Thermal Noise Research

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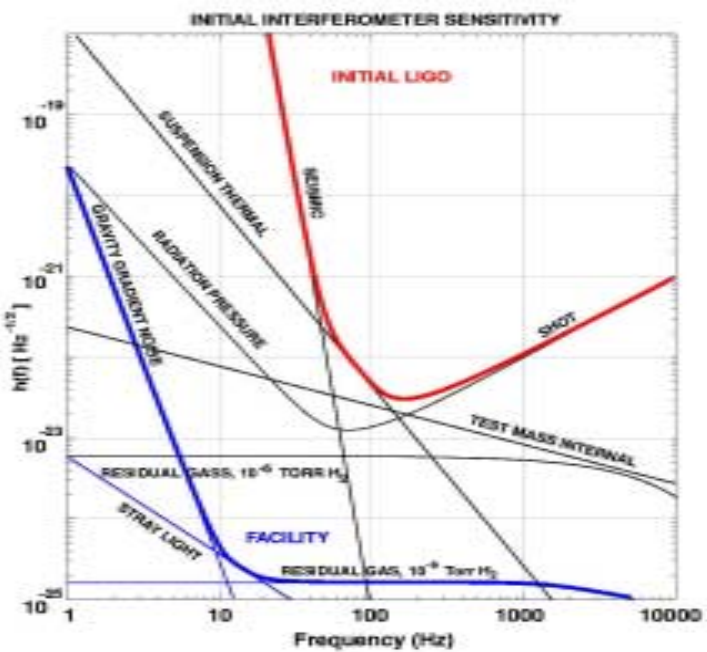
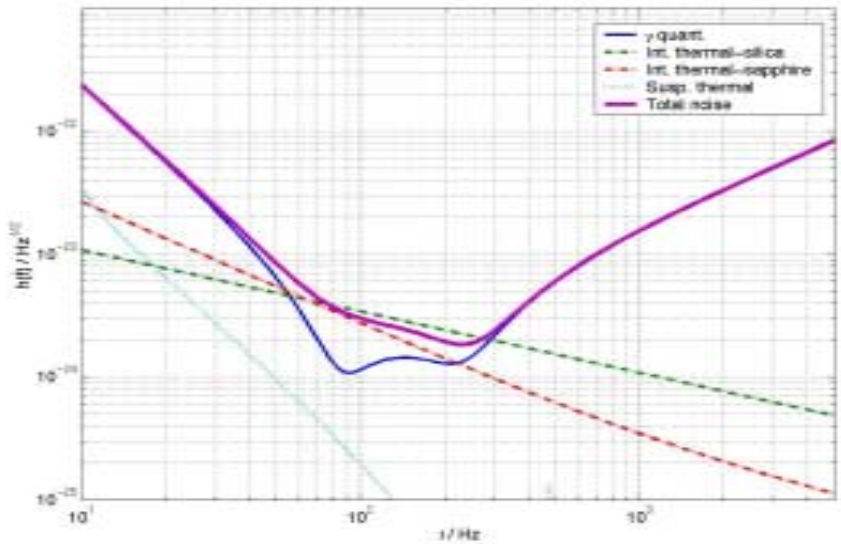
Thermal Noise in LIGO

