Coating Research Program Update

Gregory Harry
LIGO/Massachusetts Institute of Technology
- Technical Plenary -

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LSC Meeting / Hanford

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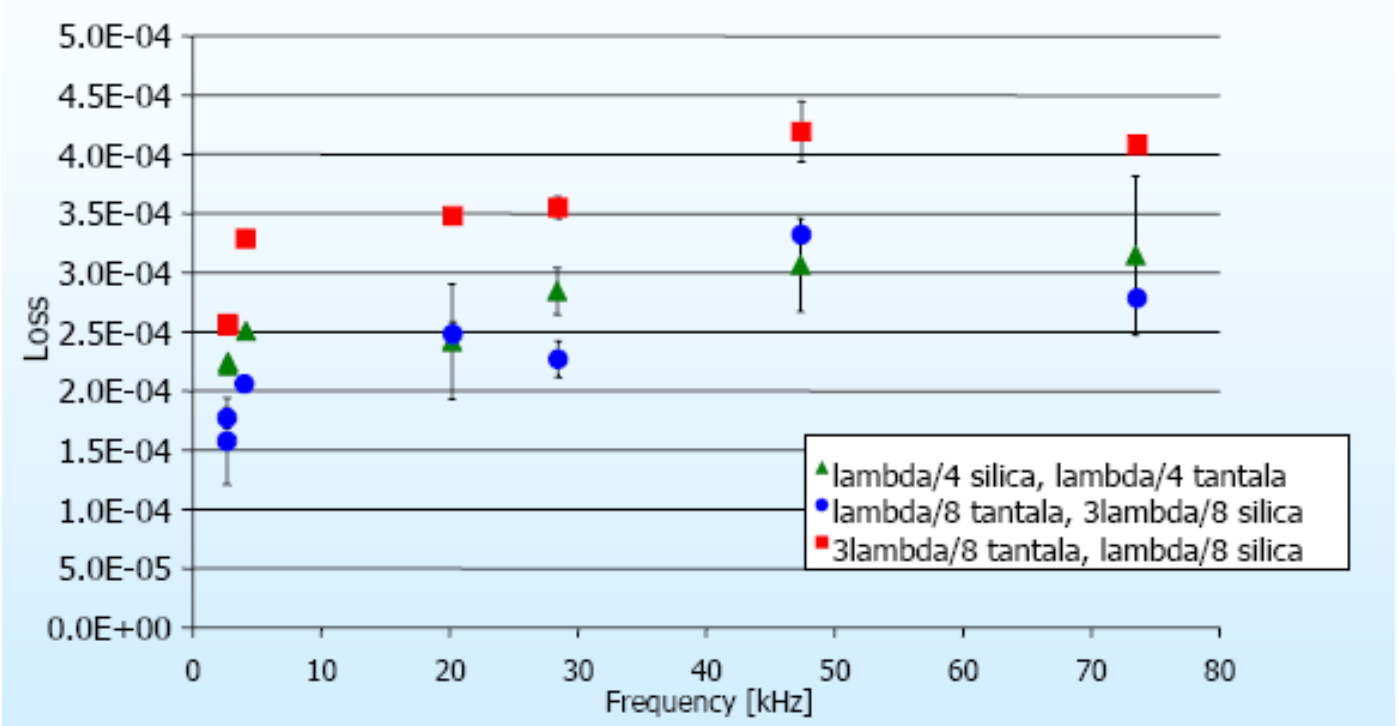
Status

- Finished contract with LMA/Virgo
  - Found titania dopant
  - Explored some other materials
  - Coated TNI mirrors with titania doped tantala
- A few more coating runs with CSIRO
  - Effects of coating parameter changes
  - Annealing studies
- Need to plan for next round of research
  - Probably final round before coating advLIGO optics
- All day coating meeting held last Saturday
  - Highlights and decisions follow

