Suspension Materials Research for LIGO II

Contributing Institutions:

Caltech

University of Glasgow

Moscow State University

Stanford University

Syracuse University

Caltech Participants: Phil Willems, Helena Armandula, John Johnson, David Berns, Dennis Coyne

Phil Willems, PAC8 Meeting, Caltech, May 1-2 2000.
DCC G000122-00-R

Fused Silica Fiber/Ribbon Research

Focus of work at Caltech:

-to qualify fibers/ribbons for a realistic suspension engineering design

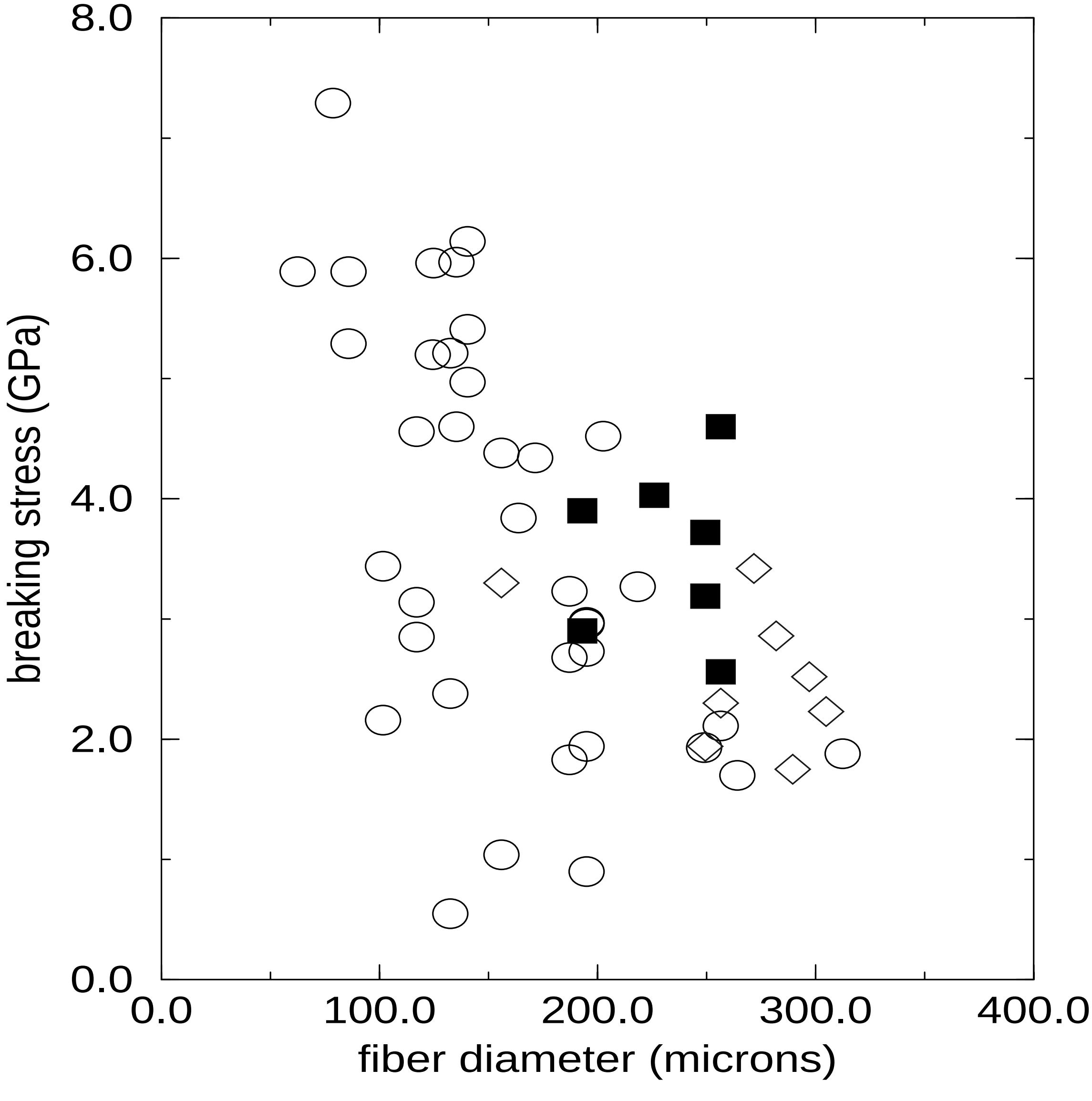
(will they break? do they flex properly?)