Initial LIGO

Internal mode thermal noise not expected to be limiting noise

Needs to be checked





Advanced LIGO

Internal mode thermal noise limiting noise in sensitive region

Coating loss effects this limit

Sapphire better than silica

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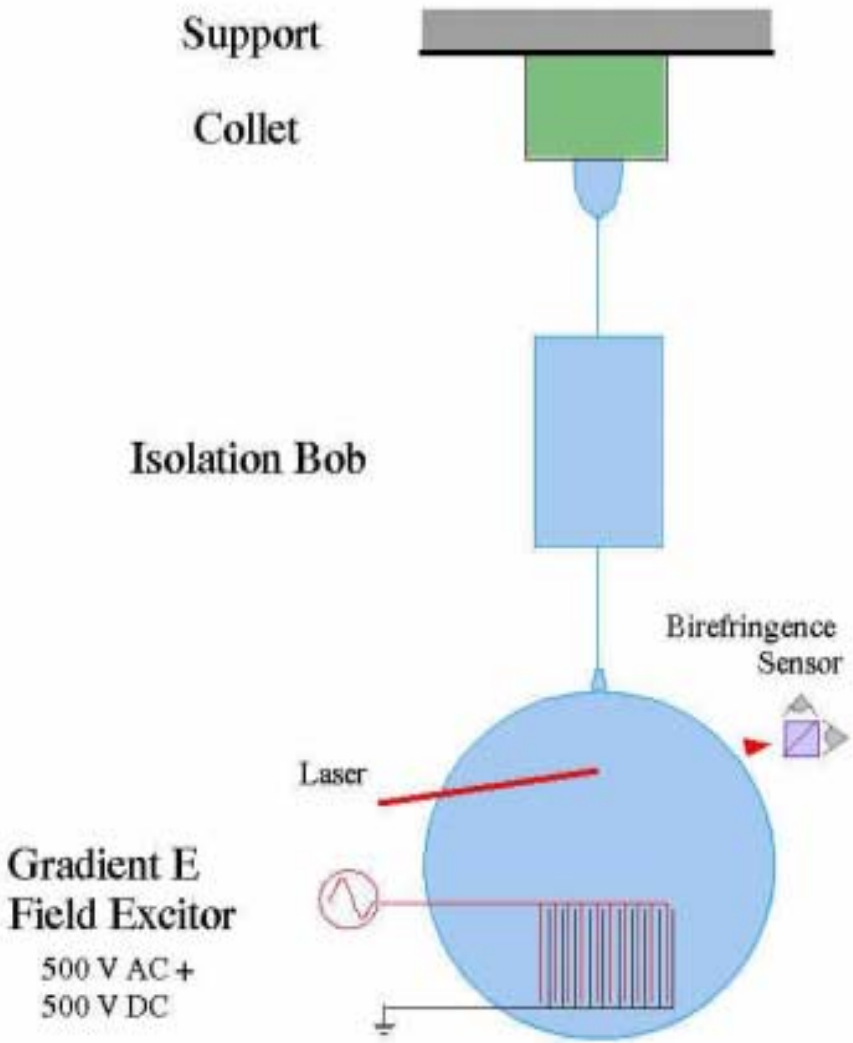
Mechanical loss in optical coatings



- Initial LIGO coatings cause too much thermal noise for advanced LIGO
- Explore alternatives by measuring Q of coated silica disks
- First step : determine source of loss in Ta_2O_5/SiO_2 coating
  - Material internal friction?
  - Interlayer rubbing?

