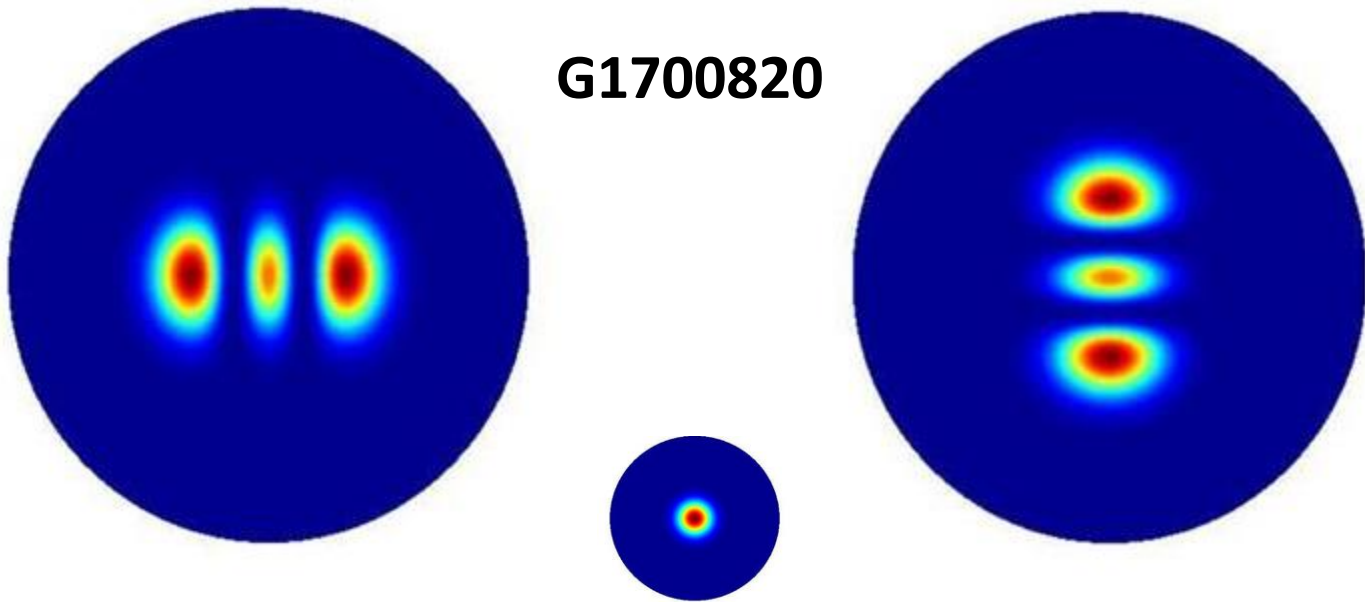


# MULTI-MODE THERMAL NOISE EXPERIMENT, MIT



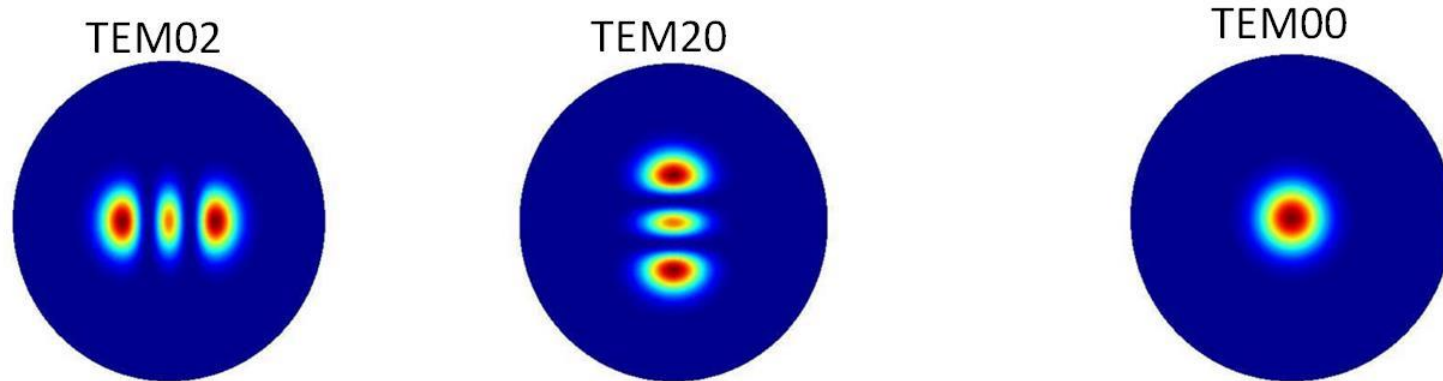
A DIFFERENT WAY OF LOOKING  
AT COATING THERMAL NOISE

Slawek Gras, Matthew Evans

## Objectives:

- Refine thermal noise estimates for current aLIGO coating,
- Test of coating candidates for 3<sup>rd</sup> generation gravitational wave detectors

Three different modes resonates in the cavity:

