Group Projects: Western Washington University

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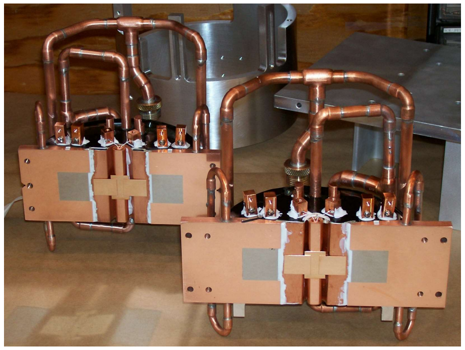
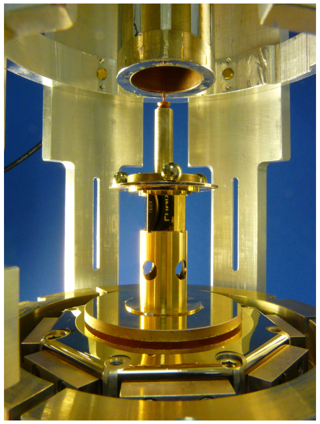
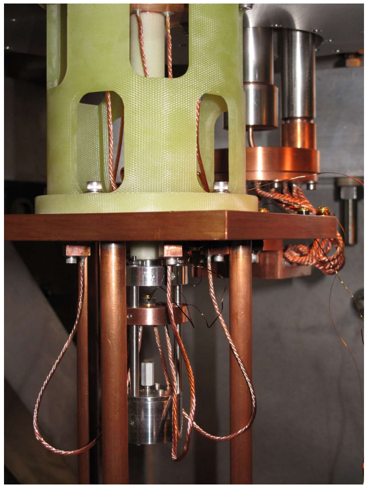
About Me– Svenja Fleischer

- New tenure-track faculty member at Western Washington University (since 2020)
  - PhD 2005, University of Heidelberg, Germany
  - Postdoc at the Max-Planck Institute for Nuclear Physics, Heidelberg and LMU Munich, Germany
  - Postdoc, then research faculty at the University of Washington, Seattle. Work on torsion balance experiments, especially
    - short-range test of the gravitational inverse-square law[1]
    - a cryogenic torsion balance operating below 10K [2]
    - a search for axion-like particles[3]







[1] J.G. Lee *et al.*, *Phys. Rev. Lett.* **124**, 101101 (2020)

[2] in preparation

[3] S.A. Hoedl, *Phys. Rev. Lett.* **106**, 041801 (2011)

It’s Official!

- Western Washington University now has an LSC member group!

Research Plans

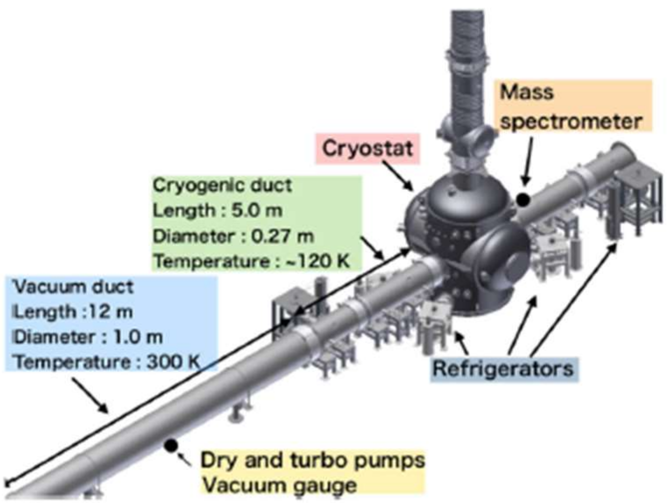
- investigate properties of ice layers accumulating on cold test masses for LIGO Voyager and study possible mitigation strategies
- contribute to building improved models of the seismic isolation system