-to develop the manufacturing capability to fabricate fibers/ribbons of predictable quality

(are they identical? are they the right size? do they have the same losses?)

To do this we have installed an automated glassworking lathe at Caltech which makes fibers of reproducible dimension. Ribbon manufacture tests are now beginning, ribbon strength tests to be done as technique develops.

Breaking Strength of Fibers



Q of Fibers

Measuring the quality factor of fiber suspensions allows us to predict their thermal displacement noise with confidence.

Q measurements are routinely done at many laboratories around the world. Measurements at Caltech are intended more as ‘quality control’ than as basic research.

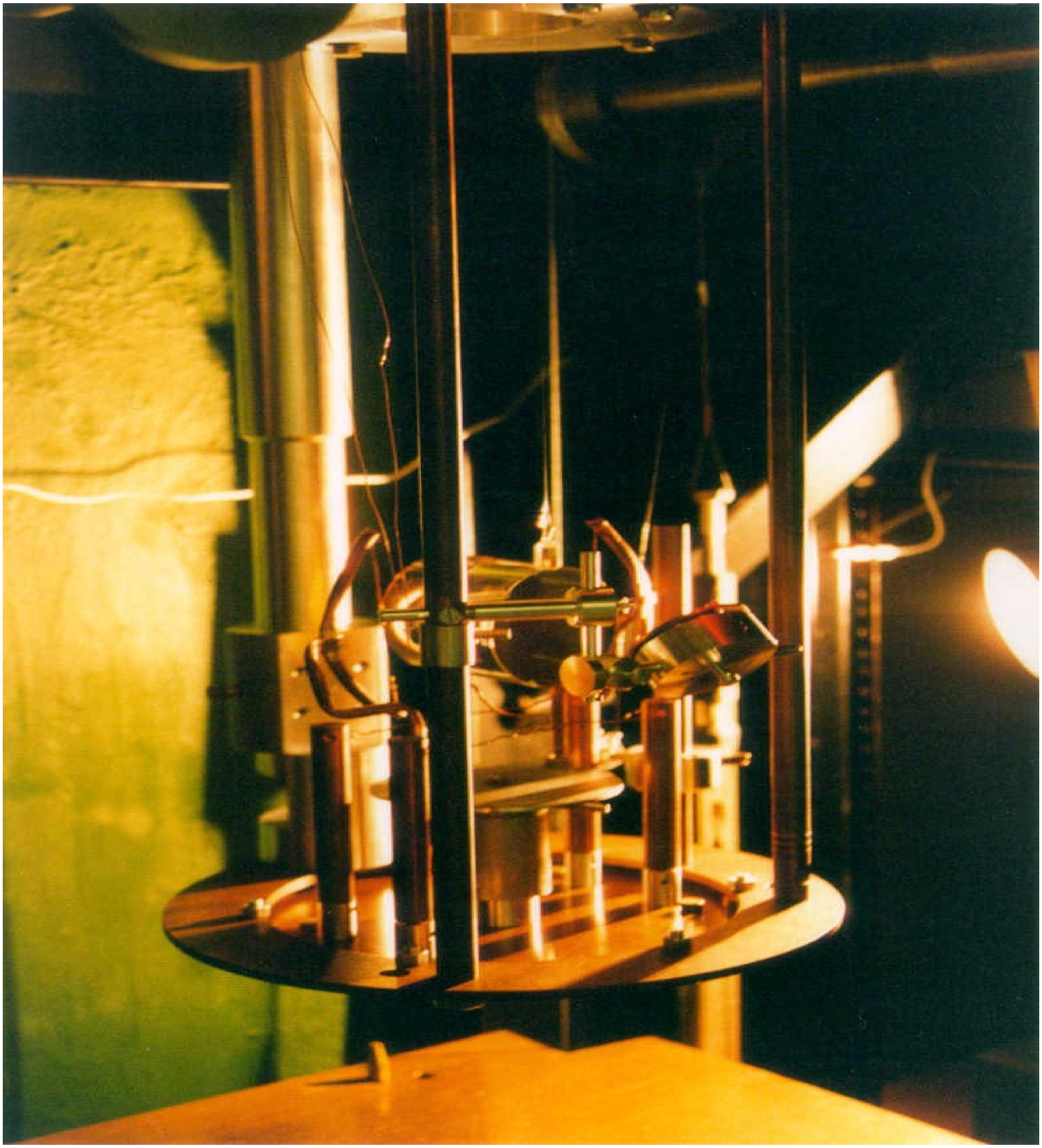
Recent measurements at Moscow using Caltech fibers in a bifilar torsional pendulum yielded a value of

