Plans for optical coatings research

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Coating Plan

- Phase I - Research and Development
  Find coating that achieves sensitivity while preserving optical, mechanical, and thermal specifications
- Phase II - Production of Advanced LIGO optics
- Request for Proposal sent out June 2003
- Many international coating vendors responded
  Submitted own plan for R&D
- LIGO/LSC chose two vendors for Phase I
- LIGO/LSC will downselect to one (two?) for Phase II

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Vendors chosen for Phase I

- CSIRO – Sydney Australia
  - R&D based national laboratory
  - Currently working with LIGO on polishing
  - Individuals experienced in coatings
- SMA/Virgo – Lyon France
  - Research oriented lab on University campus
  - Worked with LIGO on first round of coating experiments
  - Did the coatings for Virgo installed optics
  - Very experienced with coatings and coating research

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Phase I
Research and Development

- Baseline coating - Al_2O_3/Ta_2O_5
- Dopants
  - Target alloy of material and dopant
  - Target overcoated at various densities
  - Thermal diffusion from gas
- New materials
  - Hafnia HfO_2
  - Zirconia ZrO_2
  - Titania TiO_2
- Annealing
  - Temperatures up to ~ 600 C
  - Different atmospheres
- Adjustment of coating process parameters
- Change thickness of layers to de-emphasize lossy materials

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Measurements

Coatings need to be characterized for all relevant parameters

- **Mechanical loss - ringdown Q experiments (MIT, Glasgow, Stanford, and Hobart and William Smith)**
- **Optical loss- absorption measurements (Stanford)**
- **Young's modulus - acoustic reflection experiment (Stanford)**
- **Thermal expansion - optical lensing experiment (Caltech, Stanford)**
- **Direct thermal noise measurement - (Caltech, Hongo)**

  Interferometers to measure thermal noise in short cavities

  Two different spot sizes (~50μm at Hongo, 160 μm at TNI)

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Schedule

- Select coating vendors for Phase I - August 2003
- Resume coating research - (when contracts are in place) Fall 2003
- Pick candidate advanced LIGO coating - August 2004
- Final round of experiments - Fall 2004
- Select coating vendor for Phase II – Winter 2005
- Coat LASTI mirrors – Winter 2005
- Begin coating Advanced LIGO mirrors – Summer 2005
- Final coated optic - Summer 2007

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Outstanding Issues

- More correlation studies of loss with stress in coatings
- Study loss closer to advanced LIGO band
- Formula for coating Brownian thermal noise in finite sized mirrors
- New version of BENCH to include coating thermoelastic noise and more complete Brownian formula
- More collaboration with material and thin film scientists
- Direct observation of coating thermoelastic noise
- Thermal lensing experiments with advanced LIGO coating

