Advanced Coating Noise Direct Broadband Measurment

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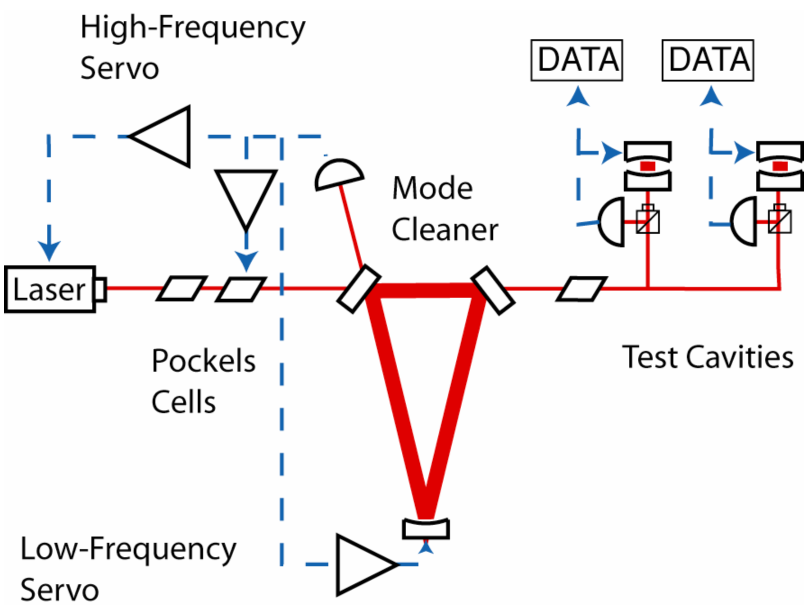
Purpose

- Fluctuation-dissipation theorem predicts noise spectrum from Q.
- Q's measured by ringdown for advanced coatings. Expect broadband noise to be reduced accordingly.
- As noise moves down, need to see if any unexpected noise sources are uncovered.
- Need to evaluate coatings for suitability in an actual, low-noise interferometer.

Thermal Noise Interferometer



- Fundamental-noise limited interferometer (thermal and shot).
- Measurement made as relevant to AdLIGO as possible in a small interferometer.
  - Lowest noise levels practical
  - Low-mechanical-loss substrates
  - Largest practical spot size

Resolving coating noise improvements

- Coating thermal noise must be improved by more than the resolution of the instrument (~ 10%), to draw any quantitative conclusions.
- Coating thermal noise must still be above the noise floor of the instrument.
  - Shot noise at high frequencies (laser power/visibility limited)
  - Substrate thermal noise at intermediate frequencies (spot-size limited)
  - Acoustic coupling to input optics (?) at low frequencies
- Coatings must be applied to TNI standard mirrors (4”x4”).

Expected Improvement

- Loss angle for silica/undoped-tantala coatings = 2.7e-4
- Loss angle for silica/doped-tantala coatings expected to be 1.7e-4
- Expect ~ 20% reduction in noise floor, which should be clearly observable.

$$x_{coating-thermal}(f) \sim \sqrt{\frac{k_B T}{\omega Y f}\frac{d}{\omega}\phi_{coating}}$$

$$\frac{x_{doped}}{x_{undoped}} = \sqrt{\frac{1.7}{2.7}} = 0.79$$

Distinguishing Coating from Substrate Thermal Noise

Coating vs. substrate thermal noise…

$$x_{Th}^2(f) \sim \frac{k_B T}{\omega Y f}\left\{\phi_{substrate} + \frac{d}{\omega}\phi_{coating}\right\}$$

Condition required to distinguish coating thermal noise from substrate thermal noise:

