LIGO-G960109-00-D

FAX TRANSMISSION

Department of Physics
201 Physics Building
Syracuse University
Syracuse, NY 13244-1130

Fax: (315) 443-9103 Tel: (315) 443-3901

****

DATE: April 29, 1996

To:

Name: Dr. Alex Abramovici

Address: LIGO Project

Fax: Tel:

FROM:

Name: Peter Saulson

Tel: (315) 443-5994, home: (315) 449-9423

MESSAGE: Dear Alex,

Thought you'd like to see what we're going to say (in your name!) at Indianapolis. Note that Mark can now demonstrate sensitivity to ~10^{-5}. Plenty good enough for the old 40-m mass. That's next. Best regards, Peter

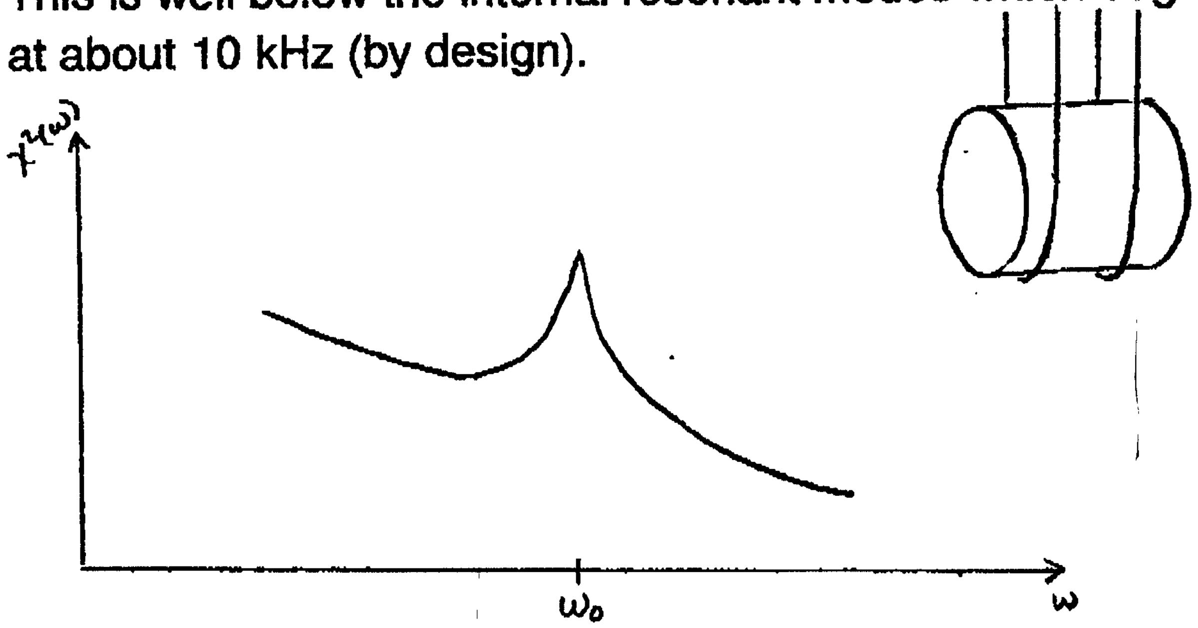
Number of pages including this cover sheet: 10 sheets

PREDICTION OF TEST MASS THERMAL NOISE BY MEASUREMENT OF THE ANELASTIC AFTEREFFECT

Mark A. Beilby and Peter R. Saulson
Syracuse University

Alex Abramovici
LIGO Project, Caltech

PROBLEM: Predict the thermal noise spectrum $x^2(\omega)$ for LIGO test masses in a frequency range 10 Hz to 1 kHz from measurement of internal friction (or loss angle) $\phi(\omega)$. This is well below the internal resonant modes which begin at about 10 kHz (by design).



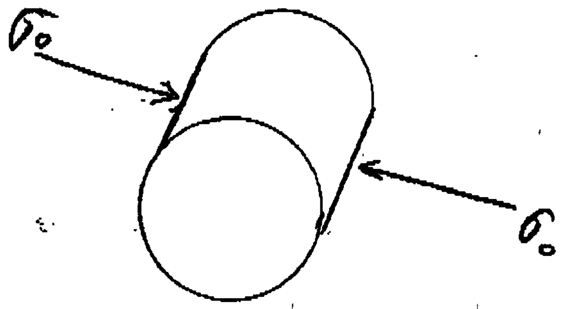
COMPLICATION: Can NOT use the trick as used in measuring $\phi(\omega)$ for pendulum modes of the suspension, by measuring *Q*'s of various violin modes, since test masses have no resonance in frequency range 10 Hz to 1 kHz.