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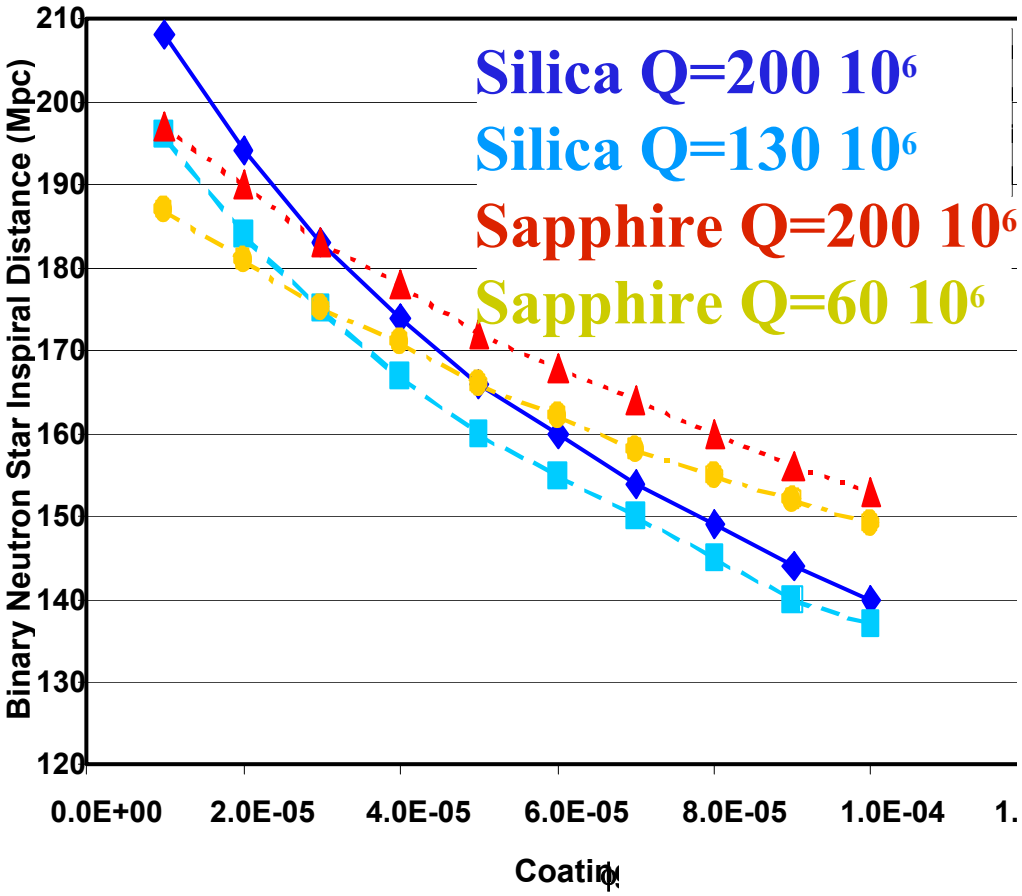
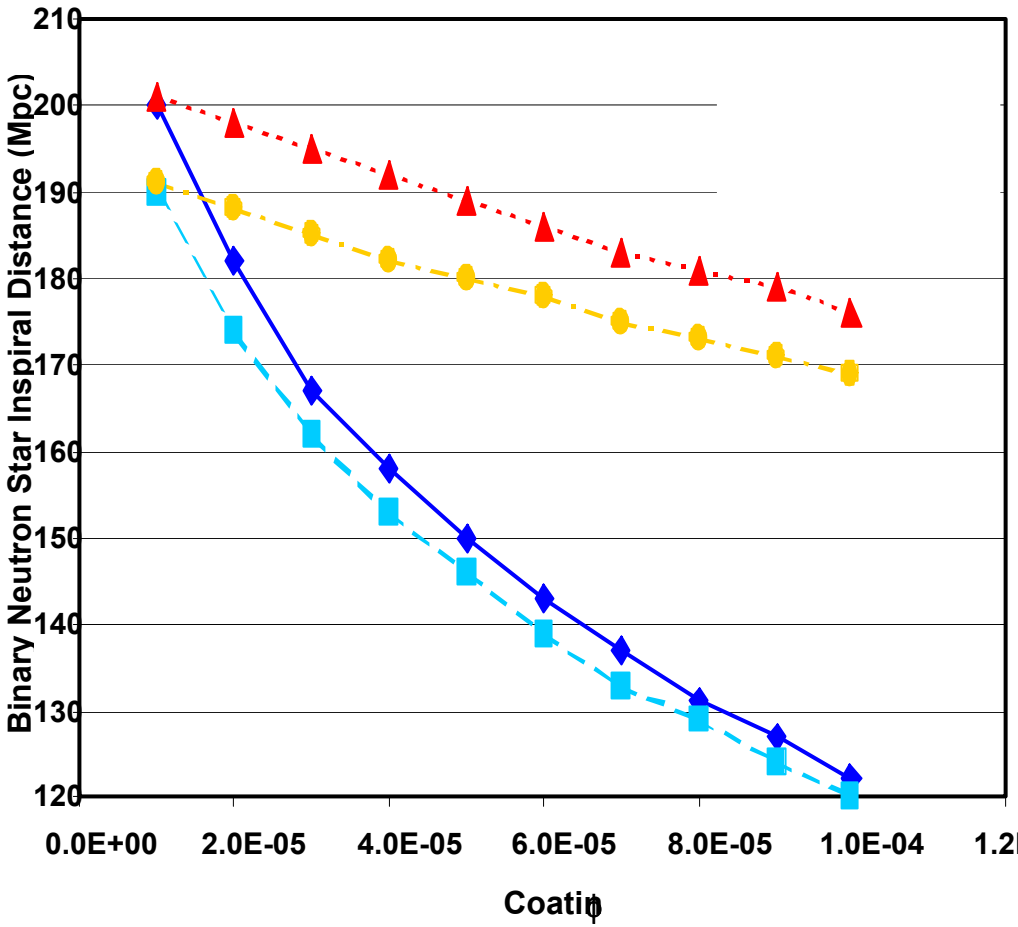
Advanced LIGO sensitivity vs coating loss angle