Re-evaluation of silica/tantala

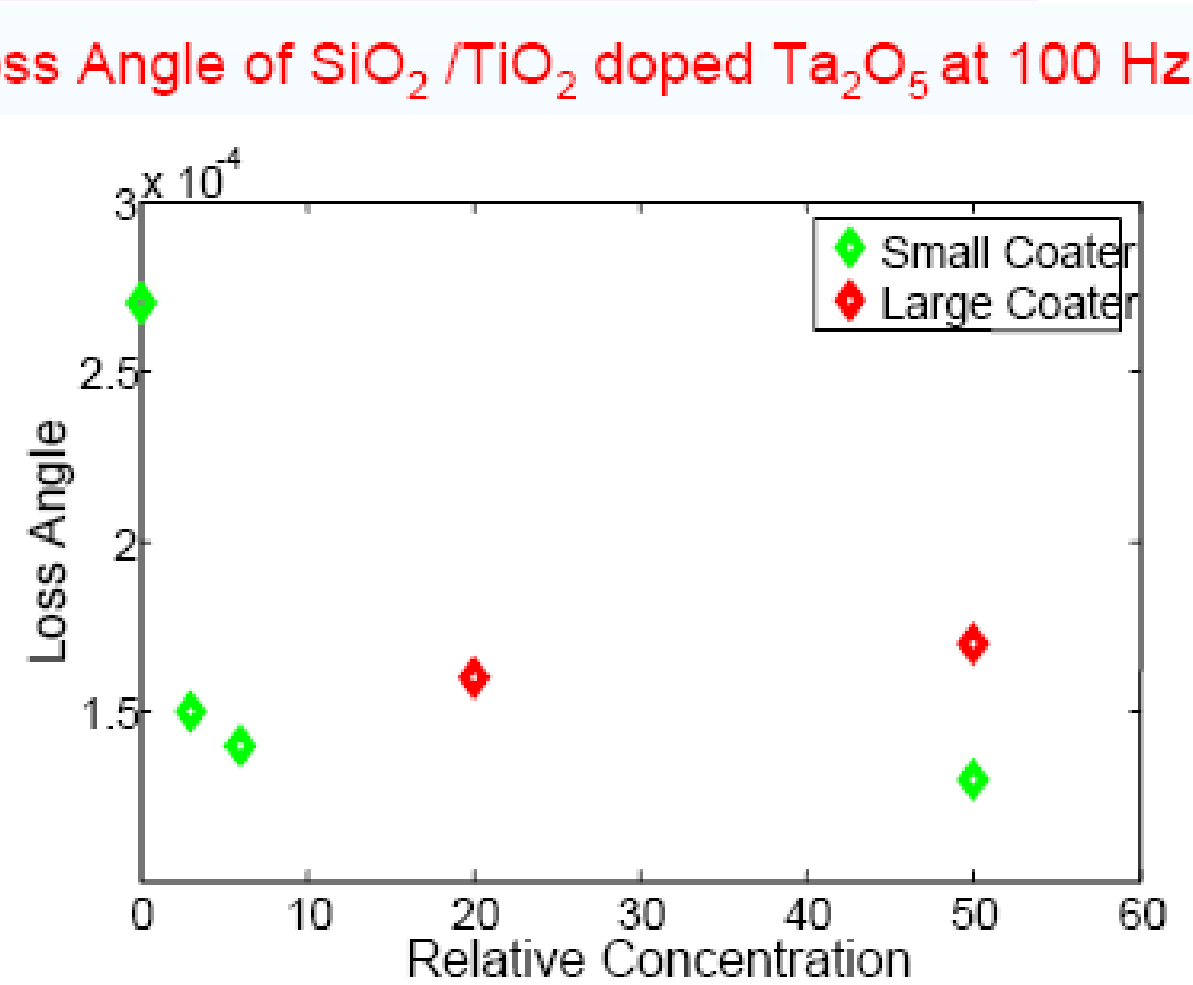
- Correction of Young's moduli in thin sample
- Better agreement between thin and thick results
- No qualitative changes



$$\phi_{Ta2O5} = (3.2 +/- 0.1)\ 10^{-4} + f\ (1.8 +/-0.4)\ 10^{-9}$$
$$\phi_{SiO2} = (1.2 +/- 0.2)\ 10^{-4} + f\ (1.3 +/-0.5)\ 10^{-9}$$