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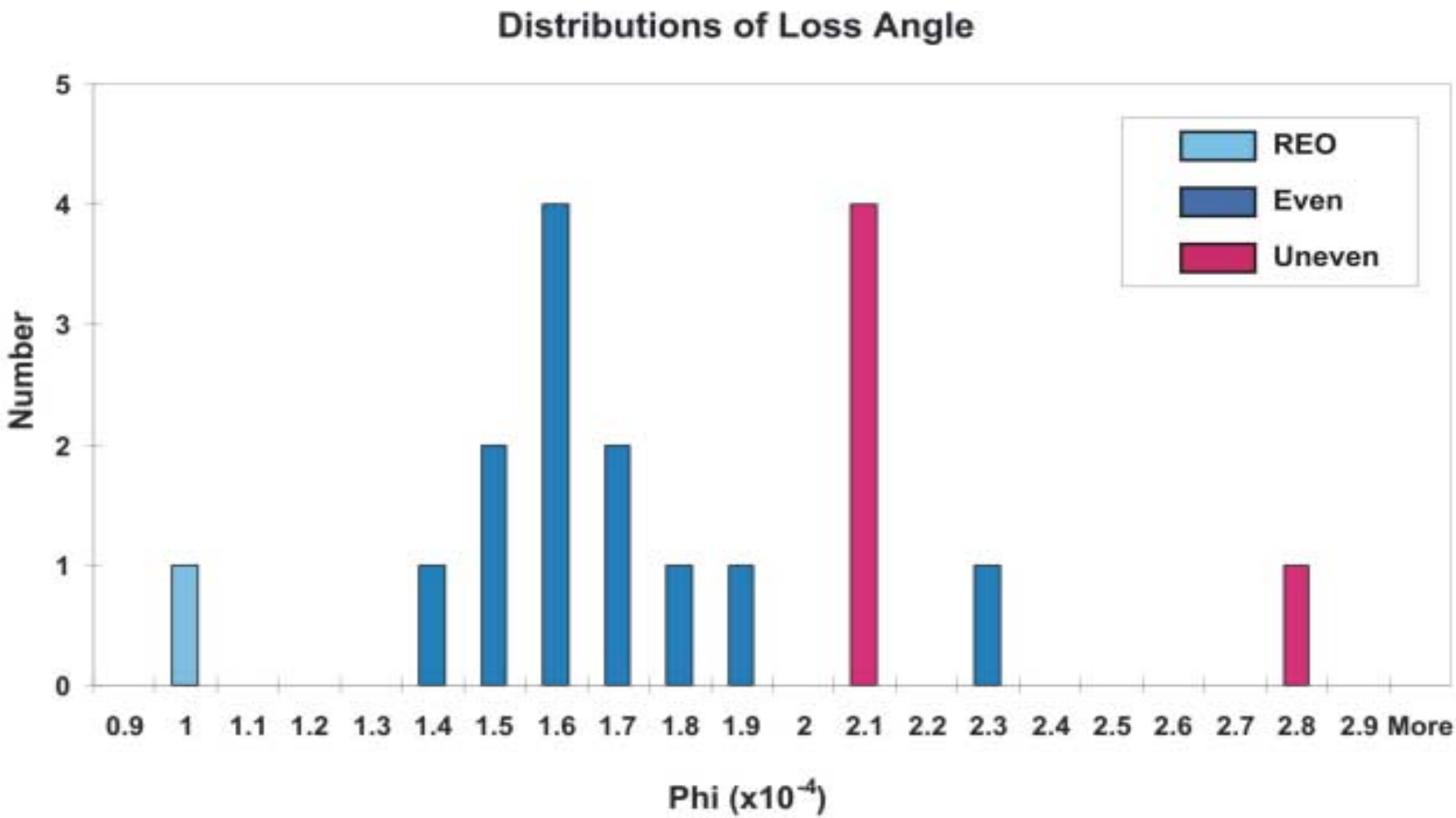
Mechanical loss in optical coatings-results



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Mechanical loss in optical coatings - future plans

Compare loss in Ta_2O_5/SiO_2 coatings from SMA/Virgo and MLD

Explore effect of annealing temperature and times

Correlate coating stress with mechanical loss

Try alternative materials

- Nb_2O_5 /SiO_2 (coating run finished at MLD)

- Al_2O_3/Ta_2O_5 (low loss from General Optics, high loss from MLD)

- others (Titania, Hafnia, ?)

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Prediction of initial LIGO thermal noise

Method of Levin/Yamamoto

- Modal expansion incorrect for inhomogeneous loss

Use Finite Element Analysis to predict elastic energy in lossy regions of test mass (wire, magnets, coating, etc)

Measure Q's of about ten modes of all IFO test masses

- LHO 2K ITMs and LLO ITMx already measured

Solve for loss in each region

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Pilot experiments - Multiple ϕ's

Isotropic materials, like fused silica, have two independant loss angles

Silica sample shaped like "I"

- **Flexure, torsional modes have similar frequencies**
- **Can excite each mode with same exciter**

Measure Q of flexure modes and torsional modes

Sapphire has five independant loss angles

Need expanded FEA code to model and extract ϕ's of sapphire measurements

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Pilot experiments - Charging vs Q

Evidence of Q degradation in pendulum mode due to charging from Glasgow group

Evidence of charge buildup on test masses from observatories and Moscow group

Measure Q vs charge for modes of thin coating disks

Various models developed and tested

- **Eddy current damping ruled out**
- **Polarization losses in silica looks promising**

May be important to study other effects of charging