SOLUTION: Measure the anelastic aftereffect, after the sample is "instantaneously" relieved of stress.

CREEP AND THE ANELASTIC AFTEREFFECT

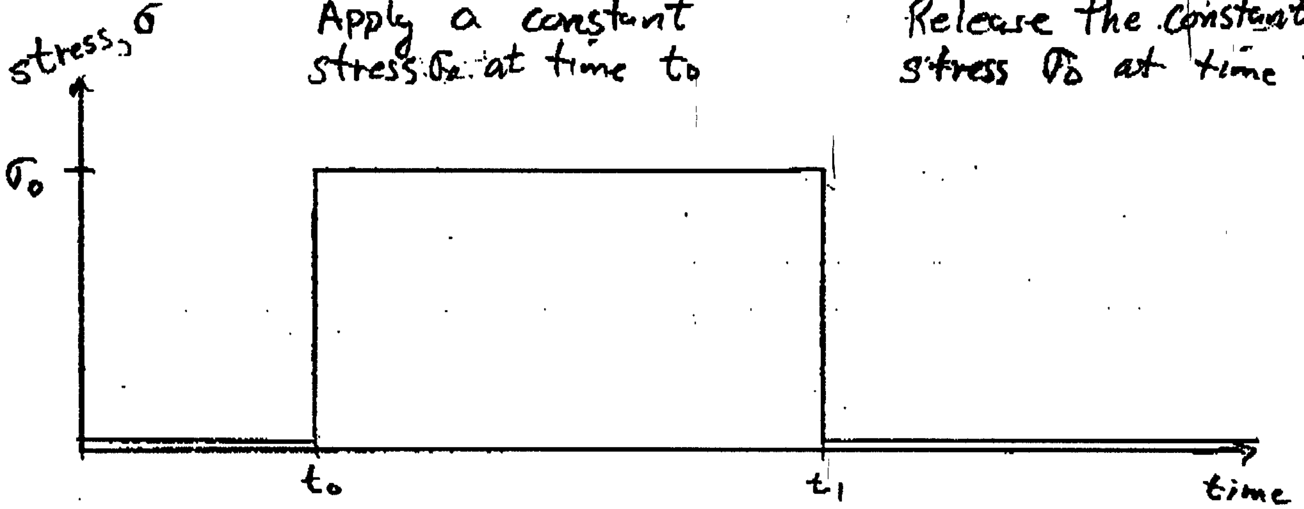
Hooke's Law:

$$\underset{\text{strain}}{\epsilon} = \underset{\text{compliance}}{J}\ \underset{\text{stress}}{\sigma}$$