Titania-doped tantala

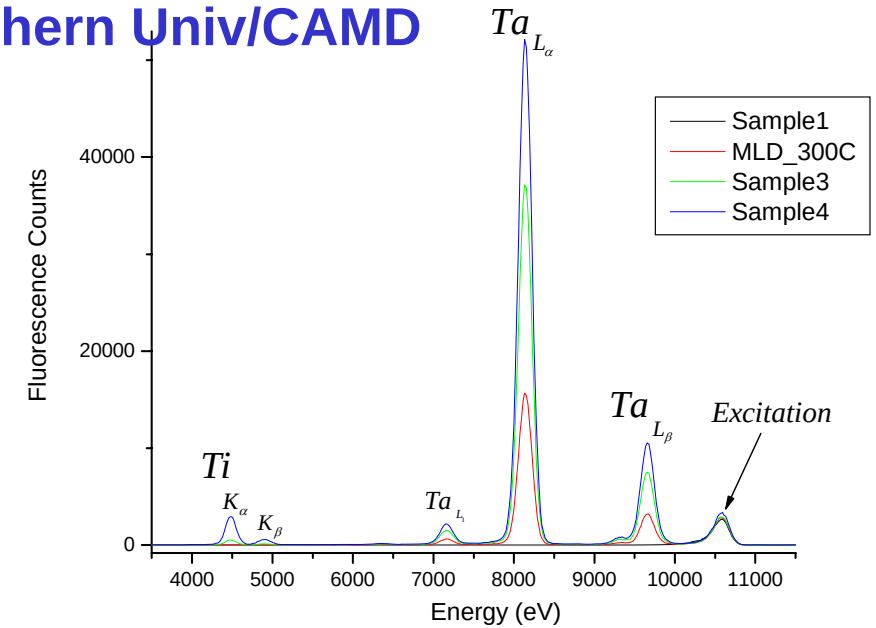
- Adding titania to tantala reduces mechanical loss
- No strong correlation with concentration
- Some evidence the large coater may be not as effective
- Optical absorption a little high, 0.9 ppm – 2.0 ppm
- Starting to get some results on direct concentration measurement



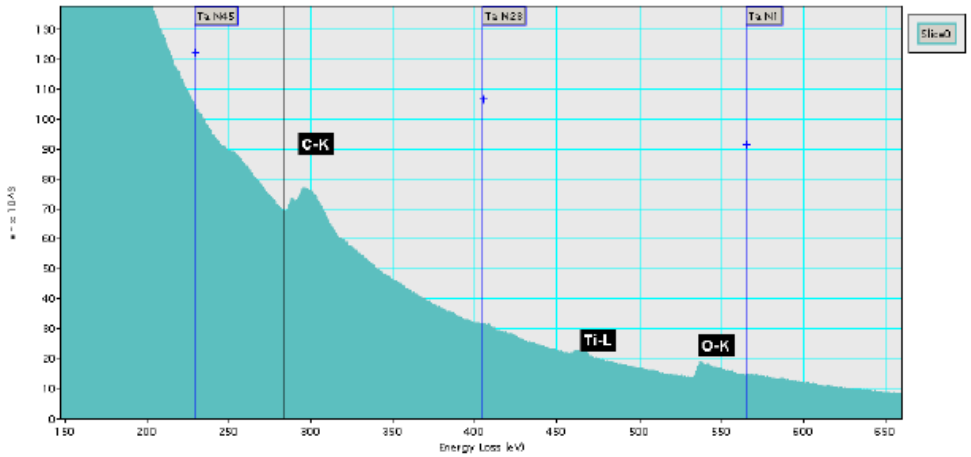
Titania concentration

- Measurements being made at Glasgow, Southern, and Caltech
- Glasgow finds on sample 1
  [Ti] = 8.5 +/- 1.2 %
- Southern finding titania using XRF
- Plans for XANES at Southern
- Hopes for further insights into coating makeup and structure