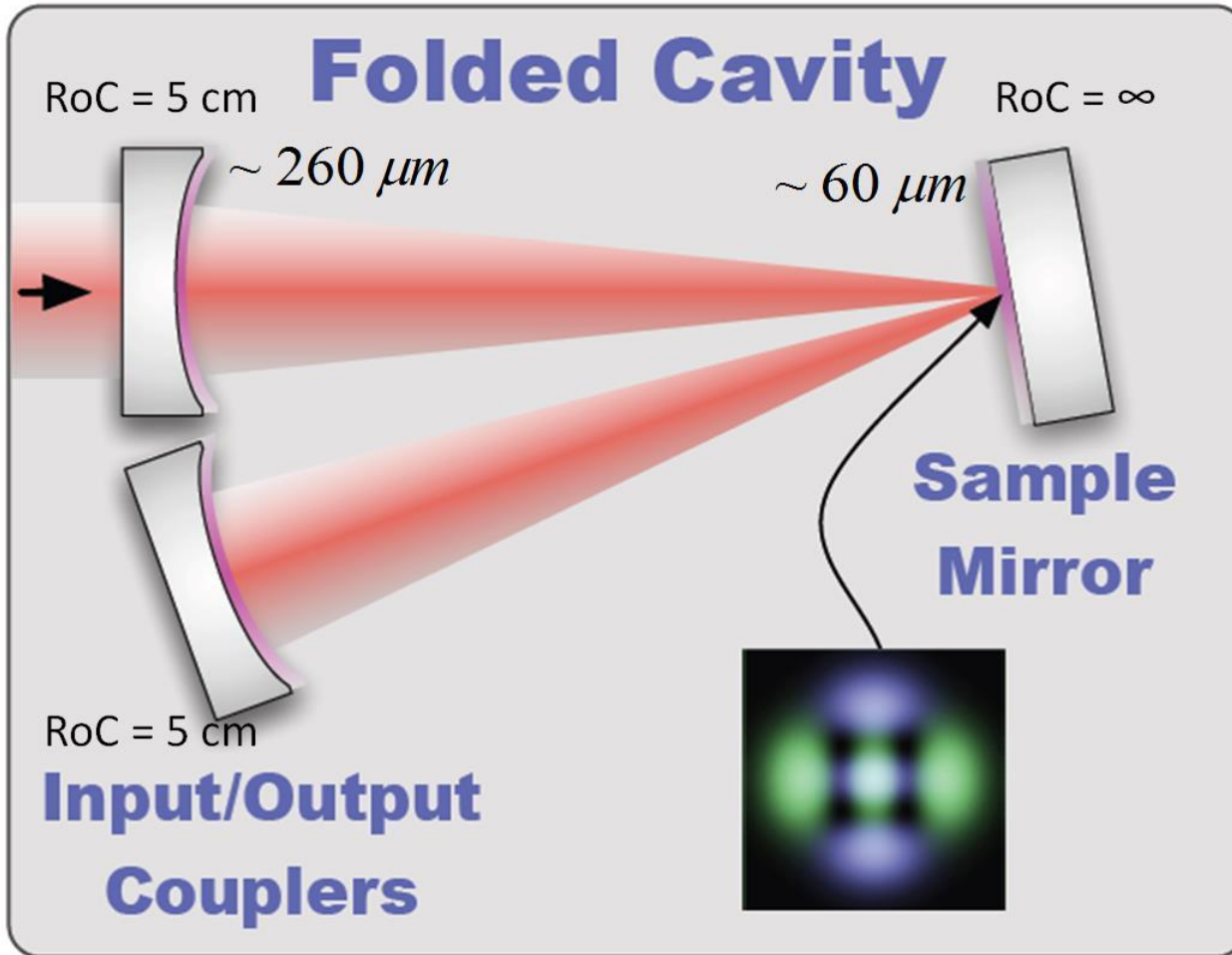


P-polarization modes

S-polarization mode  
(ties laser frequency to cavity length)

- “only” sensitive to differential signal between the TEM02 and TEM20 beams  
(even modes used to avoid alignment sensitivity)
- fluctuations which are correlated over the beam size will be cancelled  
mirror motion, clamping losses, ...

This method promises to provide a flexible means of measuring the thermal noise and material properties of a wide variety of coatings.



Coupler astigmatism:

$$\omega_{02}^{reso} \neq \omega_{20}^{reso}$$

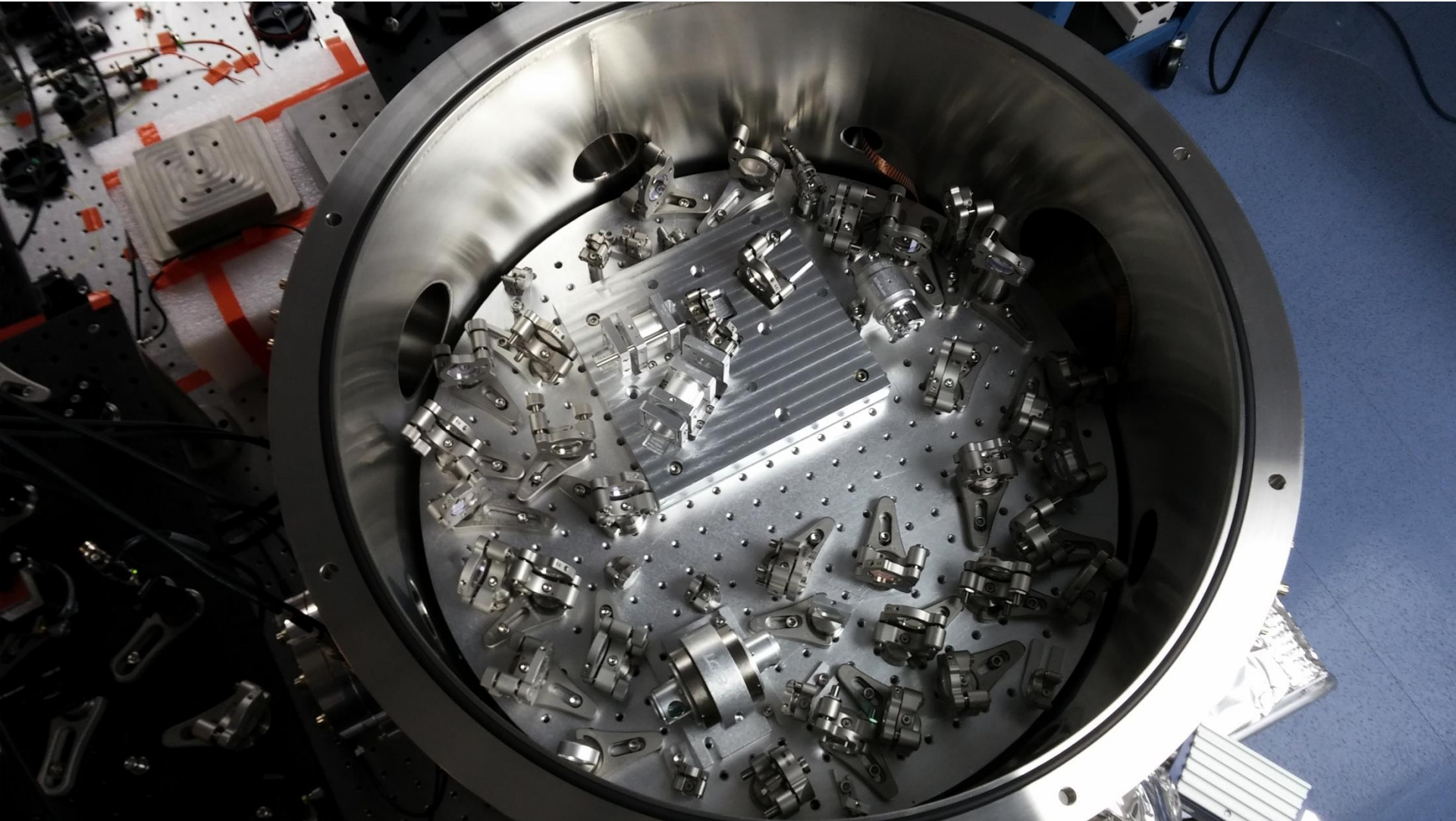
$$\Delta\omega \approx 4.5 \text{ MHz}$$