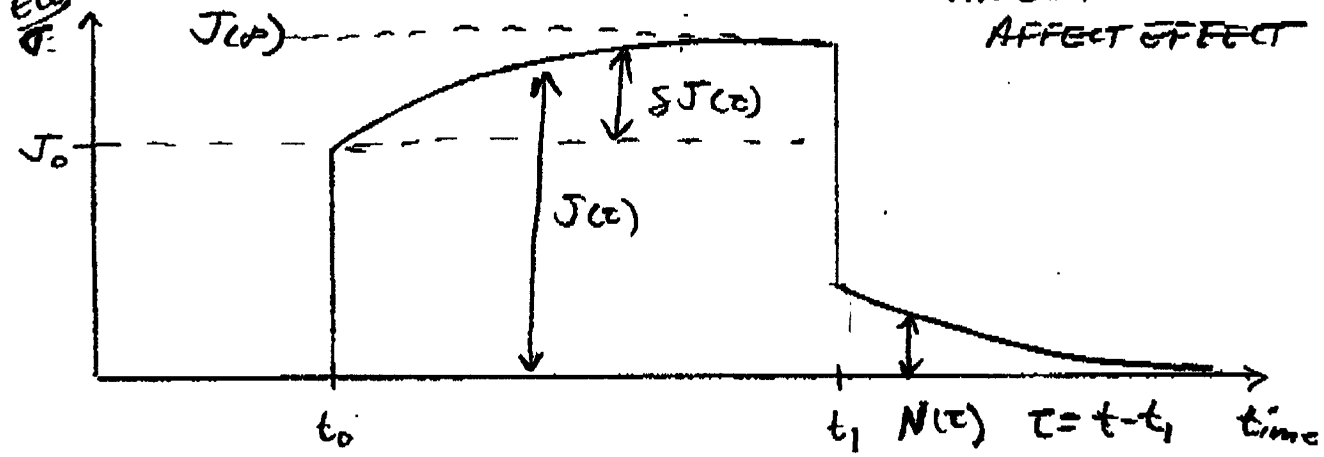
Apply a constant stress σ_0 at time t_0

Release the constant stress σ_0 at time t_1



CREEP

ANELASTIC AFFECT ~~EFFECT~~



The creep function $J(\tau)$ is defined:

$$J(\tau) \equiv \frac{\epsilon(\tau)}{\sigma_0} \qquad \tau = t - t_0$$

$$J(t_1) = J(\infty) - N(\tau)$$

4

RELATIONSHIP BETWEEN $\phi(\omega)$ AND $J(\tau)$:

$\phi(\omega)$ is well approximated by:

$$\phi(\omega) \approx \frac{\pi}{2} \left. \frac{d(\ln J(\tau))}{d \ln \tau} \right|_{\tau = 1/\omega} \qquad (\phi << 1)$$

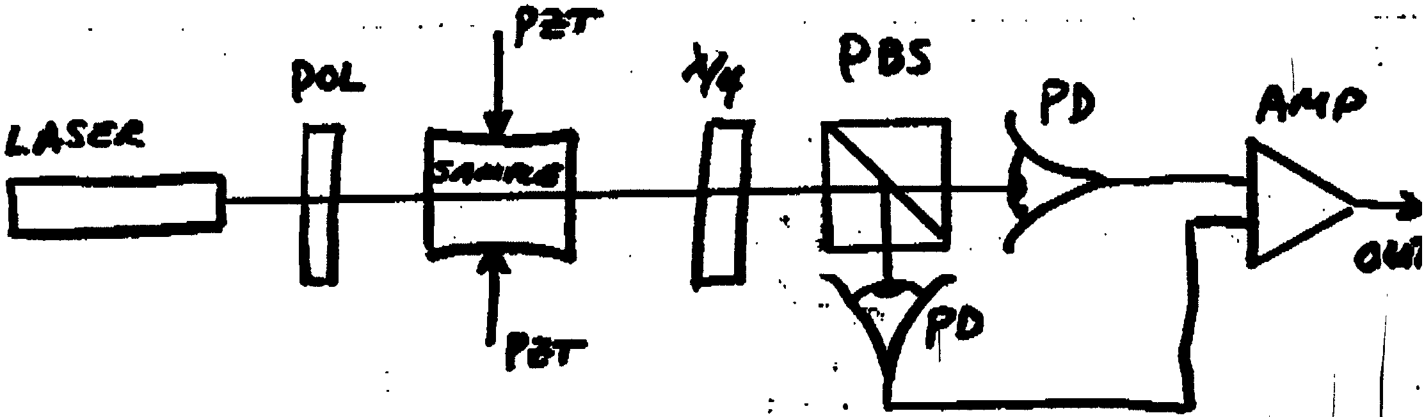
(A.S. Norwick & B.S. Berry, *Anelastic Relaxation in Crystalline Solids)*

The internal friction ϕ at some frequency ω is approximately equal to the fractional change in the strain of the sample on the corresponding time scale τ.

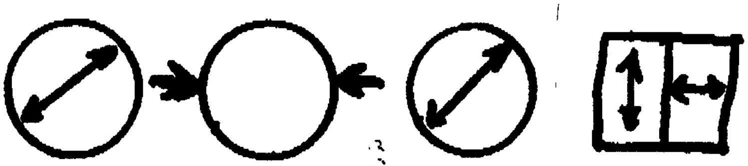
EXPERIMENTAL SET-UP

MEASURE ε(t) BY USE OF PHOTOELASTIC EFFECT (STRESS-DEPENDENT BIREFRINGENCE)