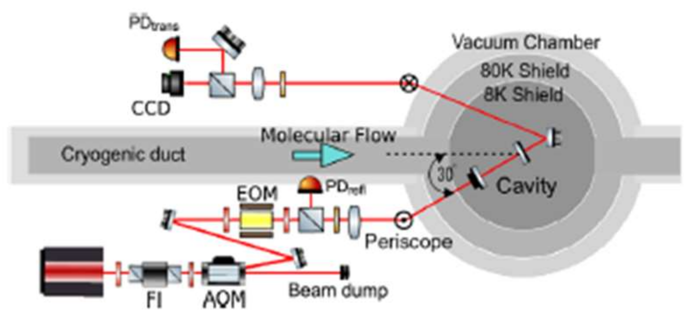
WESTERN WASHINGTON UNIVERSITY

MAKE WAVES.

Background: Ice Layers on Cold Optics

- Future GW detectors are expected to operate at cryogenic temperatures (e.g. 123 K for current LIGO Voyager design)
- Observed by KAGRA: cold optics accumulate surface contamination, mostly consisting of amorphous water ice
  - initially measured growth rate: $27 \pm 1.9\ \mathrm{nm/day}$

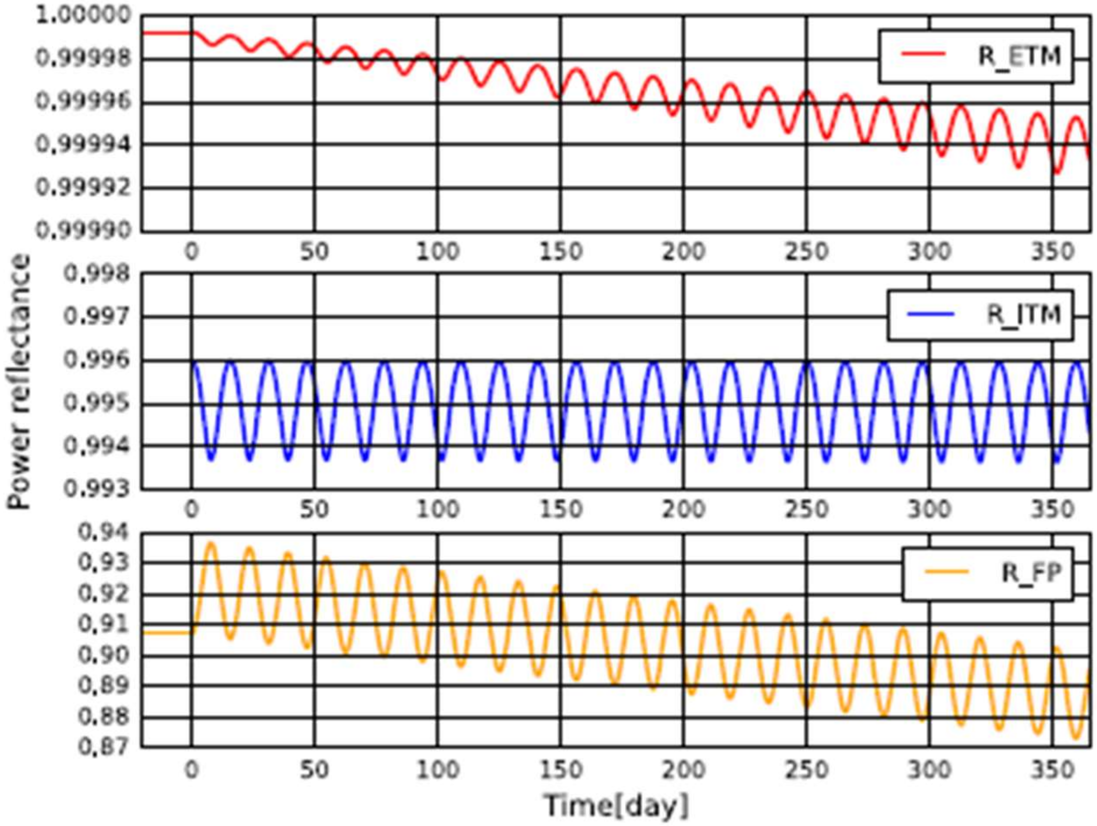




from Hasegawa et al., *Phys. Rev. D* **99**, 022003 (2019)

