



Coatings for Q factor reduction of

Stuart Reid

University of Glasgow

UK

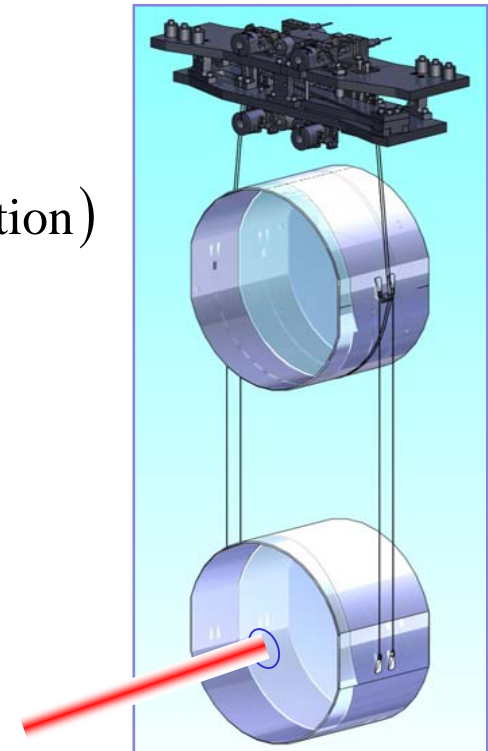
18th July 2007

Reminder - spatially inhomogeneous loss

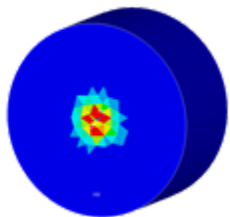
- Using the fluctuation-dissipation theorem Levin (1998) showed the thermal noise in a test mass mirror, $x(f)$ can be written:

$$x^2(f) = \frac{2k_b T}{\pi^2 f^2} \frac{W_{diss}}{F_o^2} \quad W_{diss} = 2\pi f \times \text{elastic energy} \times \phi(f, \text{position})$$

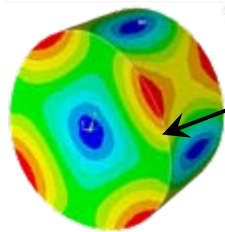
- where W_{diss} is the average power dissipated when a force of peak value F_o is applied to the suspended mass and ϕ is the loss tangent of the materials
- Here the force is applied over the profile of the laser beam interrogating the test mass
- Thus **loss, ϕ , located closer to the location where beam senses the mass, has a larger effect on thermal noise**
- This is why **mirror coatings** are clearly of particular significance



Laser incident on front surface of test mass mirror



Sensing of the interrogating laser beam



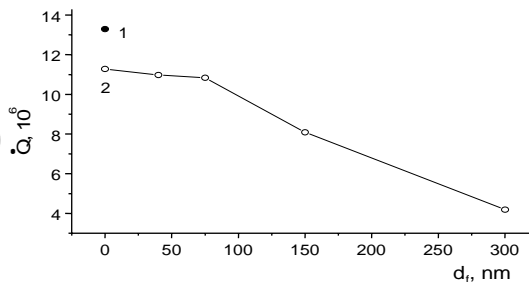
Energy distribution for the clover-4 mode for a GEO mirror

Q reduction from coatings

- Thermal compensation
 - gold barrel coatings (see LIGO DCC: G070146-00-Z)
 - (requires Cr adhesion layer)

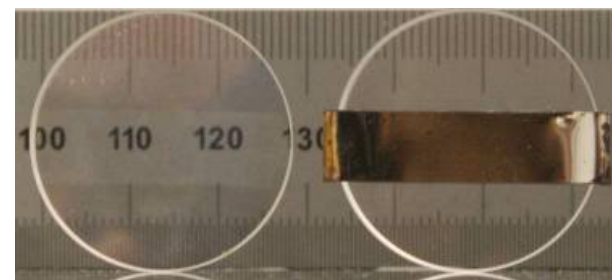
$$\phi(\omega)_{\text{GOLD}} \sim 2 \times 10^{-3}$$

B.S. Lunin *Physical and chemical bases for the development of hemispherical resonators for solid-state gyroscopes.*

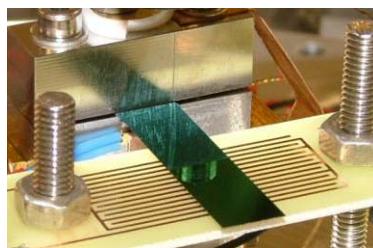


- Electrically conductive coatings
 - conductive transparent oxides (tin oxide, gallium oxide...)

$$\phi(\omega)_{\text{SnO}} \sim 3 \times 10^{-3} \text{ (Mitrokhin et al., Reid et al.)}$$

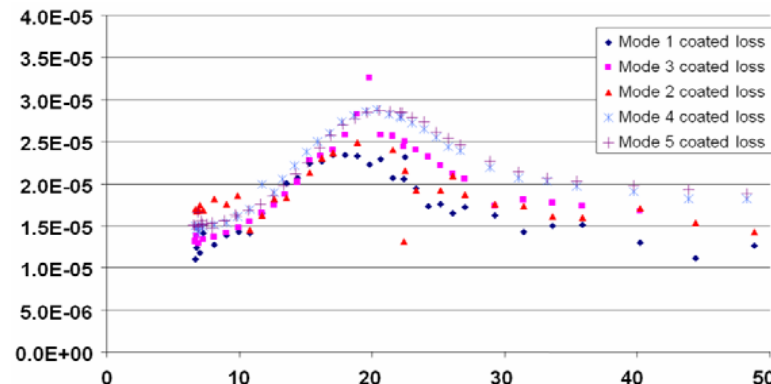


- Other
 - e.g. optical ion-beam coatings: $\phi(\omega)_{\text{Ta}_2\text{O}_5} \sim 2 \times 10^{-4}$
 - Tantalum Pentoxide Ta_2O_5 . (Iain Martin et al.)