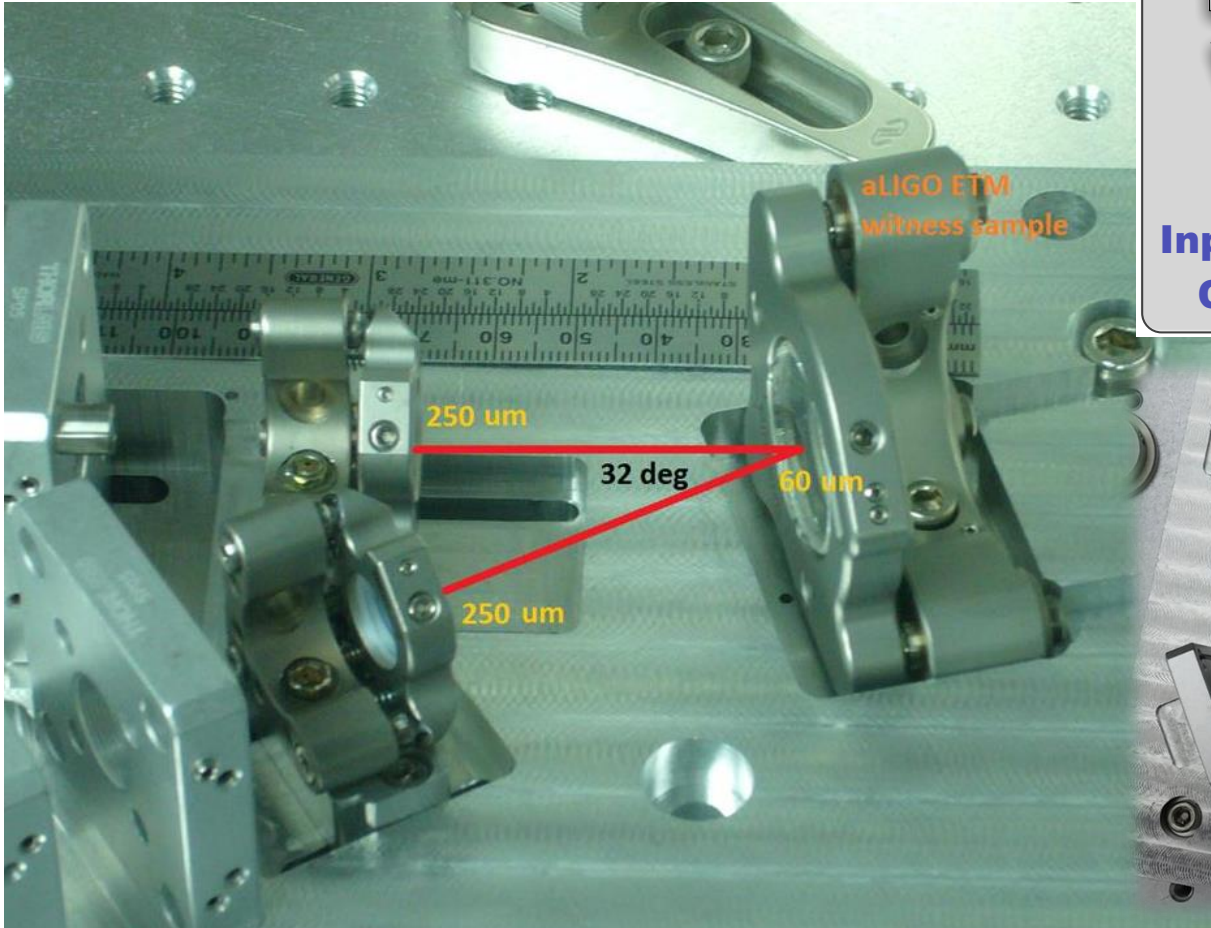
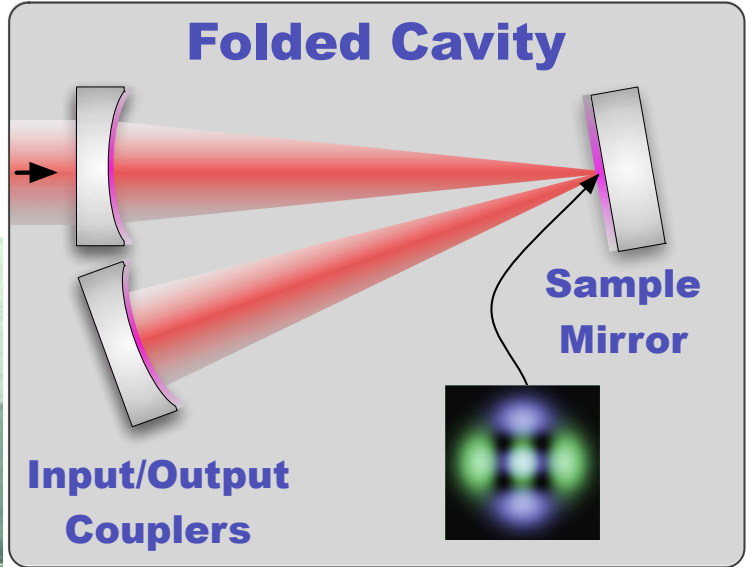
T = 200 ppm  
 FSR = 1.6 GHz  
 TMS = 225 MHz  
 Finesse = 14k

large spots on non-sample optics, sample is any 1" HR flat (e.g., typical witness sample)



# The Experiment

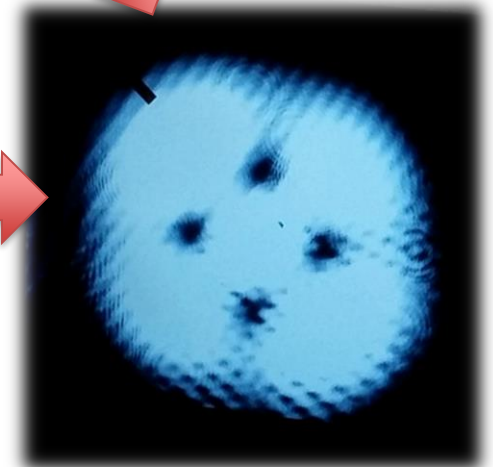
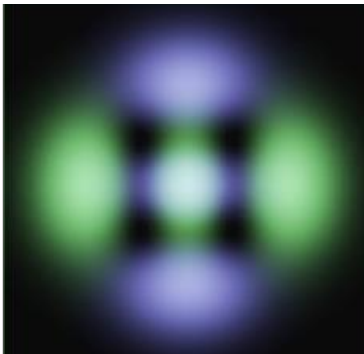