Effects of Ice Layers I

- changing reflectance (here shown for KAGRA ITM, ETM, and arm cavity)



from Hasegawa *et al.*, *Phys. Rev. D* **99**, 022003 (2019)

Effects of Ice Layers II

- increase in coating thermal noise (CTN)

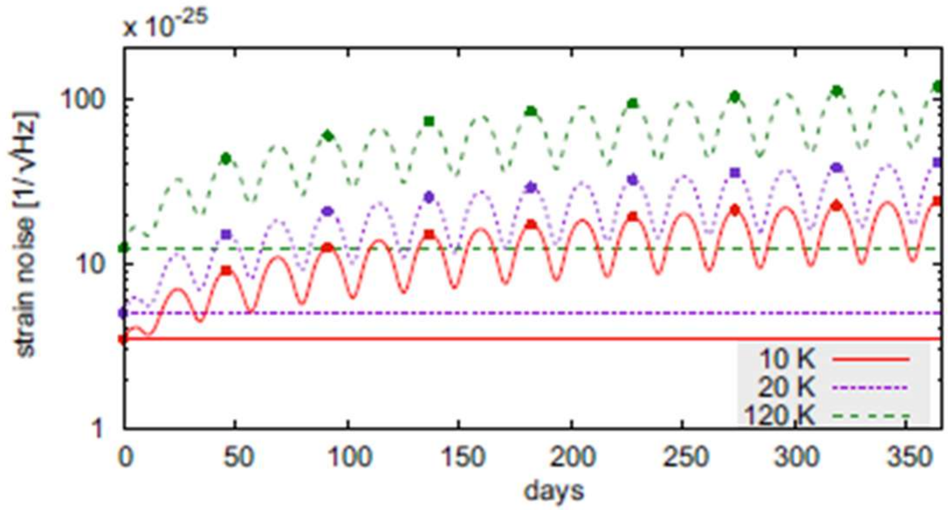


FIG. 6. Total detector CTN over one year at a reference frequency of 10 Hz at temperatures of 10 K (red, solid line), 20 K (blue, dotted line), and 120 K (green, dashed line). The oscillating curves show CTN with an ice layer growing on the mirrors, while the constant lines show CTN without ice. The 10-K curve and line are identical to the red curve and line in Fig. 5. Points on the oscillation represent thicknesses of ice at which $n \times d_1$ is an integer multiple of λ.

from J. Steinlechner, I. Martin, *Phys. Rev. Res.* **1**, 013008 (2019)

Effects of Ice Layers III

- probably most concerning: increased optical absorption

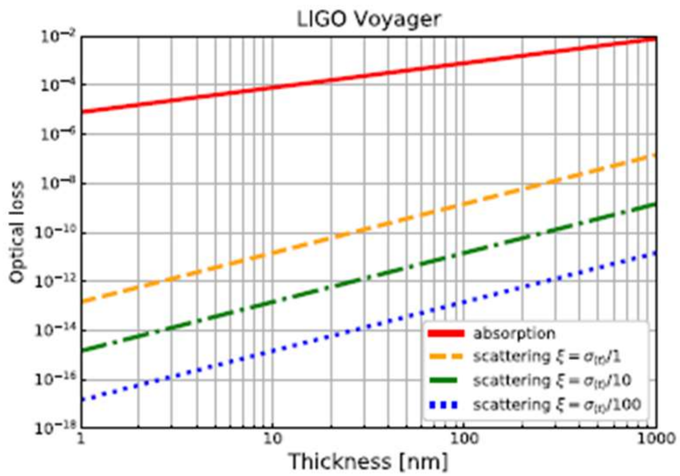


FIG. 7. Scattering and absorption loss for the case of LIGO Voyager. The assumed wavelength is $\lambda = 2000$ nm. In the same manner as the case of the ET, the red solid line represents the absorption, while the yellow dashed line, green dash-dotted line, and blue dotted line represent the scattering with the correlation lengths of $\xi = \sigma_{(t)}, \sigma_{(t)}/10$ and $\sigma_{(t)}/100$, respectively.

