NSF Proposal: "Thermal Noise Research for Advanced LIGO Interferometers"

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Aim: Understanding and minimizing thermal noise

- Thermal noise already a limit in LIGO I near 100 Hz

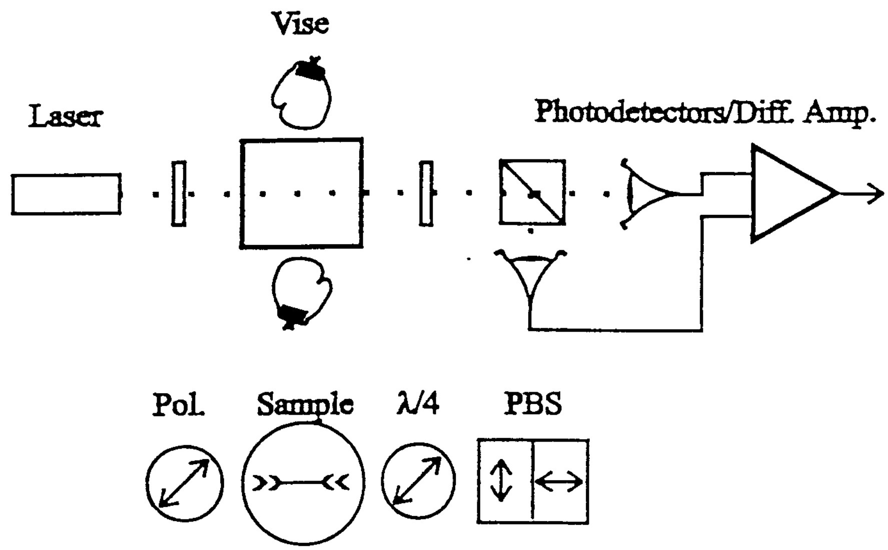
$$Q_{pend} = 1.6 \times 10^5, Q_{tm} = 1 \times 10^6$$

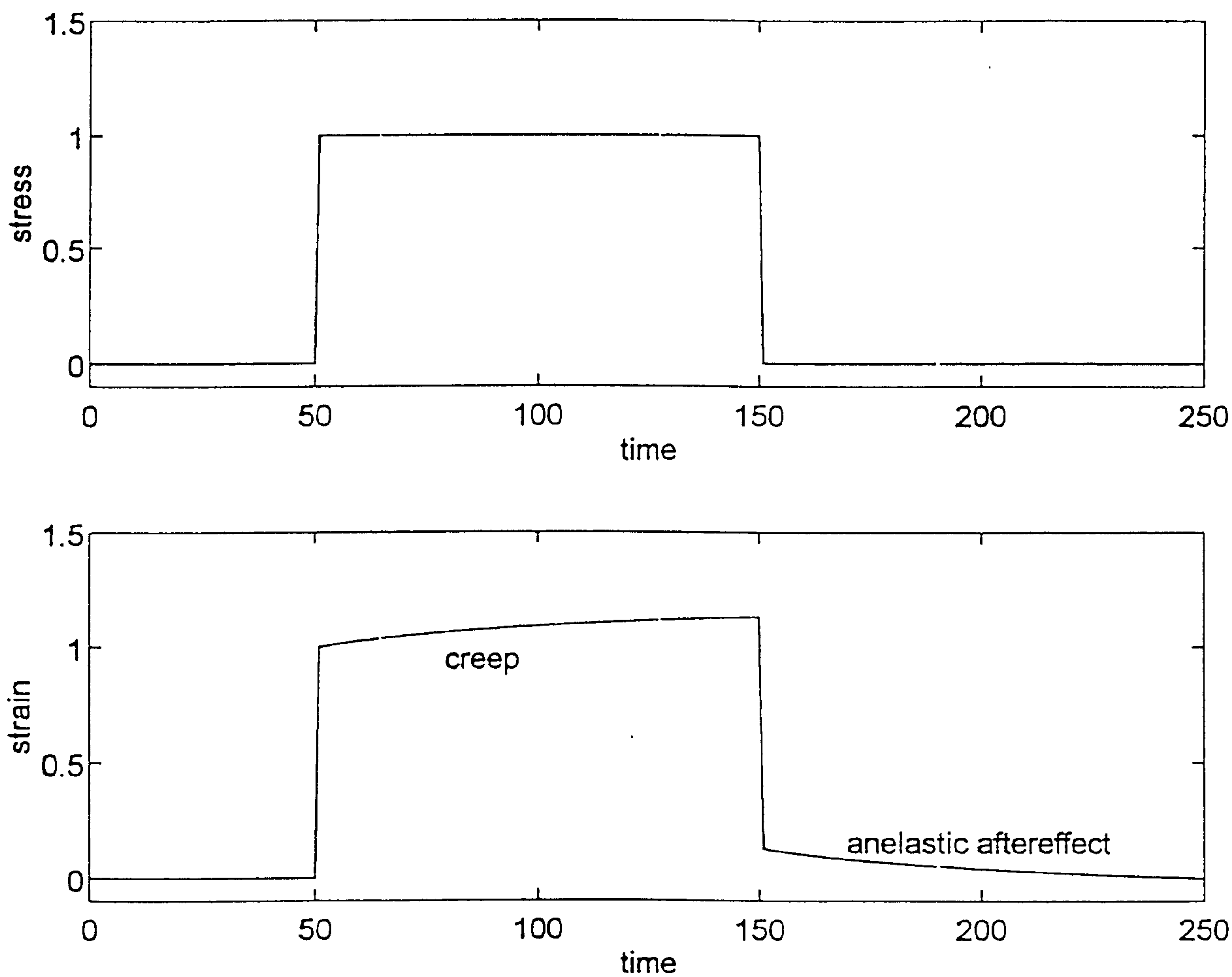
- White Paper's goals for LIGO II will demand dramatic improvements