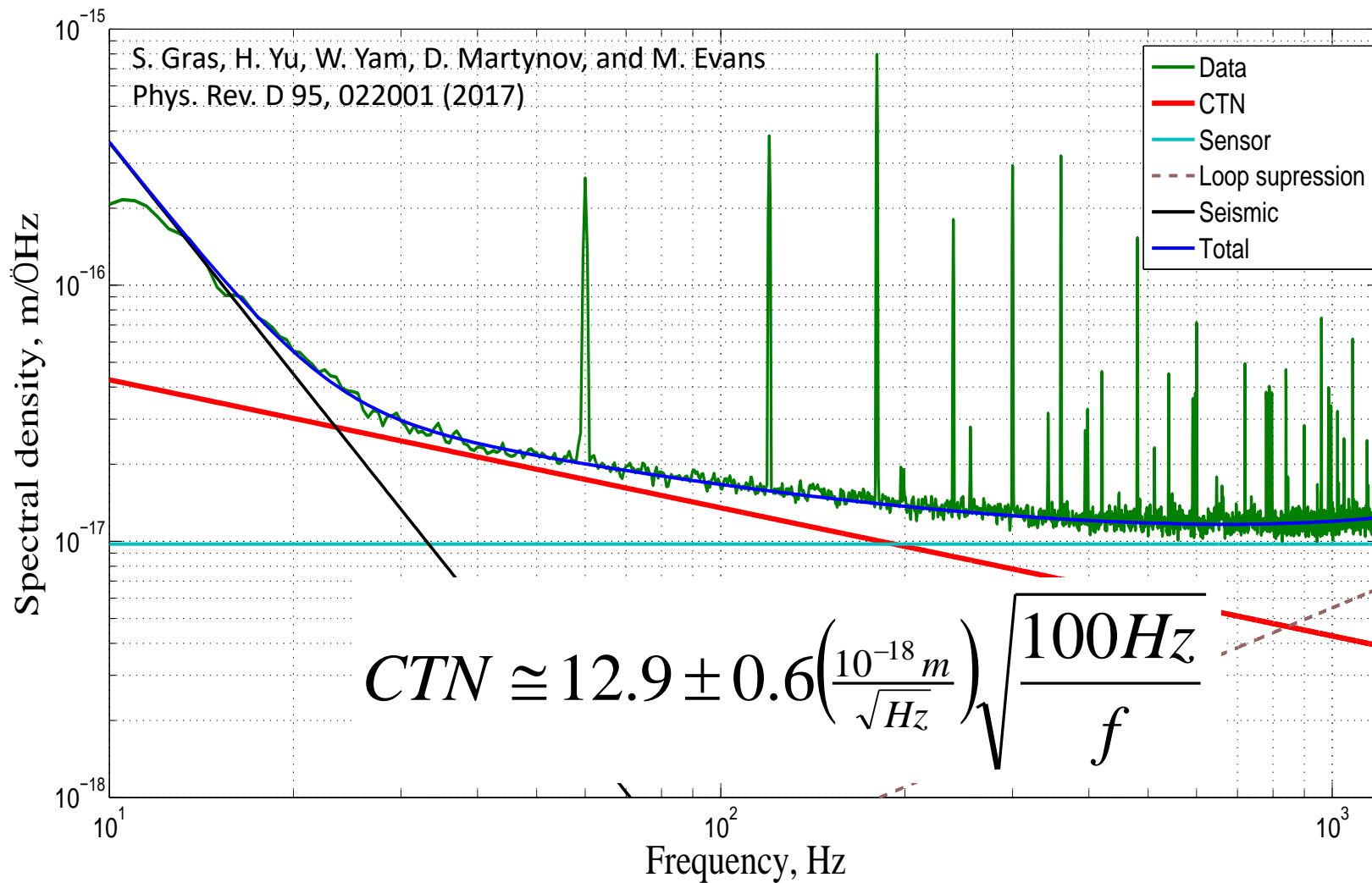






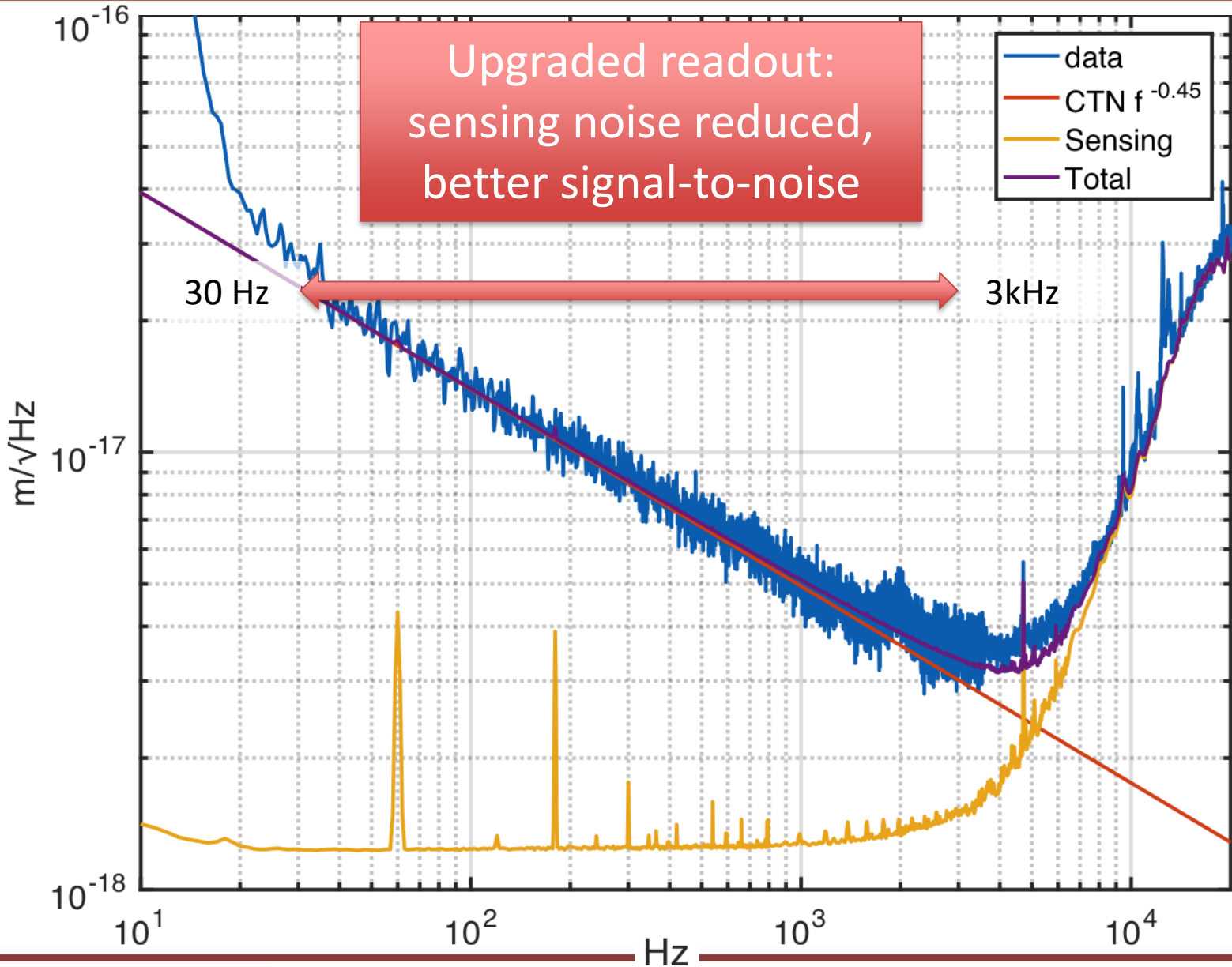
Theory

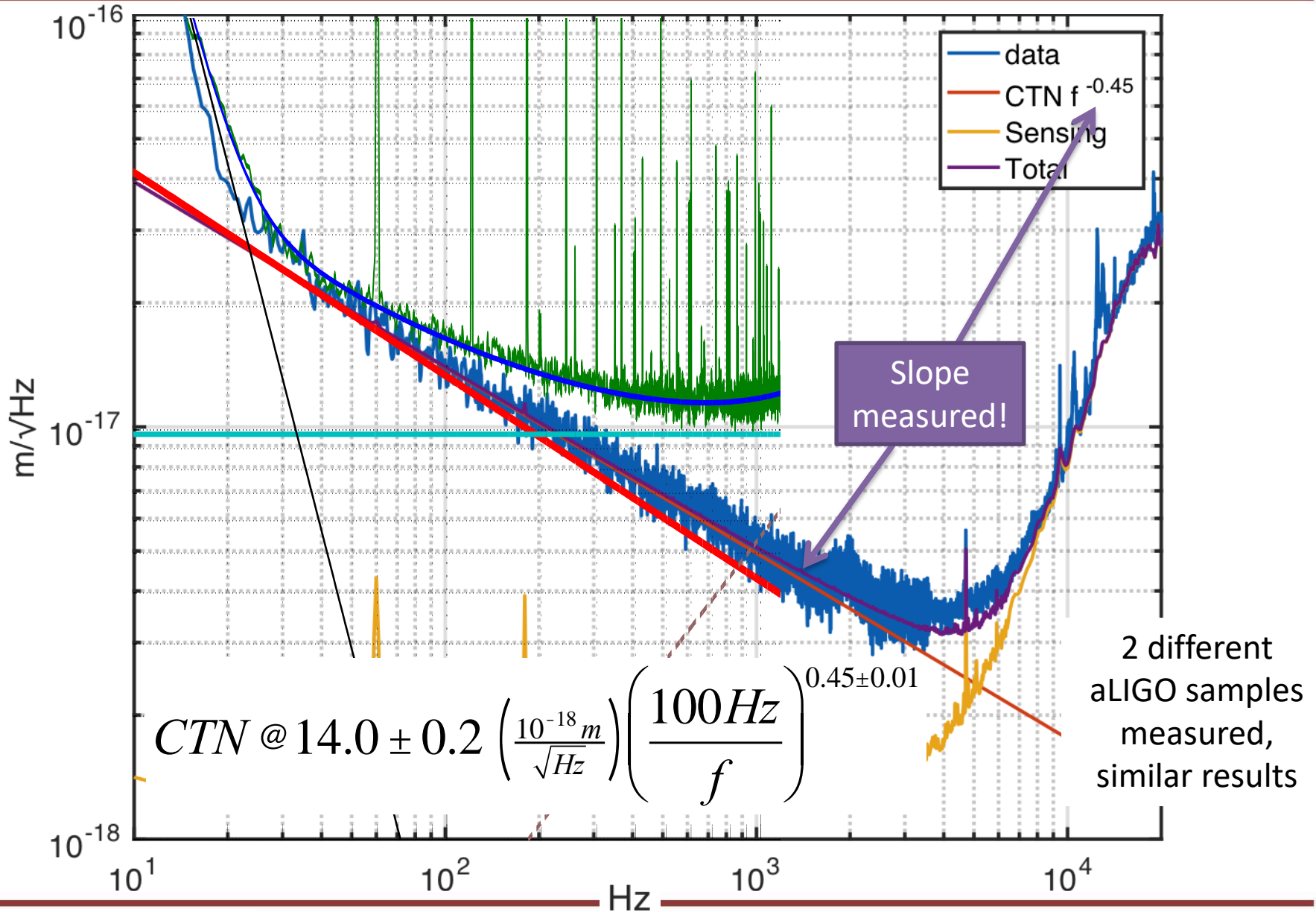