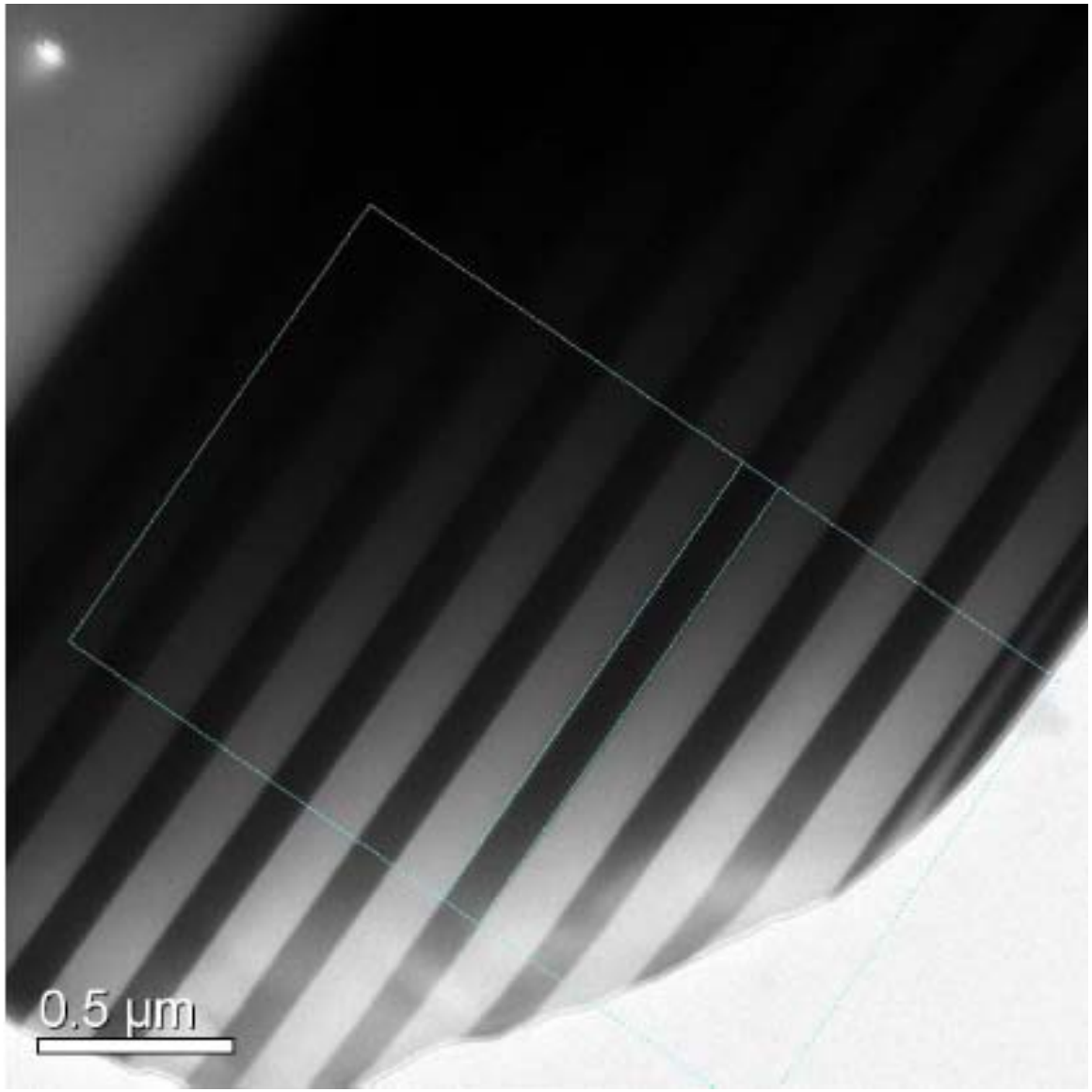
X-Ray Florescence Results from Southern Univ/CAMD