$$\phi_{coating} >> \frac{\omega}{d}\phi_{substrate}$$

For the TNI,

$$\frac{\omega}{d} \approx \frac{160\mu m}{5\mu m} = 32$$

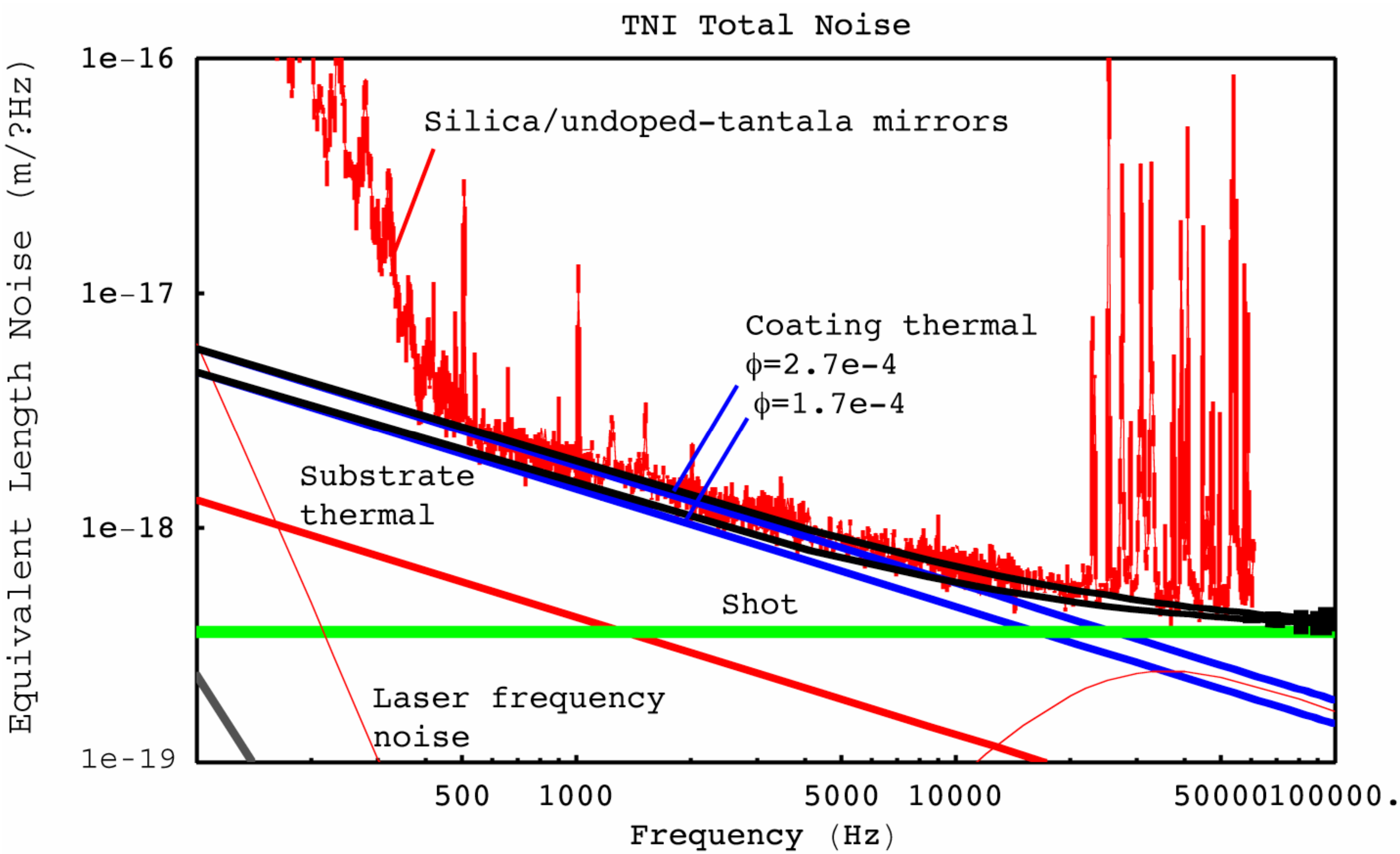
$$\phi_{substrate} \le 3\times 10^{-7}$$

Expect to resolve coatings from substrate as long as $\phi_{coating} \ge 1\times 10^{-5}$

Instrument noise floor

- Shot noise should be ~ 3e-19 m/√Hz
- Low frequency (acoustic?) noise falls off steeply above 500Hz
- Laser frequency noise, etc. negligible compared to thermal noise above 500Hz

Resolving coating noise improvements



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Advanced Coating Measurement

- Most loss appears to be in tantala layers.
- Doping (Ti) reduces measured mechanical Q's.
- Advanced coatings were deposited on an existing set of 4"x4" fused-silica mirrors.
- Scheduled delivery of middle of May 2005, arrived June 30.
- Expect ~ six weeks from receipt of mirrors to data, based on sapphire experience.
- NAC mirrors installed, balanced, and aligned without incident.
- SAC visibility anomalously low (<50%).
- Sealed vacuum chamber August 9.
- First lock with new mirrors August 10.
- Preliminary noise floor not as low as expected.
- Debug upon return (August 16).