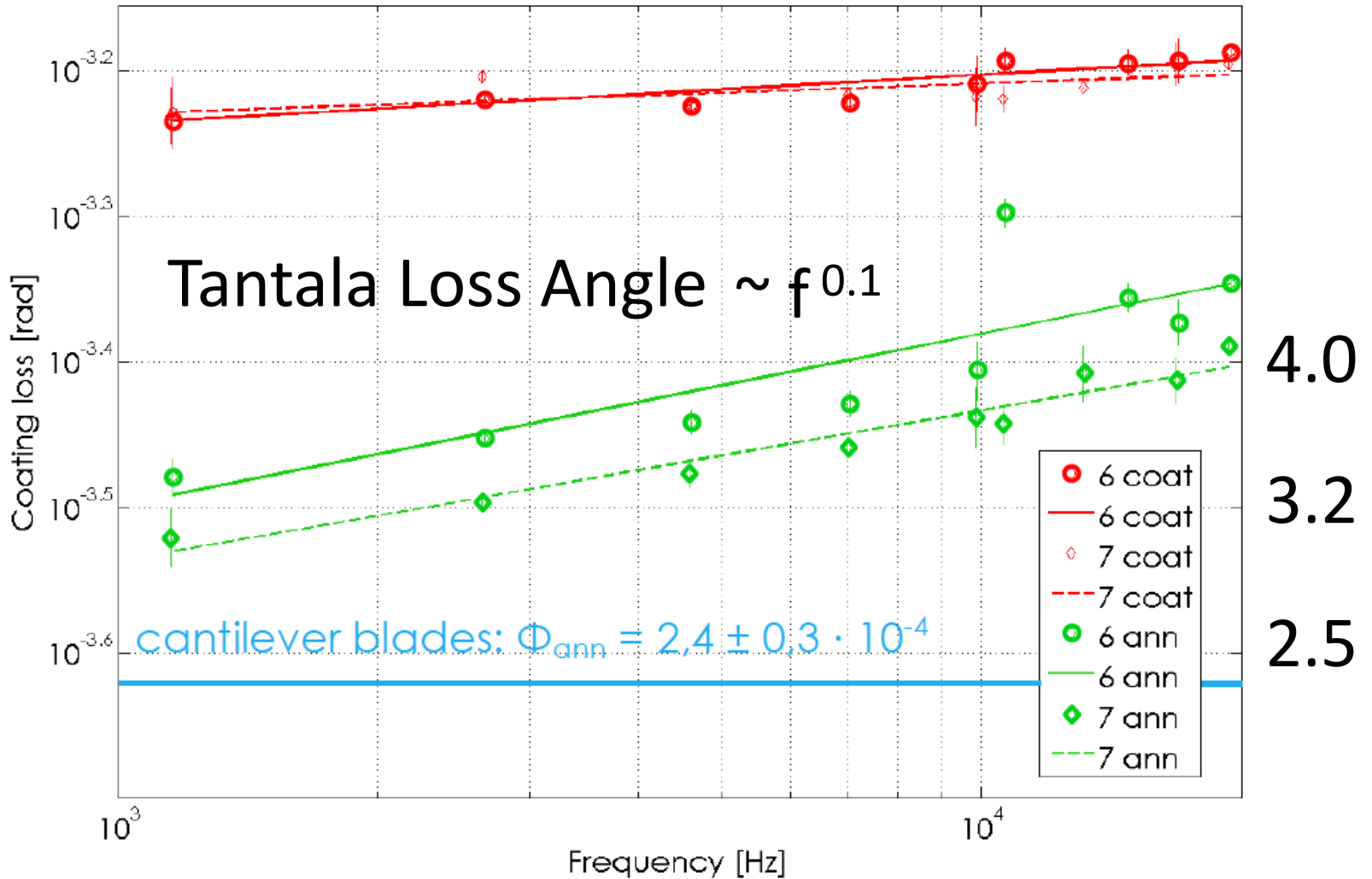
30 Hz ← → 300 Hz

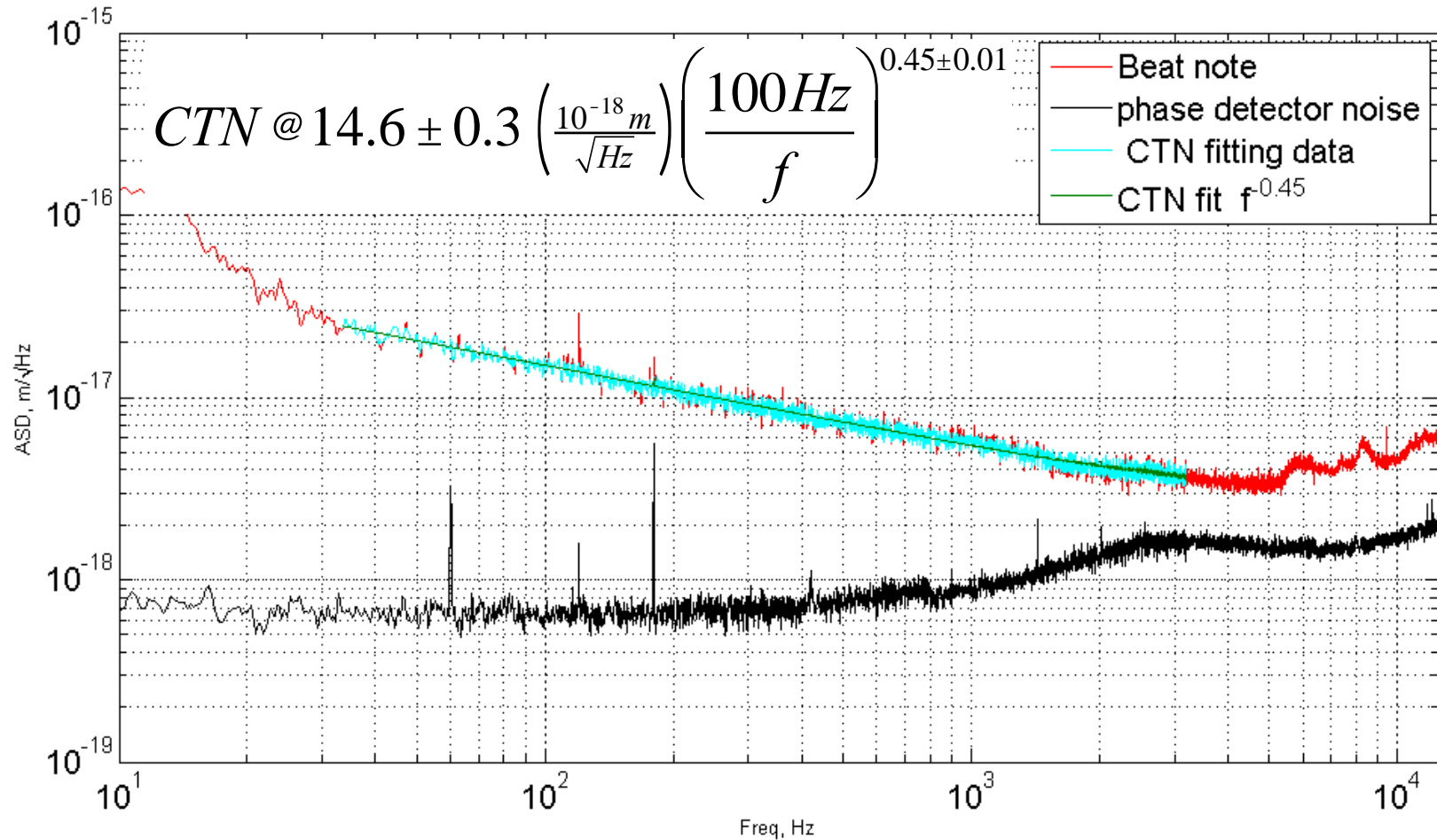