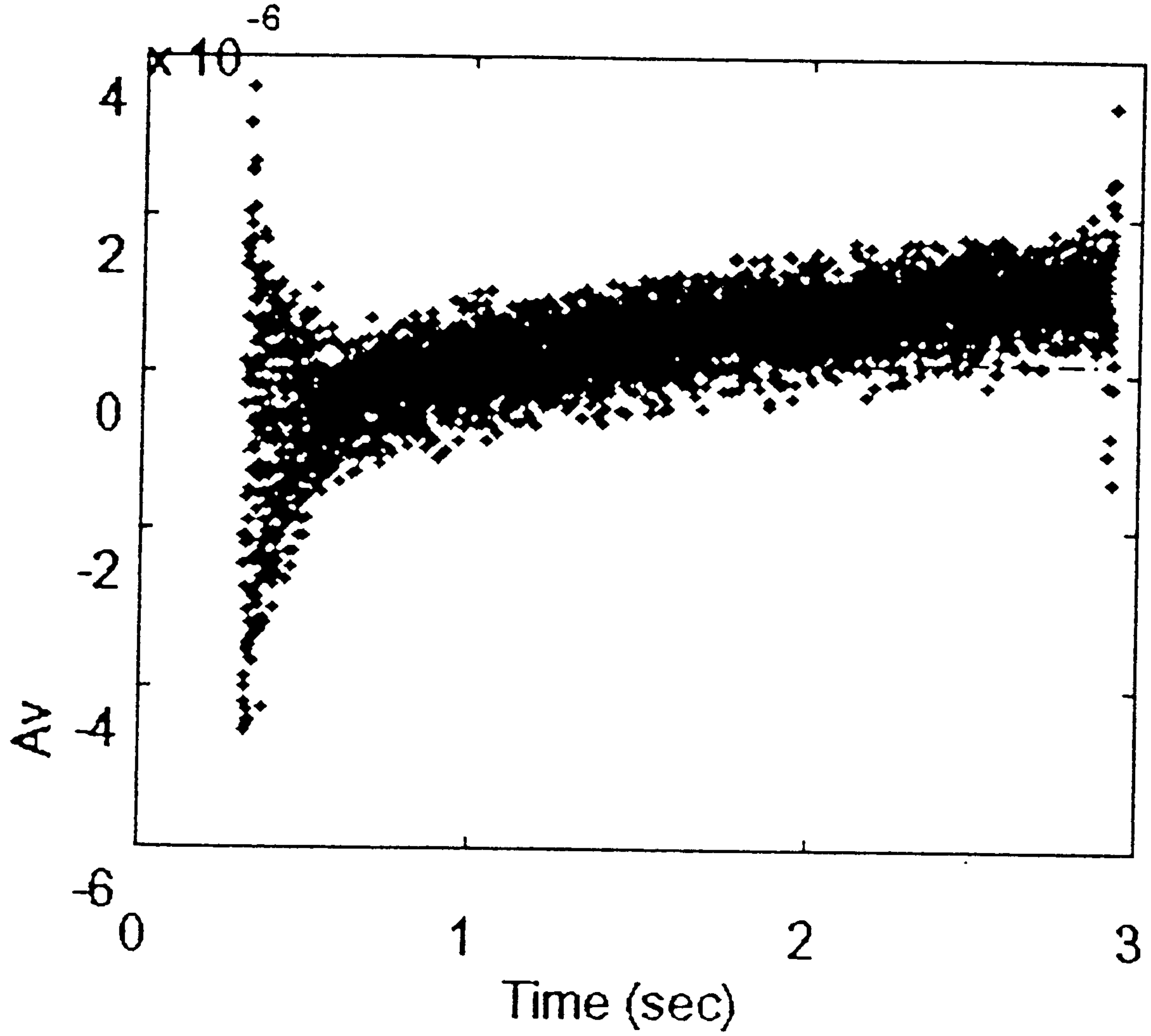
$$Q_{pend} = 3 \times 10^7, Q_{tm} = 3 \times 10^7 \rightarrow 2 \times 10^8$$