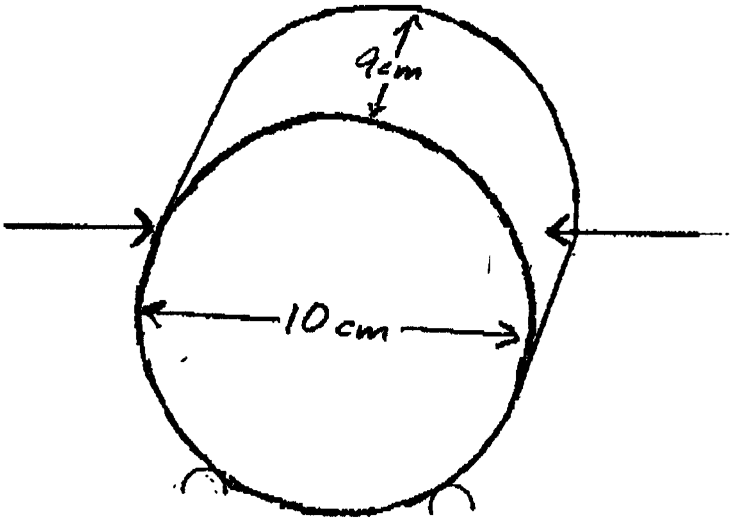
$$\underset{\substack{\uparrow\\ \text{index of refraction}}}{\Delta n_x} = \underset{\uparrow\text{constant}}{C}\,\Delta \epsilon_x$$