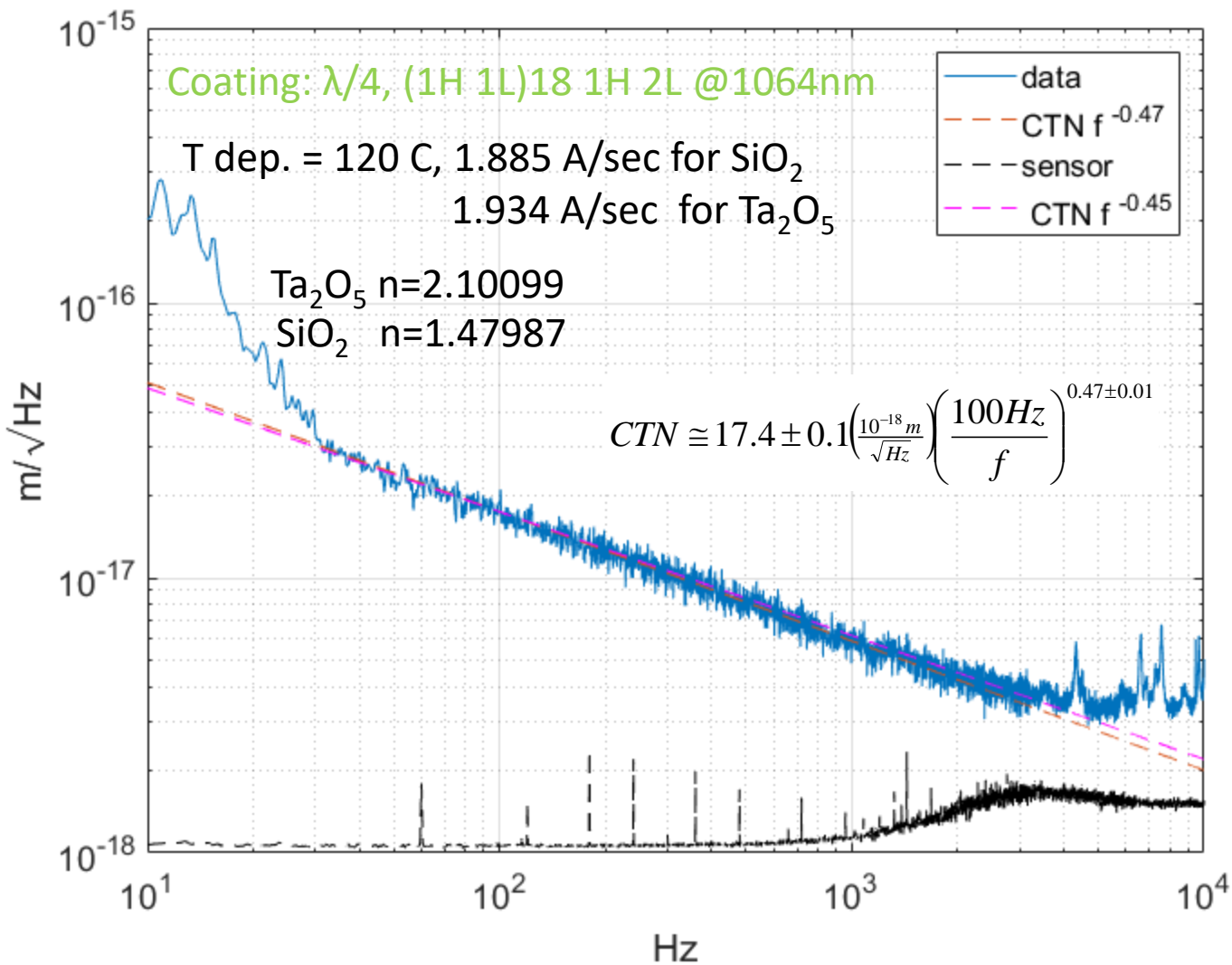
M. Granata





Same slope ( $\sim f^{0.45}$ ) as Advanced LIGO witness sample