$$Q = 7.3 \times 10^{7}$$

The best value, measured at the same laboratory:

$$Q = 2.4 \times 10^{8}$$

Reasons for the discrepancy are being explored.



Loss Mechanisms in Suspensions

Intrinsic losses (material internal friction)

Surface losses (processing, contaminants, ??)

Recoil losses

Nonuniformities (diameter, stress)

Thermoelastic damping

$$\phi \sim \alpha^2 T_0 / C_v$$

Nonlinear thermoelastic damping (preliminary)

$$\phi \sim (\alpha - \varepsilon Y'/Y)^2 T_0 / C_v$$

...better data are needed for Y'

Things Yet to be Done (Partial!)

-resolve ribbon manufacturing technology

-verify losses of advanced fiber/ribbon suspensions

-determine needed precision in welding of fibers and how to achieve it

-incorporate all the above into full suspension fabrication/installation procedure

-determine excess noise of fiber/ribbon suspensions

Attachment of Fibers to Mirrors

Welding of fibers/ribbons directly to test masses introduces destructive thermal stresses and is thus not practical for LIGO II

Two schools of thought on attachments:

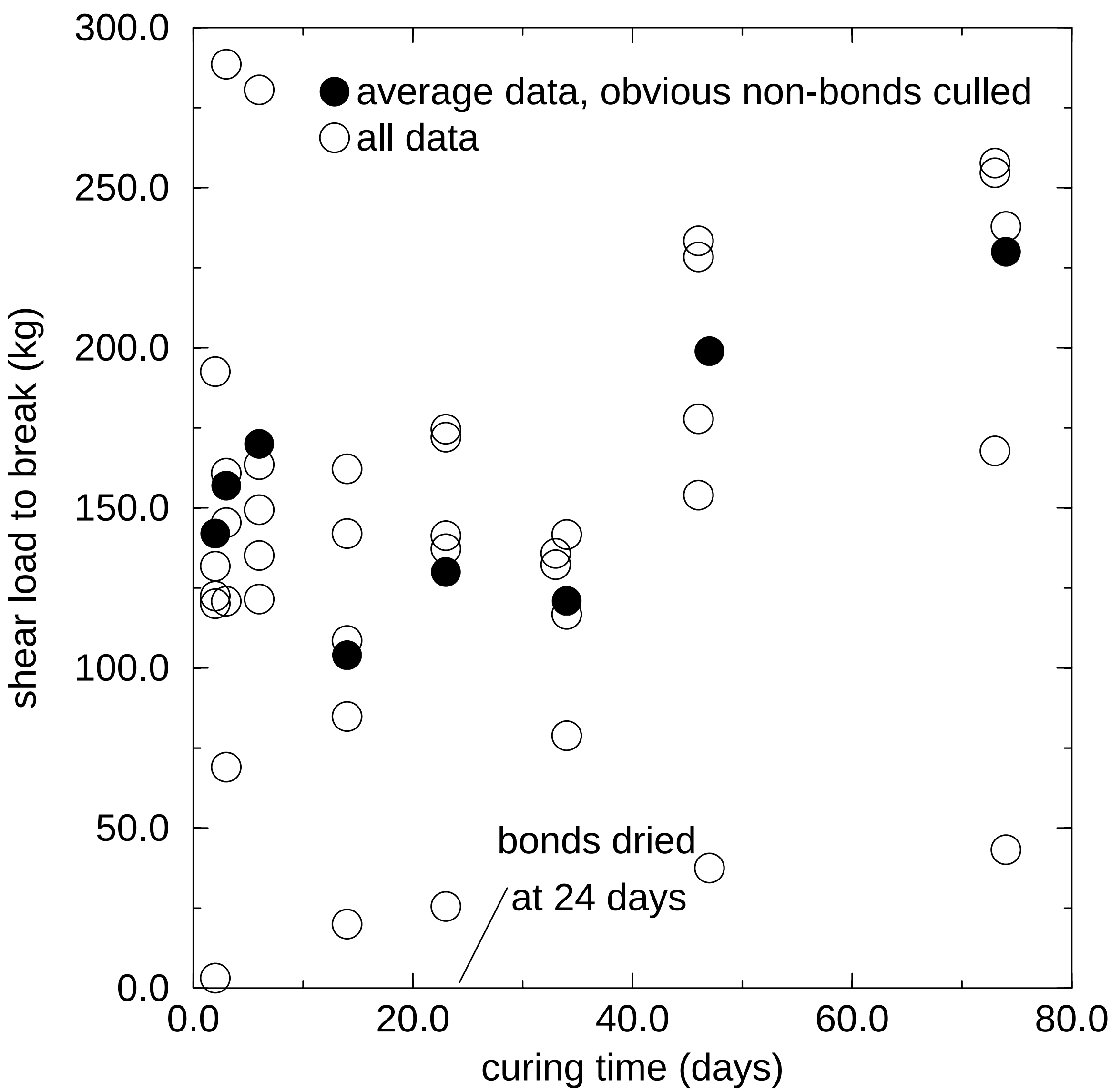
-machine 'pegs' into sides of test mass and weld to pegs (Moscow approach)

...promising, but impossible for sapphire mirrors

-bond 'ears' onto sides of test mass and weld to ears (Glasgow approach)

...also promising, but requires qualification

Stanford silica/silica bond strength



Future Silicate Bonding Work

-Evaluate ultrasonic flaw detector as nondestructive bond tester

-Check bond curing under stress (can test mass be hung after ~2 days?)

-Measure silica/sapphire bond strength

-Measure effect of silicate bond on Q of sapphire test mass (has already been qualified for silica test mass)

All tests will be carried out this year at Caltech & Stanford.

