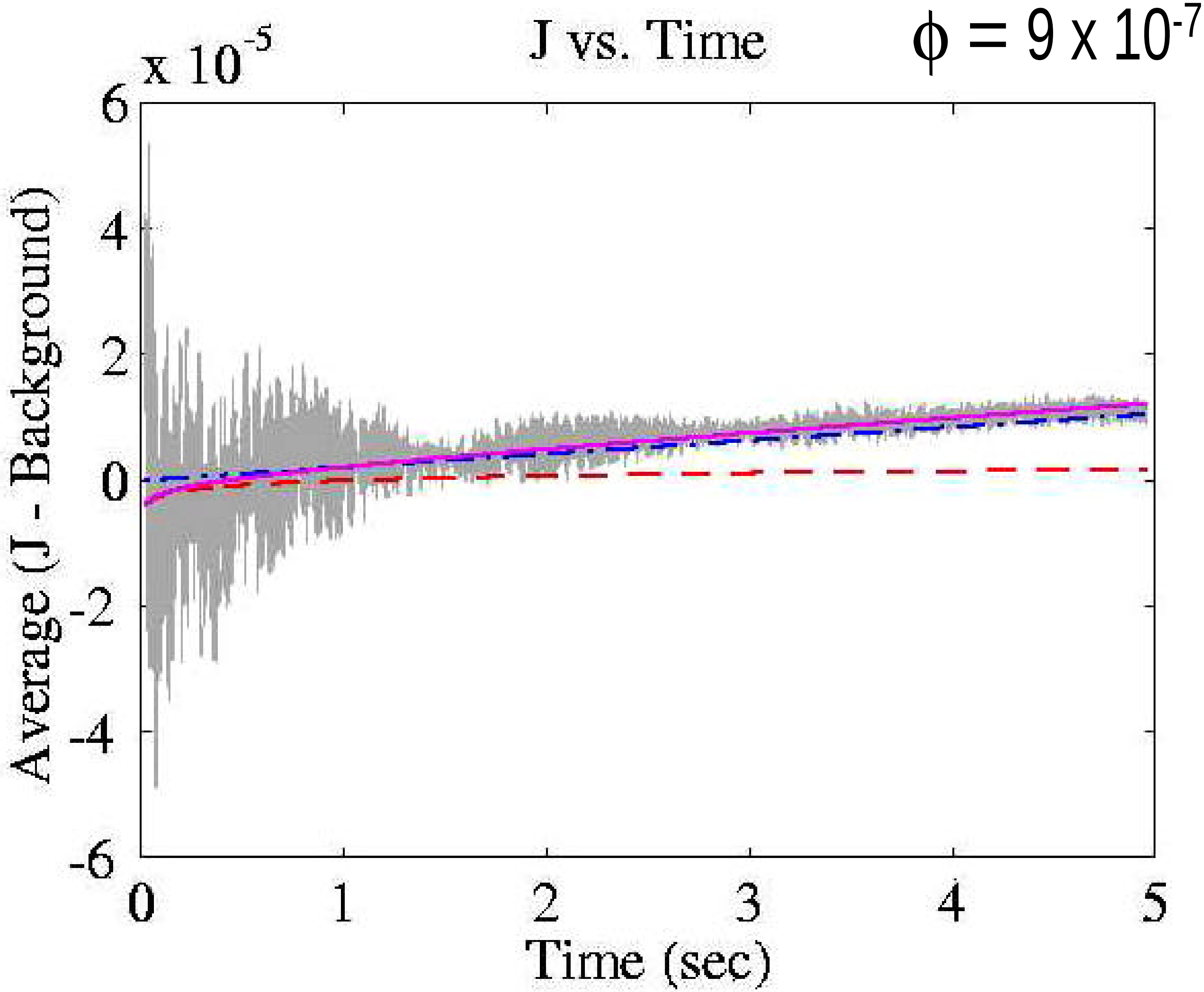


Polarization (looking downstream)



Anelastic Aftereffect

Anelastic Aftereffect



J vs. Time
$\phi = 9 \times 10^{-7}$
x 10^-5
Average (J - Background)
Time (sec)
6
4
2
0
-2
-4
-6
0
1
2
3
4
5