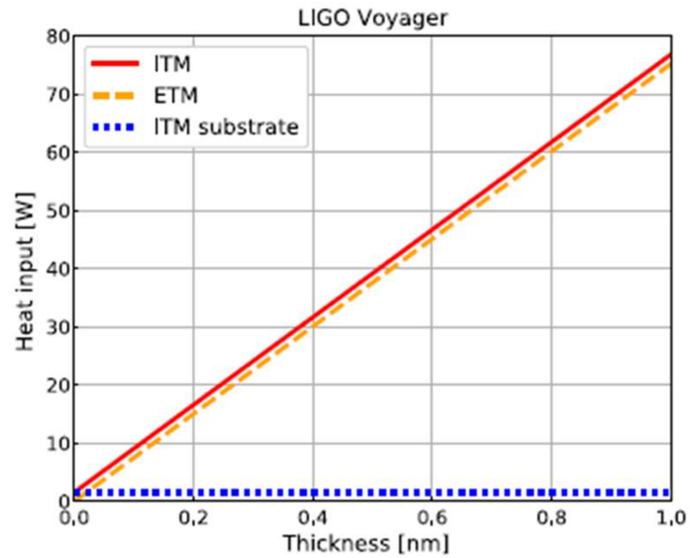


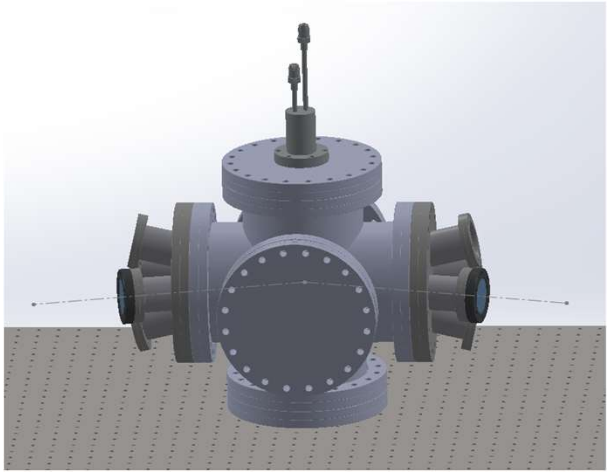
FIG. 8. Heat input to each test mass mirror in LIGO Voyager induced by the optical absorption of the CML. It should be noted that the radiation from the beam ducts is not taken into account for the case of LIGO Voyager.

from Tanioka *et al.*, *Phys. Rev. D.* **102**, 022009 (2020)

For LIGO Voyager, this would suggest that **even a sub-nanometer layer of ice could increase the heat load to levels preventing radiative cooling to 123K**.

Planned Research Program

Ice layer formation on the cold optics could potentially be a major issue for LIGO Voyager.



Plan: Benchtop experiments to study ice layers

a) develop and build a cryostat to study thin ice layers under controlled conditions, including tools to measure their thickness

b) explore some of the proposed mitigation strategies, especially periodic heating