LIGO

Test Mass Q Measurements

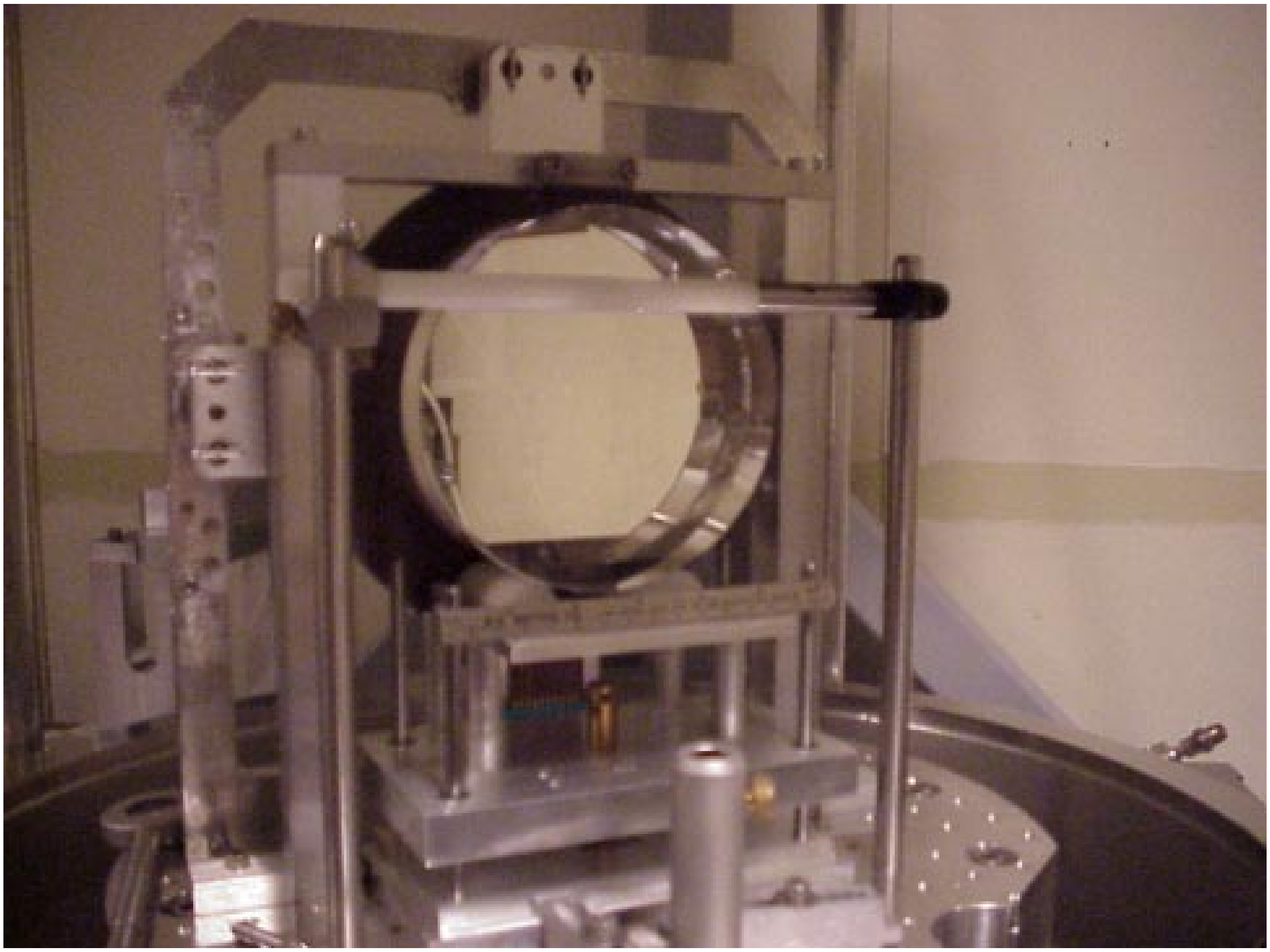
Q measurements of internal modes of a test mass cannot give a complete picture of thermal displacement noise in LIGO II, since they are limited to frequencies >10 kHz.