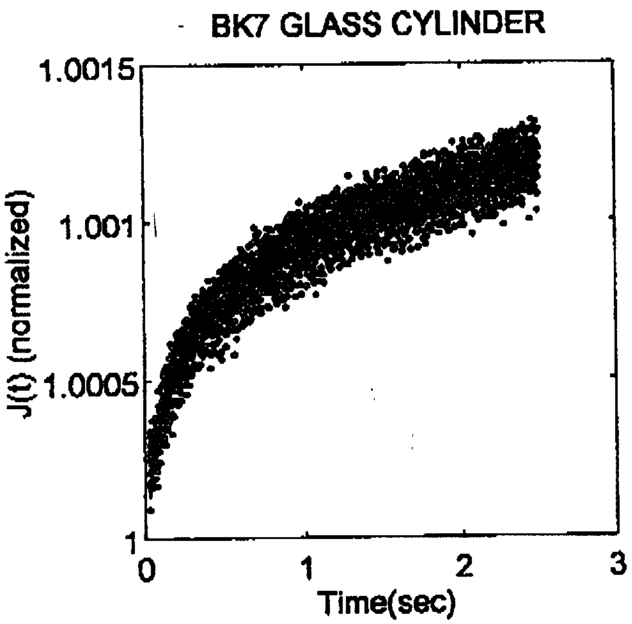


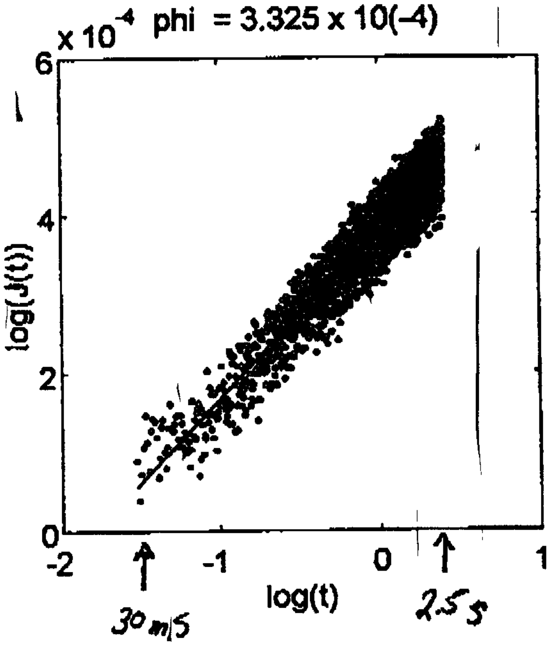
FRONT VIEW OF COMPONENTS



null output when birefrigence = 0
first order sensitive to birefringence

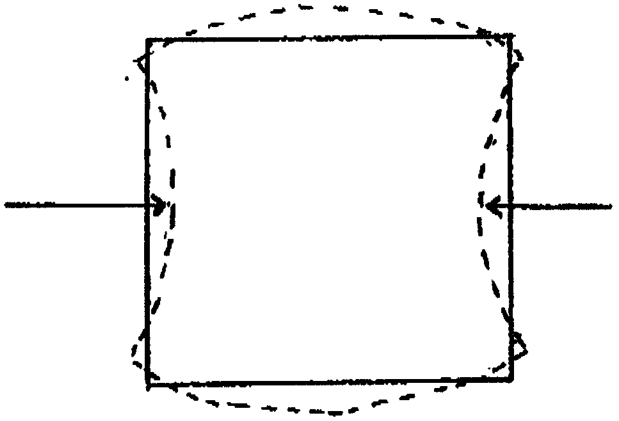


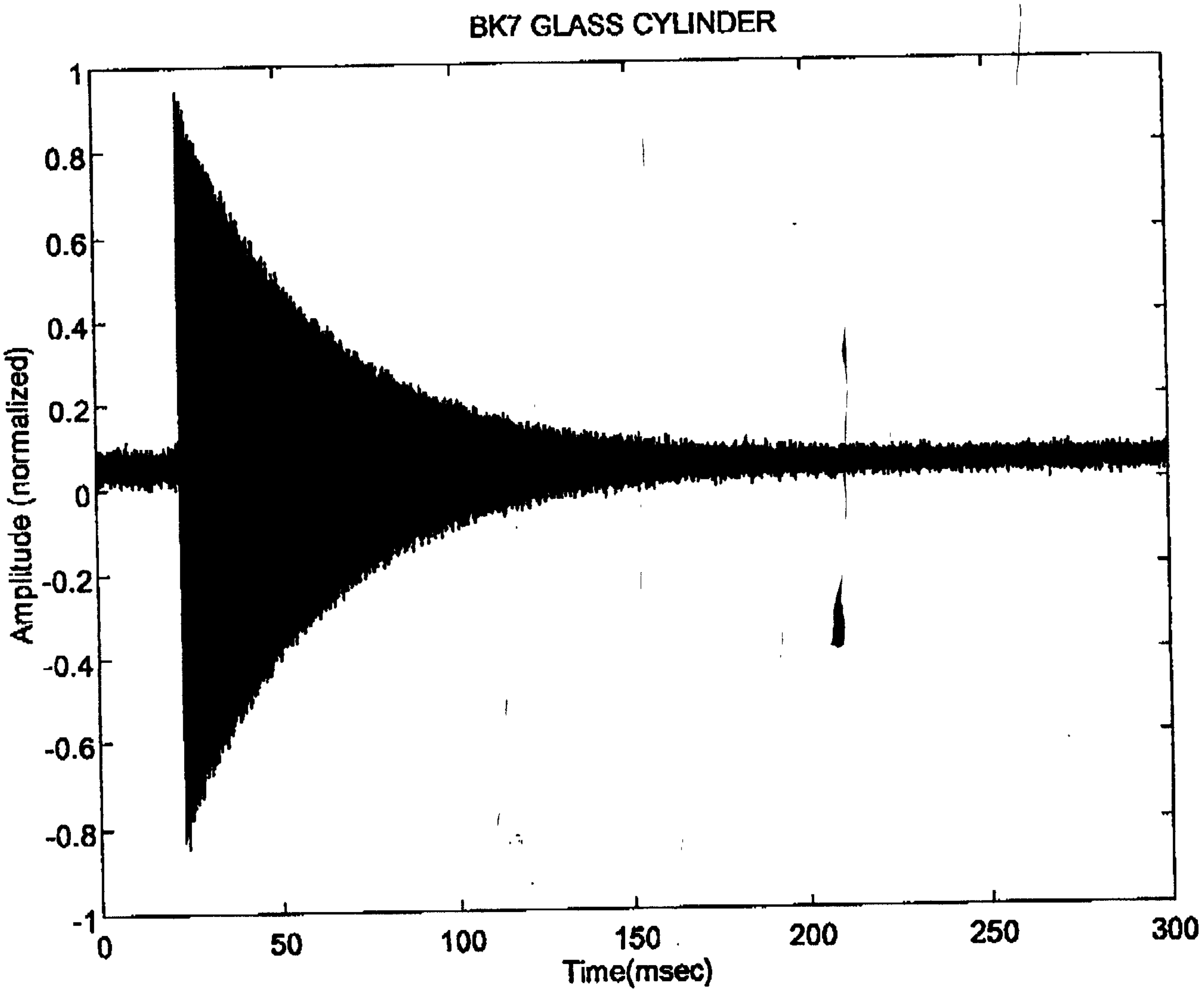

BK7 GLASS CYLINDER


x 10^-4 phi = 3.325 x 10(-4)