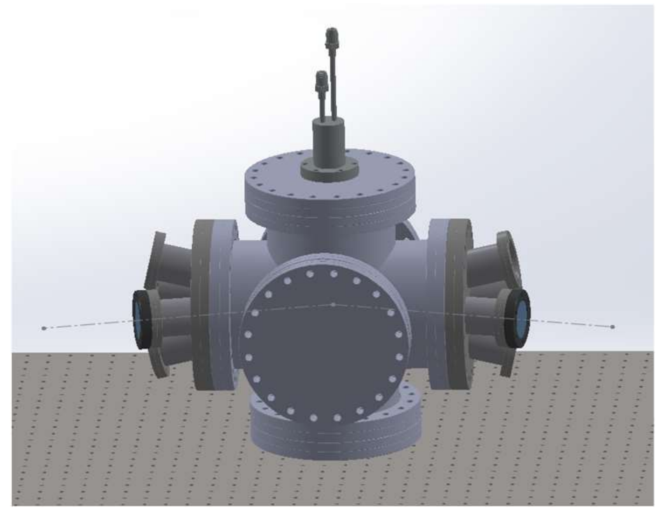
c) possibly study how the presence of intense laser light affects the build-up of such layers by increasing desorption

d) possibly make a direct measurement of the optical absorption of thin ($d \ll \lambda$) amorphous ice films

Additional Future Opportunities

If built in a modular fashion, the suggested experimental setup might also be useful to study other issues in the future:

- measuring the birefringence of silicon (suggestion from Joshua Smith, CSU Fullerton)
- *in-situ* measurement of thermo-optic coefficients for materials in optical coatings?
- other optical properties of coatings at 123K?



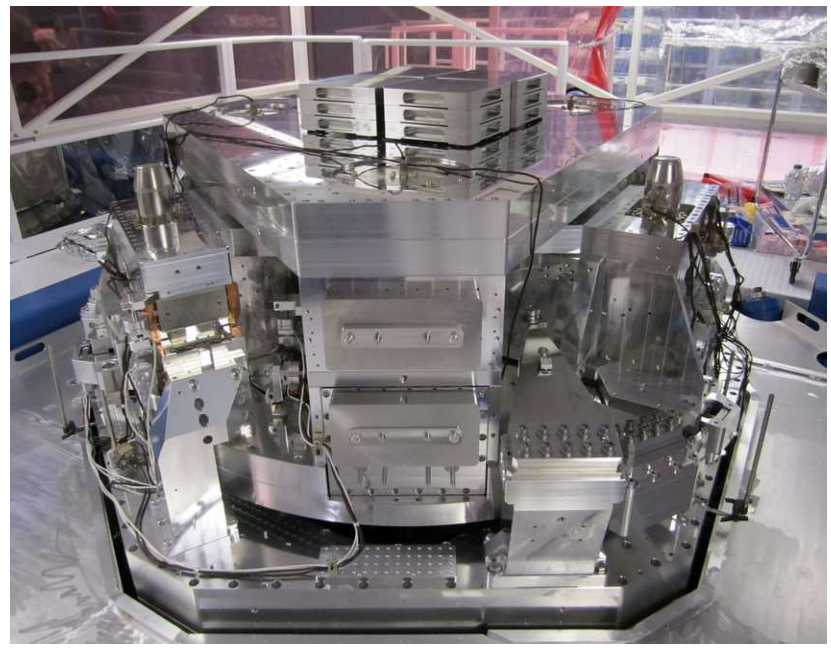
Background: Control System Enhancements for the Existing System

- Advanced LIGO has a large array of sensors and a complex control system
- achieving best interferometer performance depends on finding optimal ways to combine sensor information

A Useful Tool: Modeling

→predictive models of the seismic isolation system allow to evaluate the impact of new filters or sensors

→provide a noise budgeting tool to better understand the current noise performance



Credit: Caltech/MIT/LIGO Lab

Modeling of Seismic Isolation Systems

- already existing: several HAM-ISI models, some partial BSC-ISI models, some suspension models

Plan:

- contribute to building improved noise models for seismic isolation systems
  - → complete BSC-ISI model?
  - → concatenating models of ISI and test mass suspension?
  - → live noise budget?
- in the longer term, also interested in contributing to the development and commissioning of new sensors (e.g. HoQi, rotation sensors)
- possibly explore some areas of need repeatedly mentioned by LHO staff (e.g. optical levers)

Thank you for your attention!