Electron Energy Loss Spectroscopy results from Glasgow



LIGO Electron microscope view of coating layers



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Young's Modulus

Acoustic reflection technique used to measure coating impedance in collaboration with Stanford (I Wygant)

MLD alumina/tantala 176 +/- 1.1 GPa
MLD alumina/tantala 167 +/- 1.3 GPa
MLD silica/tantala 91 +/- 7.0 GPa
WP alumina/tantala 156 +/- 20 GPa

Uses assumed values for material densities

Infer material Young's moduli
Y_{Ta2O5} = 140 +/- 30 GPa
Y_{Al2O3} = 210 +/- 30 GPa (MLD)
Y_{Al2O3} = 170 +/- 30 GPa (WP)

Large errors problematic when propagated

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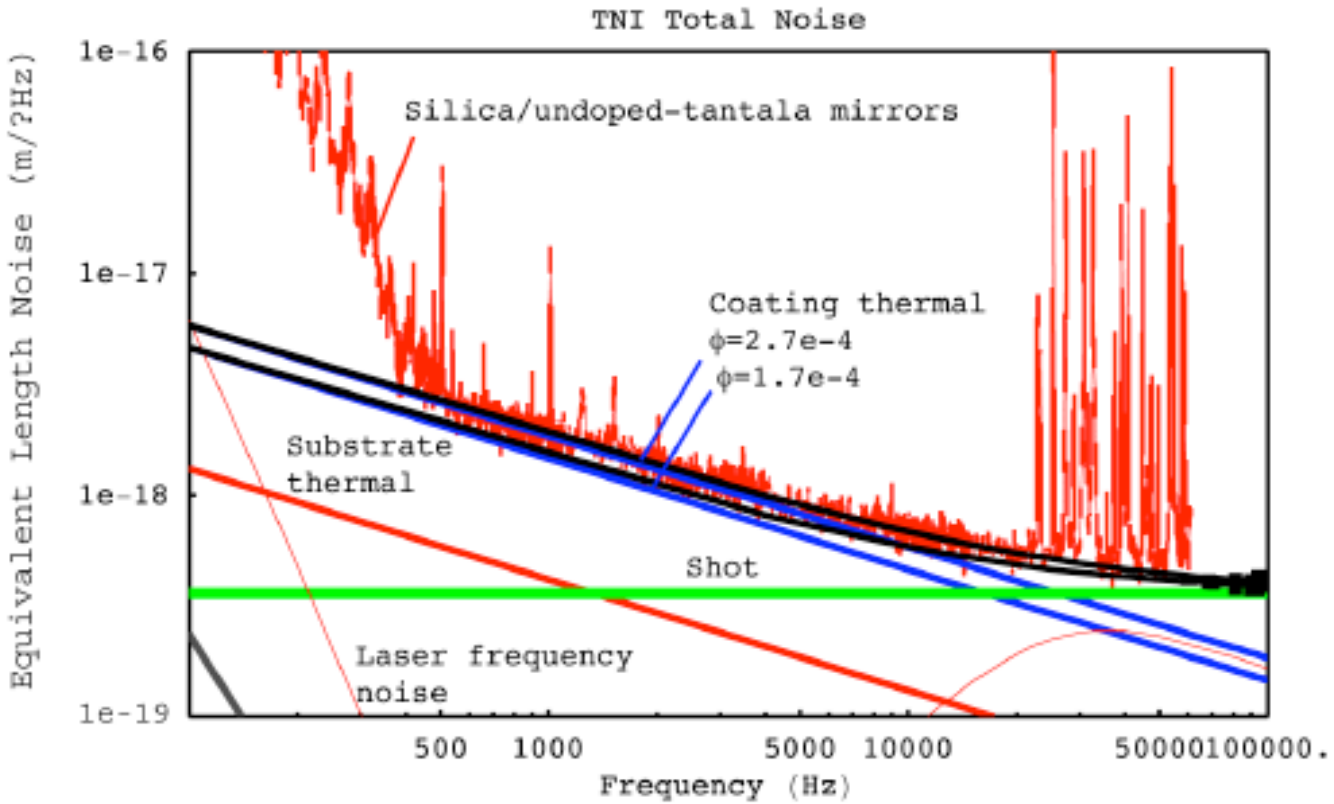
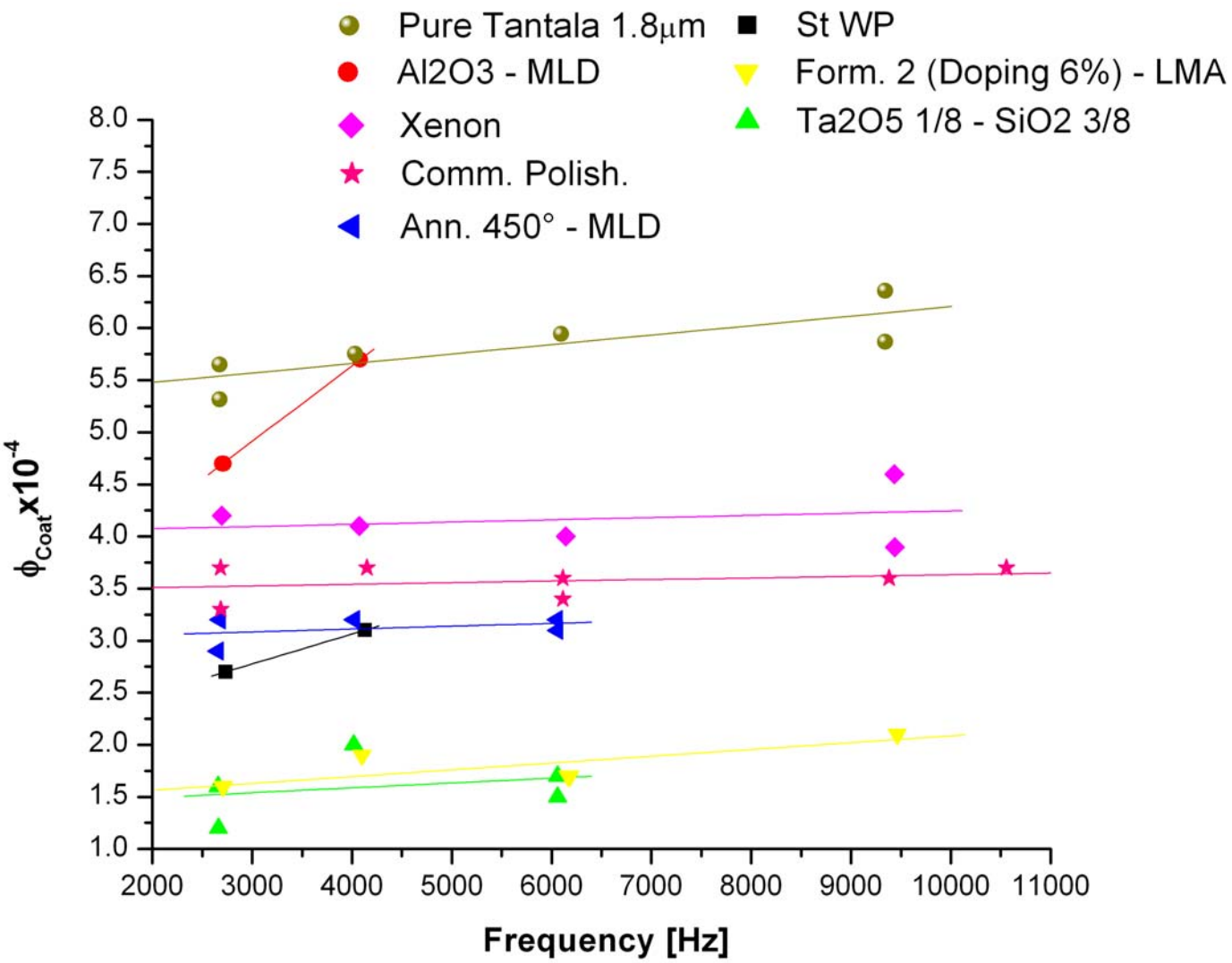
TNI Progress