$\phi = (3.25 \pm 0.15) \times 10^{-4}$

5 Hz → 0.06 Hz



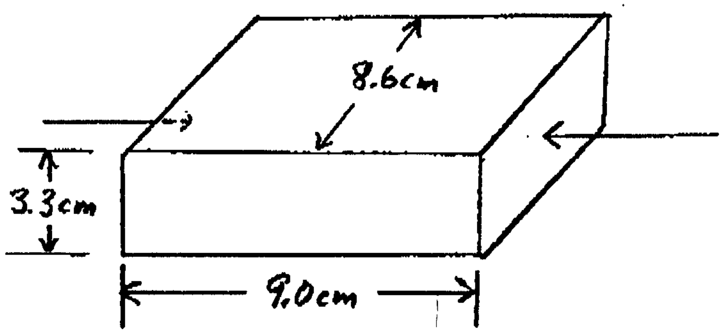


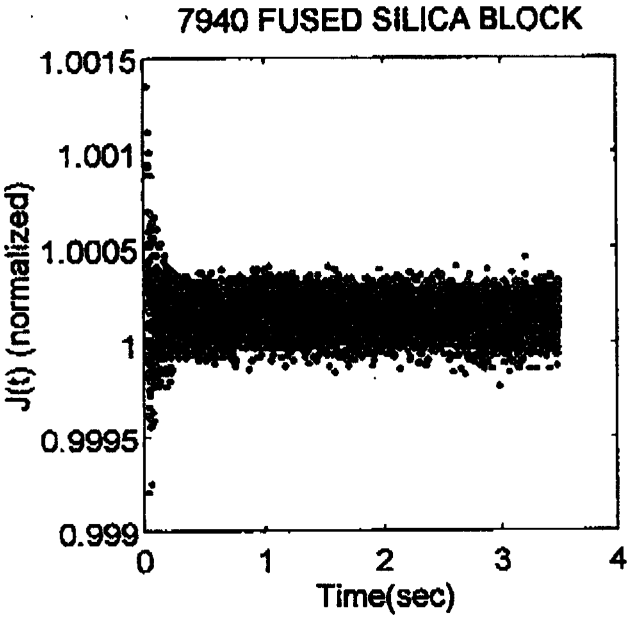
$\tau_{damp} \approx 0.040$ sec

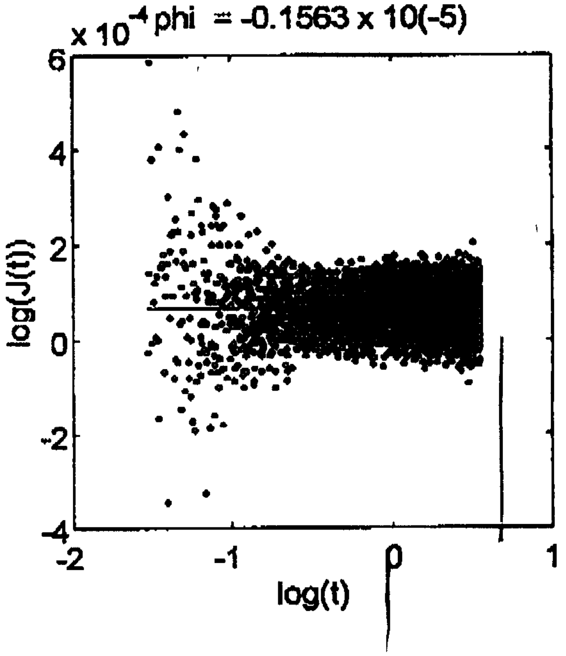
$f_{resonance} = 26{,}900$ Hz

$Q = 3.4 \times 10^3$

$\frac{1}{Q} = \phi = 2.9 \times 10^{-4}$




7940 FUSED SILICA BLOCK


x 10⁻⁴ phi = -0.1563 x 10(-5)

$\phi = (-1,5 \pm 1,4) \times 10^{-5}$ 5 Hz → 0.05 Hz

FUTURE PLANS

- measure $\phi(\omega)$ for pre - Oct. 1994 LIGO test masses.
- Improve the measurement technique of $\phi(\omega)$ to 10^{-6} or better, so $\phi(\omega)$ of other low internal friction optically transparent samples can be measured.
- design an anelastic aftereffect measuring apparatus that can be used to test actual test masses as suspended on the full scale LIGO.