Recent Results on Q

- Fused silica bulk Q measurements (Startin):
  - blocks and cylinders show $Q \geq 1 \times 10^7$
  - Corning 7940, 7980, 7958 indistinguishable
  - probably limited by suspension loss
- Fused silica fiber Q (Gretarsson):
  - Q up to 5.6×10^6
  - vs. fused quartz Q of 1.4×10^6
  - 3 mm rod has $Q > 2.0 \times 10^7$


Vise
Laser
Photodetectors/Diff. Amp.
Pol.
Sample
λ/4
PBS


stress
time
strain
creep
anelastic aftereffect
time



x 10^-6
4
2
0
-2
-4
-6
Av
0
1
2
3
Time (sec)

Recent Results on Photoelastic Measurement of Anelasticity

- Noise, systematics reduced (Startin,Penn)
- Random error in $\phi \leq 5\times10^{-8}$ (at 1 Hz)
- Now see anelasticity of fused silica, at a level of roughly $\phi \approx 3 \rightarrow 6\times10^{-7}$
- Still checking for systematics in mounting, optics, electronics, ...?

Program I: Anelasticity (Penn)

- Work on improving sensitivity, and esp. frequency response
- More study of fused silica, incl. larger samples
- Study anelasticity of sapphire and other crystalline materials (e.g., YAG, spinel) (w/ Stanford)

Program II: Violin Mode Monitor (Gretarsson)

- Develop simple & robust monitor for violin modes, sensitive to Brownian motion (highly focused, servoed, optical lever)
- Extend Braginsky group tests for excess noise to LIGO I suspension
- Check macroscopic vs. microscopic Q in cases where rubbing friction may dominate

Program III: Friction in mirror coatings (Harry)

- Coatings may limit Q of test masses, once bulk Q is reduced to 2×10^8
- We'll build flat thin fused silica resonators (w/ Stanford)
- Measure Q uncoated, then with coatings
- High surfact to volume ratio will emphasize dissipation in coating.

Program IV: LIGO III Topics

- Cryogenic test masses (w/ LSU, Stanford):
  - crystalline materials can be cooled for further thermal noise reduction
  - examine suspension design issues, then start tests of *Q* at 4 K
- Internal thermal noise monitor:
  - Re-examine Weiss' idea to measure and subtract thermal noise; spatial resolution would help to disentangle modes

Resources

- Group size: PI, two postdocs (Penn and Harry), two grad students (Startin and Gretarsson).
- Annual budget: ~ $300 k