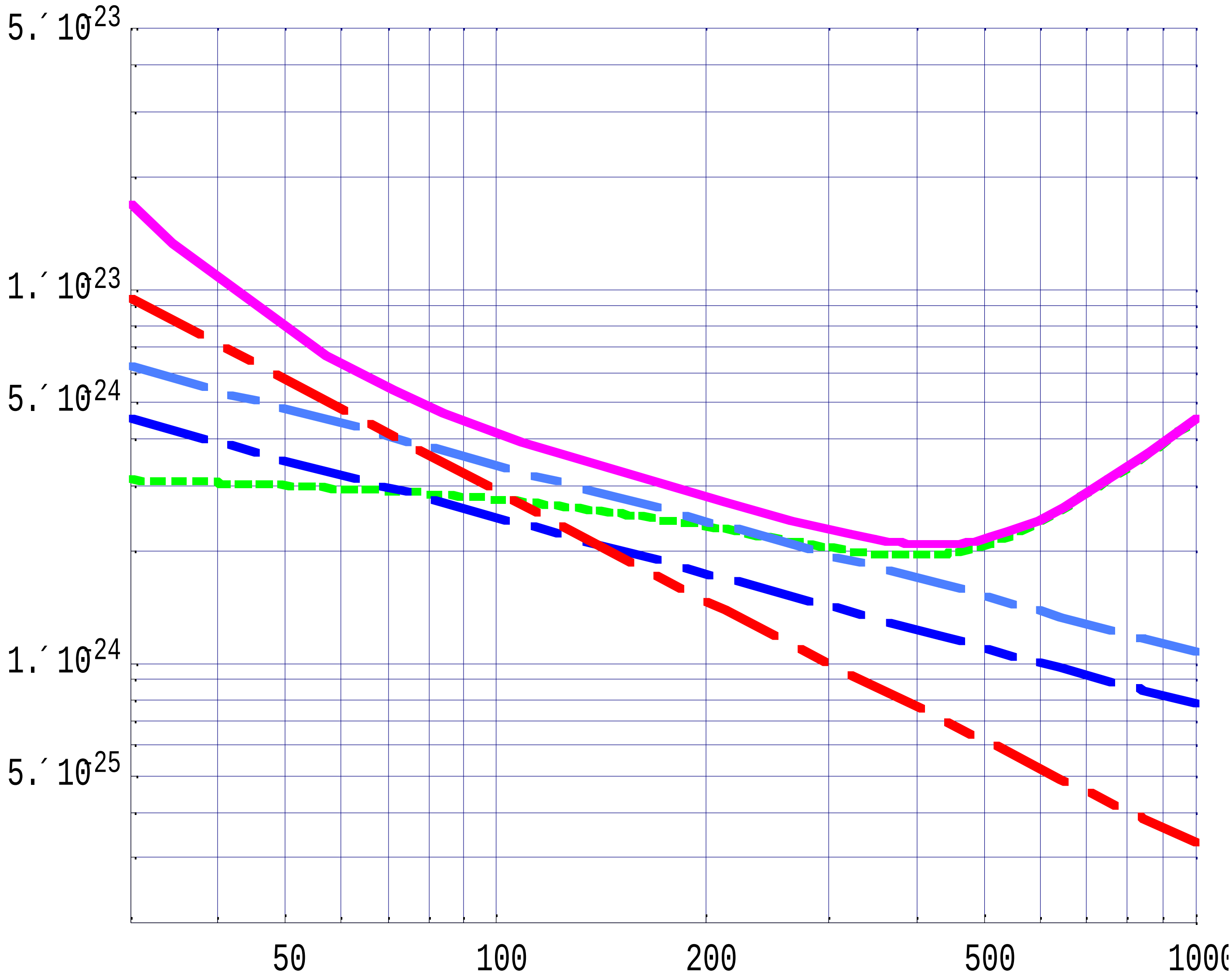
Recent Progress in Anelastic Aftereffect

- New wire sling mount in use. Primary suspension modes characterized and subtracted from output signal.
- Mock data software has tested the ability of the data analysis software to extract $\phi < 10^{-8}$ from data.
- Mock data reveals that incomplete oscillation removal inflates ϕ by >100.
- FEA package tested by modeling modes in fibers and disk samples.
- Work in progress to use FEA package to model stress profile in fused silica and sapphire.

Current Status in Anelastic Aftereffect

- Statistical error at 10^{-8} , but Systematic errors from the mounts are on the 10^{-7} level.
- Fused Silica has been just beyond our reach. Mounting and alignment difficult with vise which squeezes with 10^5 N and 1 mil clearance on either side. Sling mount fully implemented. Ultimately we could resort to silicate bonding.
- Mock data generator verifies accuracy of analysis code.
- Sapphire ϕ should be easily measurable barring any problems with birefringence.