- **Verified thermal noise from silica/tantala coatings**
- **Installed silica/titania doped-tantala mirrors this summer**
- **Expect results soon**

Other Coating Q Work

- Xenon as bombardment ion
- Commercial versus superpolish
- Starting to look at single layer tantala and effect of annealing



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Results of Meeting

- White paper written – T050130-00-R
- Start looking at single layer materials
  - Mechanical loss does not depend on interfaces, switch to single layers for convenience
  - Need to do silica on sapphire, silicon, or other substrate
  - Simplify Young's modulus and other measurements
- Some upcoming coating runs for optical loss reduction
  - Focus on reducing absorption in doped-tantala
  - Hedge bets, as doped-tantala is marginally acceptable for adv LIGO thermal noise
- Some coating runs with additional vendors
  - MLD, ATF, REO – more bet hedging
  - Both technical and market changes since bids
  - Strong feeling that going to a single vendor would be disastrous

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Additional characterization

- More information on mechanical/thermal properties
  - Primarily Young's modulus, very important for thermal noise
  - Coat thin samples to measure density
  - Explore continuing collaboration with Stanford
  - Look into Brillioun scattering and other techniques
  - Measure thermal conductivity at TNI apparatus
- Need more input from theory/modelling/analysis
  - Focus on silica, loss mechanism has theoretical explanation
  - Explore computer modelling with Hai-Ping Cheng at UF
  - Further results of titania concentration studies
  - Look at other chemical constituents with XANES, XRF, EELS
  - Study structure of materials, bond angles etc.
  - Measure Q vs temperature for loss mechanism studies

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Concerns about power

- Concerns about high power on coatings
  - Primarily in mode cleaner
  - Initial LIGO mode cleaner exceeds adv LIGO arms in intensity
  - Hints that titania-doped tantala may have lower power handling
  - Need to do some table top studies – UF making plans
  - Gingin ultimately will test adv LIGO coating at high power
- Need to look at stability of optical absorption over time
- Develop improved cleaning, handling, and installation procedures
  - Results of LHO 4K ITM replacement not conclusive yet, but could be a cleanliness issue
  - Could be useful to monitor absorption of initial LIGO optics

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Coating Runs

- Plans for Q coating runs
  - Silica doped into titania and/or tantala
  - Single layers of tantala, doped tantala, silica, alumina
  - Lutetium or other rare earths as dopants
  - Hafnia with stabilizing dopants
  - Multiple dopants, possibly including cobalt
  - Doping into silica
  - Annealing studies
    - Systematic including zero stress
    - Ozone or helium atmospheres
  - Plasma coating for final optics

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Other coating improvements

- Continue to progress with Mexican hat mirrors
  - About 1 year to demonstrate angular stability
  - Need full theory of thermal noise
  - Look at higher order Gaussian modes
- Further work on optimized coating thickness
  - Clear improvements
  - Need to include material absorption into algorithms
  - Possibly include more than 2 materials
- Need for additional personpower
  - More Q measuring could speed progress
  - Opportunities exist to bring in some experienced labs