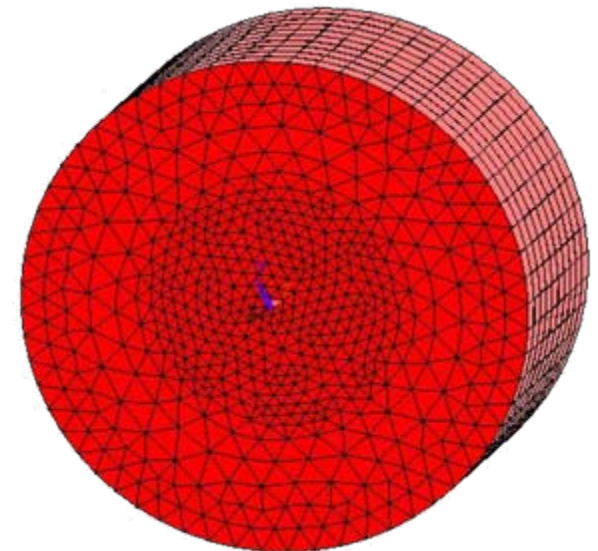
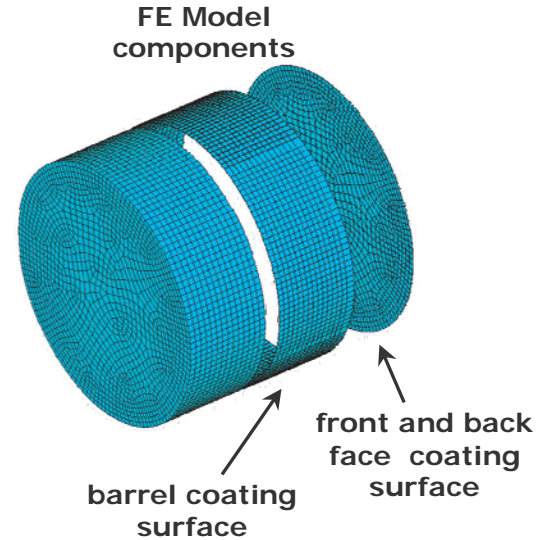
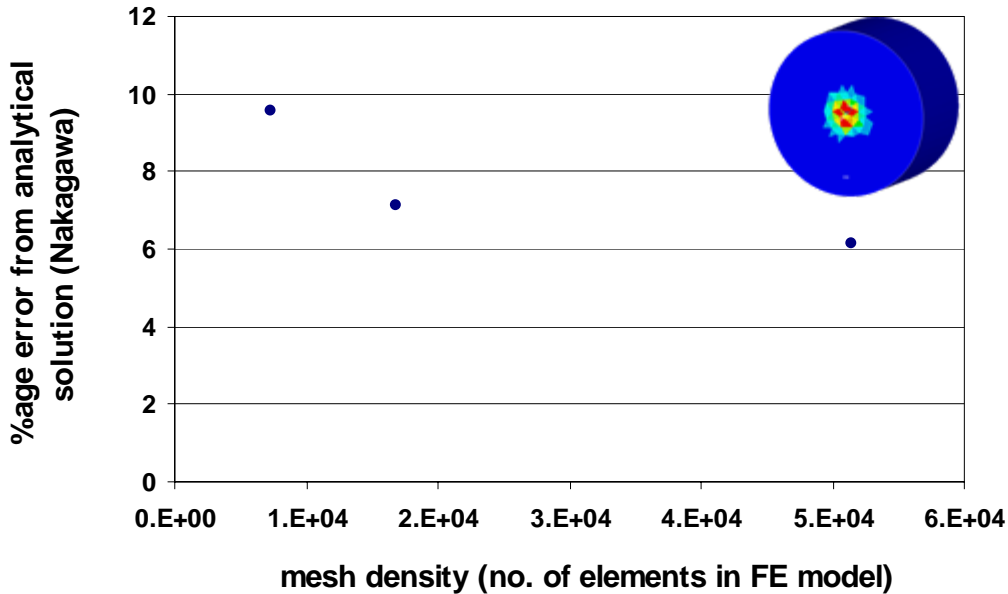
titania doped tantalum coated silicon cantilever in situ

- (undoped $\phi(\omega)_{\text{Ta}_2\text{O}_5} \sim 4 \times 10^{-4}$)



FEM - convergence & comparison to analytical

■ Testing FEM results "20node95"



Tests: damping from HR coatings (negligible)
 damping from barrel coatings (thicker than HR!)
 damping from suspensions (not phi damping but energy coupling through suspensions)