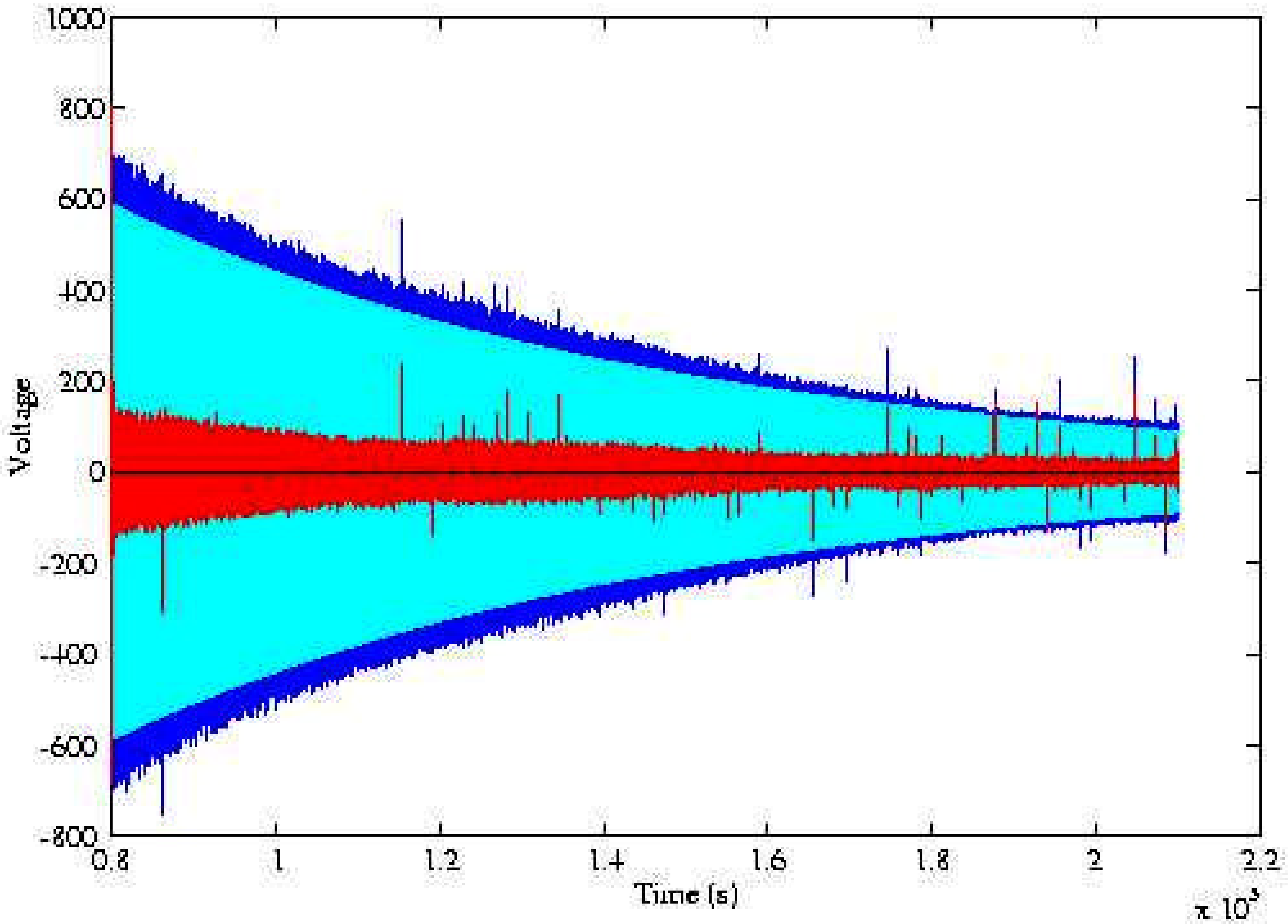
Measuring Sapphire in Anelastic Aftereffect



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

File: 081400a.dat, Freq = 305.870Hz, Tau = 68701.084s, Q = 6.602e+07 ± 3.262e+04



FLUCTUATION-DISSIPATION THEOREM

- $x^2_{\text{therm}}(f) = \dfrac{k_B T}{\pi^2 f^2} \quad (Y(f))$

  where $Y(f) = v(f)/F(f)$ and $\text{Re}[Y(f)] = 2\pi f \phi(f)/k$

  and the spring constant is $k(1 + i\phi(f))$

- At resonance $\phi(f_n) = \dfrac{1}{Q_n}$

- For a test mass under an harmonic stress, ϕ is the phase shift in the strain.

- OR, we can derive ϕ from measurements of the anelastic aftereffect or creep

Prospects for Measuring ϕ of Sapphire with Anelastic Aftereffect

- Fused silica $\phi < 10^{-6}$ but systematics from the test mass mount limit our sensitivity

- Thermoelastic Noise in Sapphire is calculated to be $\phi(f = 1\ \mathrm{Hz}) \approx 10^{-5}$ (quite detectable?)

- Inherent Birefringence may prove troublesome for our suspended mounts

- Large Stress-induced birefringence must be achievable with our PZT vise