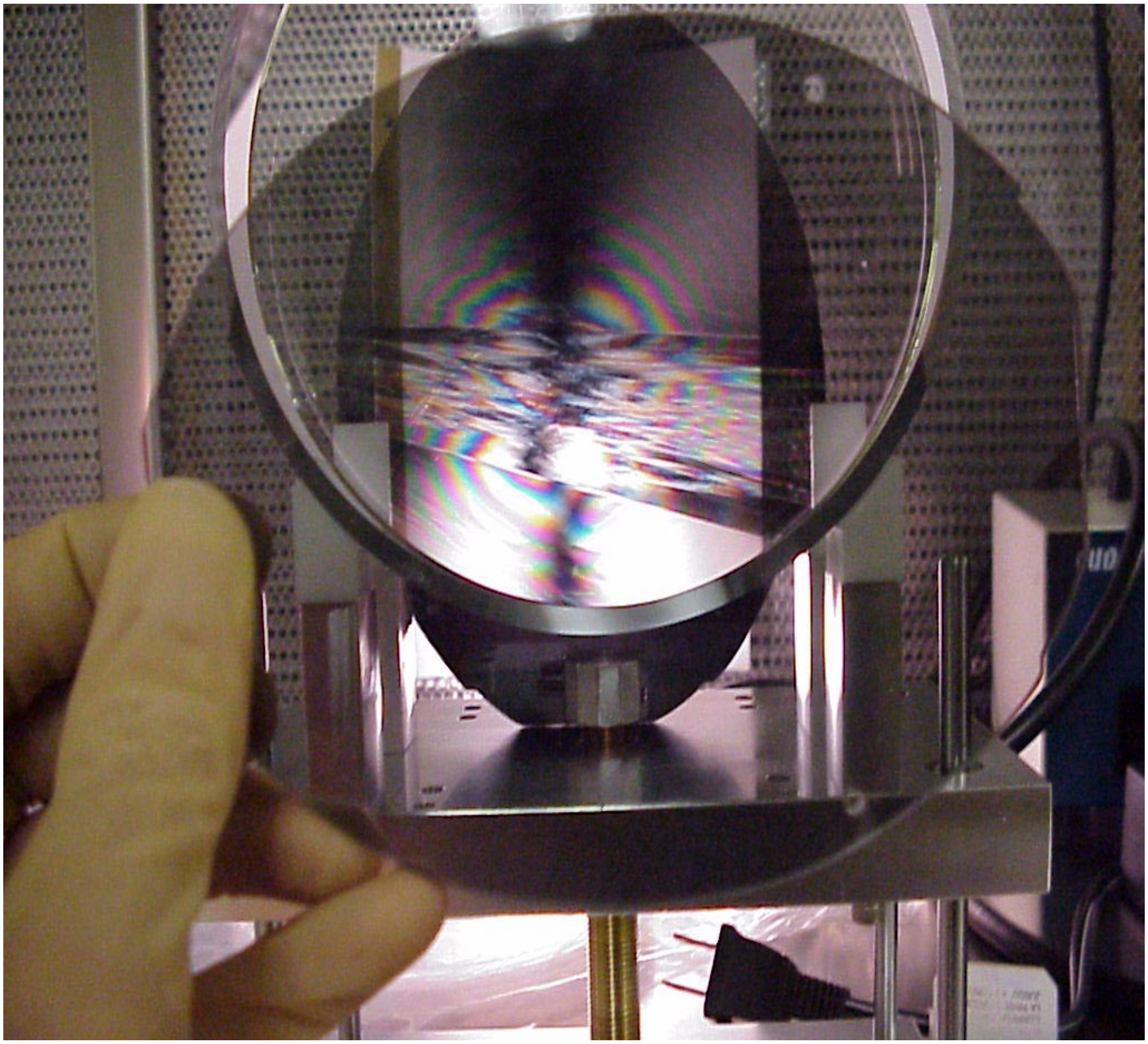
However, with them we can learn a lot with relatively little effort.

Fused silica test masses have $Q=2x10^7$ routinely.

Sapphire test masses are being measured with $Q>2x10^8$ in many laboratories, including Caltech;

LIGO





Coating Losses

Data taken to measure the effect of bonded magnets on the Q of a fused silica test mass have been reanalyzed in comparison to modal calculations to look for losses in the coating.

No effect is found at the 10^{-7} level:

Mode Freq (kHz)	ϕ, without magnets ($x10^{-7}$)	ϕ, with magnets ($x10^{-7}$)
9.31	71.9	102
14.43	1.02	1.04
22.22	19.2	19.6
22.49	.775	1.31
26.11	2.86	3.45
27.28	3.65	5.92
30.07	.637	1.66
31.02	.565	1.33
31.99	1.20	2.46
35.41	.529	.78
40.76	.787	1.75
48.13	1.12	33

Coating Losses Continued

Preliminary results from GEO see coating-related losses. Therefore, any specific coating should be qualified before use in LIGO II.

Coating losses will also be measured for sapphire test masses during 2000, at Caltech, Stanford, Syracuse and Glasgow. Direct anelastic measurements are also planned at Syracuse.