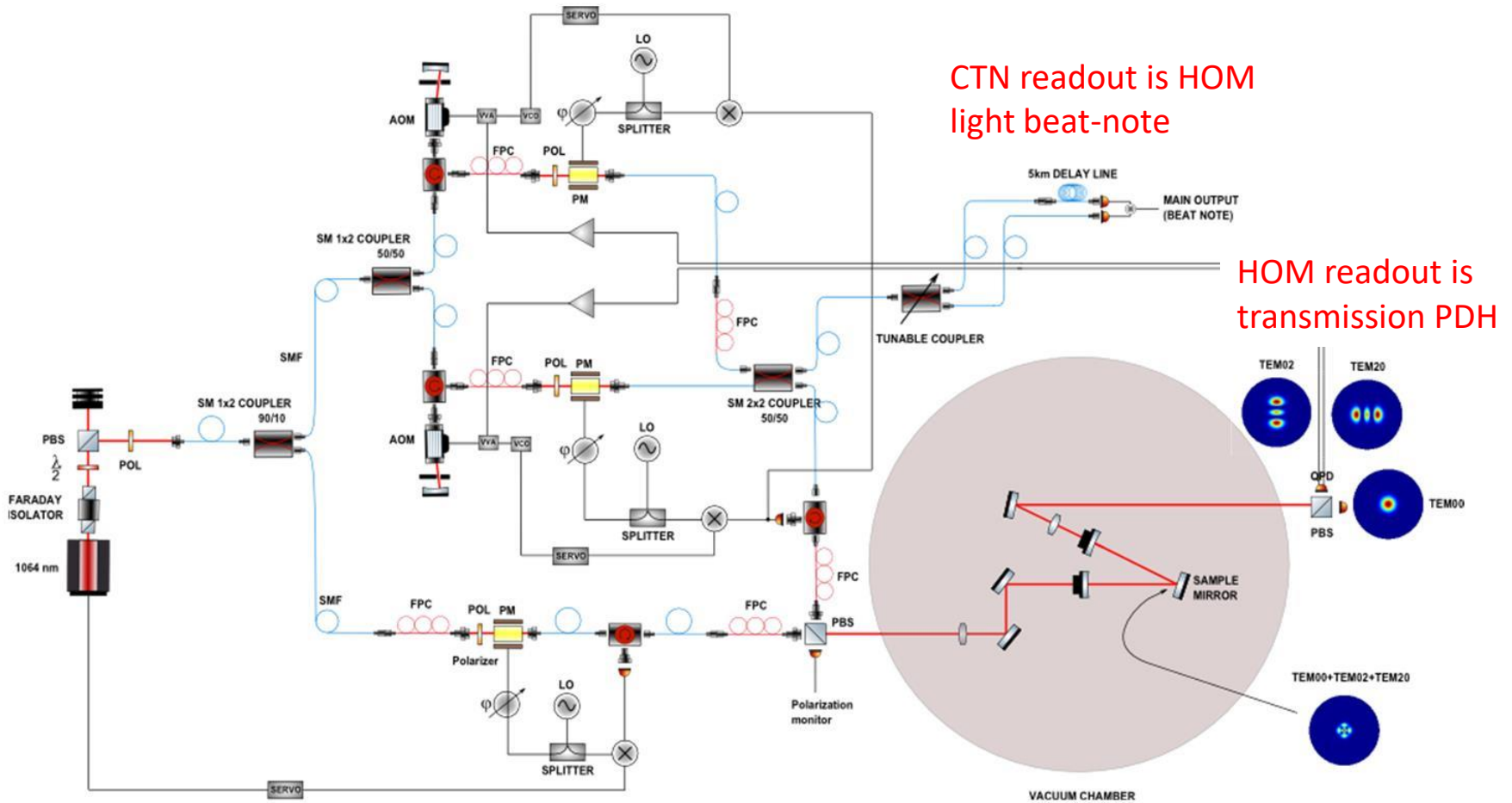
Different slope ( $\sim f^{0.47}$ ), CTN  $\sim 25\%$  higher than aLIGO witness sample