$Y_{coat} = 70\ 10^9$ Pa



$Y_{coat} = 200\ 10^9$ Pa



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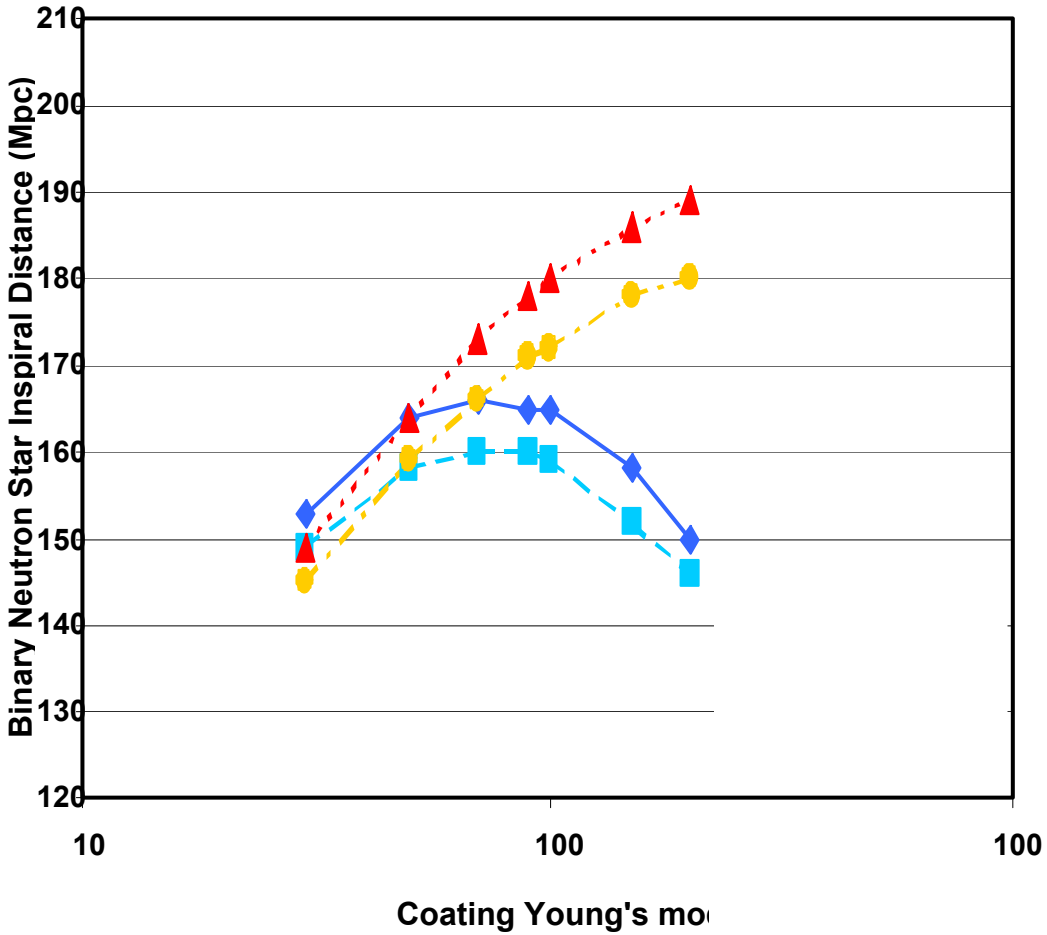
Advanced LIGO sensitivity vs coating Young's Modulus

$\phi_{coat} = 5\ 10^{-5}$



$\phi_{coat} = 1\ 10^{-5}$