- MIT Lincoln Laboratory:
  - coating machine that allows production of new coating designs
    - ➔ Quick turnaround of coating production
- LMA (more details in Granata's talk)
- Coming next:
  - study of CTN vs beam spot size
  - study of interface losses
  - measurement of crystalline coatings

- So far the MIT multi-mode coating thermal noise experiment has measured two aLIGO samples, one LMA sample, and one test coating from Lincoln Lab
- Improved experiment readout allows measurements with high SNR
- **Recent results**
  - improved measurement of Advanced LIGO samples shows slope  $\sim f^{0.45}$
  - same slope observed in new LMA coating design (4% higher noise in amplitude over Advanced LIGO sample)
- Transitioning to “facility” mode:
  - We can measure any 1” flat high reflector
  - Mirror swap + measurement now take one day, very quick
  - **IF YOU HAVE A NEW COATING TO TEST, LET ME KNOW!**

Thanks!

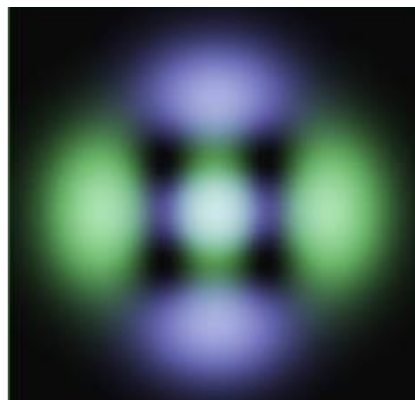




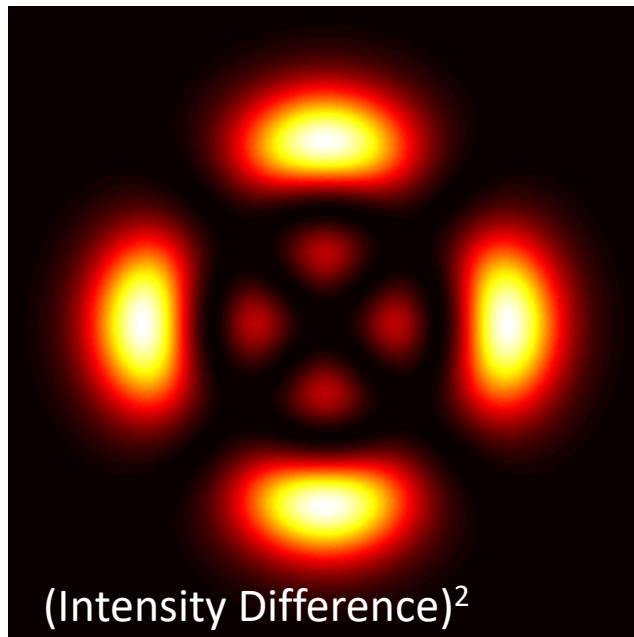
# Coating Thermal Noise in TEM02 - TEM20 signal

$$\frac{CTN_{02-20}}{CTN_{00}} \gg 1.07$$

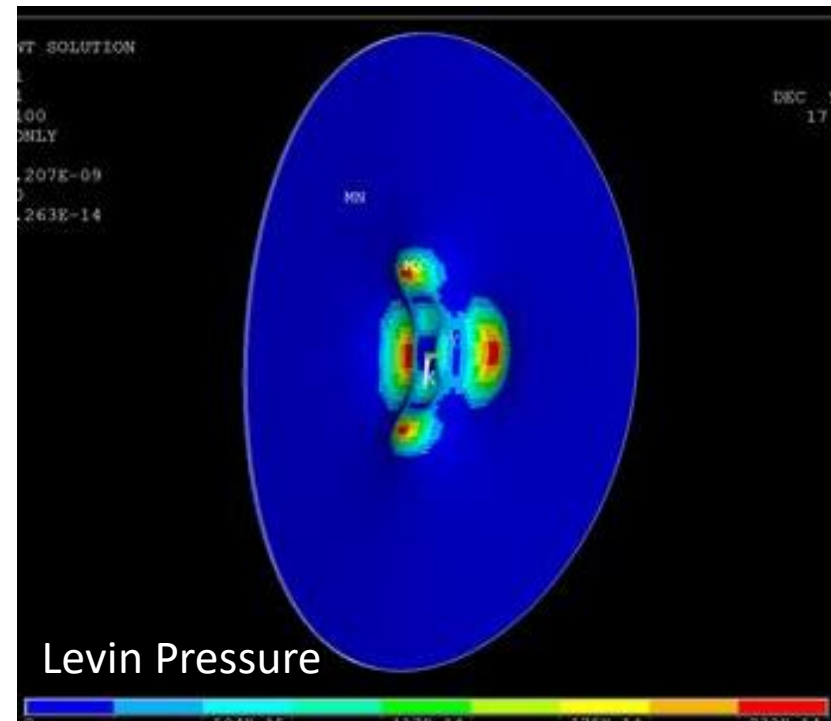
(for our beam size, coating thickness,  
and substrate material)



Intensity



(Intensity Difference)<sup>2</sup>



Levin Pressure

# Advanced LIGO Sensitivity

