GWANW 2024 Group Update WWU

Icy Mirrors, Gravity, and Outreach

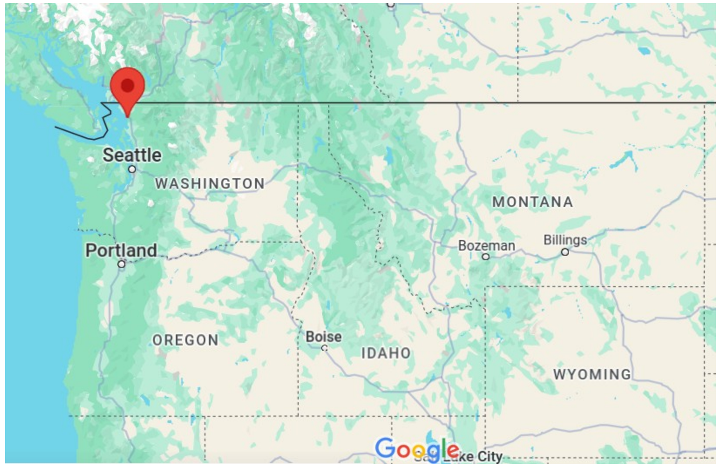
Svenja Fleischer

Western Washington University

Western Washington University (WWU)

The Salish Sea

- Public university in Bellingham, WA, primarily undergraduate institution, ~16,000 students
- Random trivia: WWU is the northern-most university in the Lower 48!

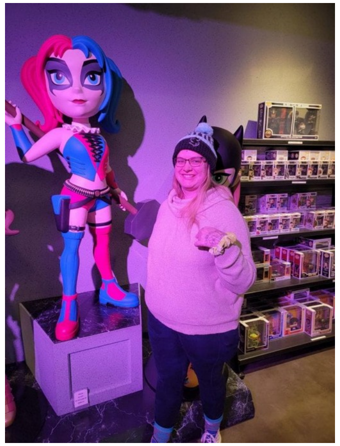


(c) Google Maps

LIGO @ Western Washington University

WESTERN WASHINGTON UNIVERSITY
MAKE WAVES.

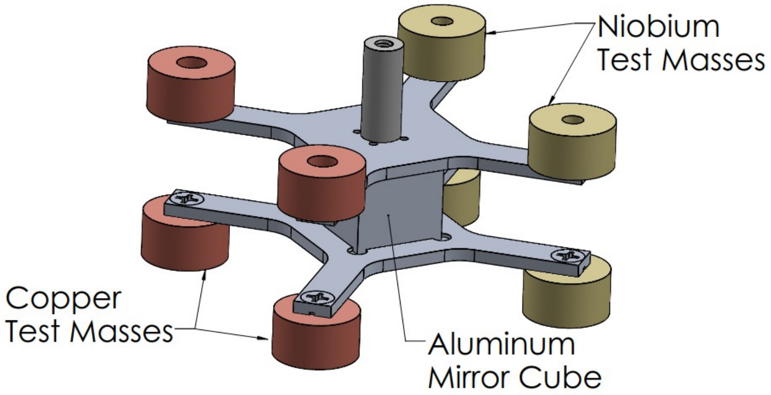
- WWU has a LIGO group since 2021: SF and currently 3 undergraduate students
- two other students just graduated: congratulations Douglas Slater and Jackson Larsen!



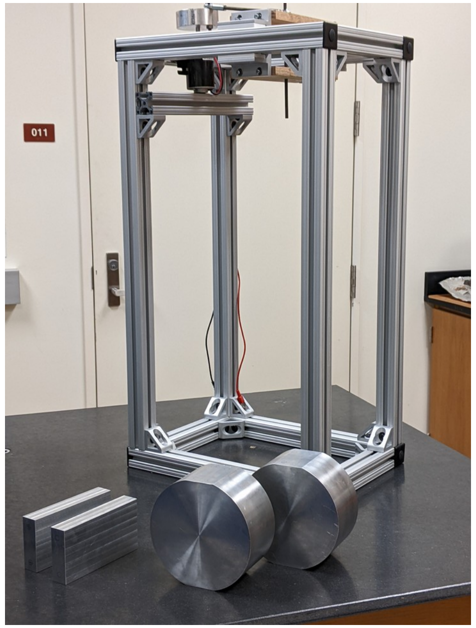
Oli del Rio

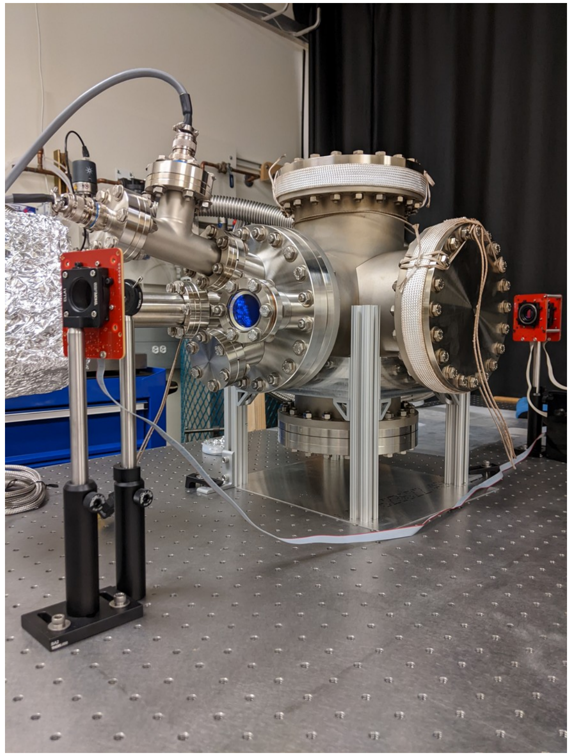
no photo yet...

Group Projects WWU



- Ice formation on cold test mass surfaces in cryogenic GW detectors
- An interactive exhibit for LexC: quad-suspension model
- Some torsion-balance work with the UW Eotwash Group





WESTERN WASHINGTON UNIVERSITY
MAKE WAVES.

Icy mirrors in cryogenic gravitational wave detectors: background

Oli del Rio

no photo yet...

Operating future gravitational wave detectors at cryogenic temperatures would have some attractive benefits:

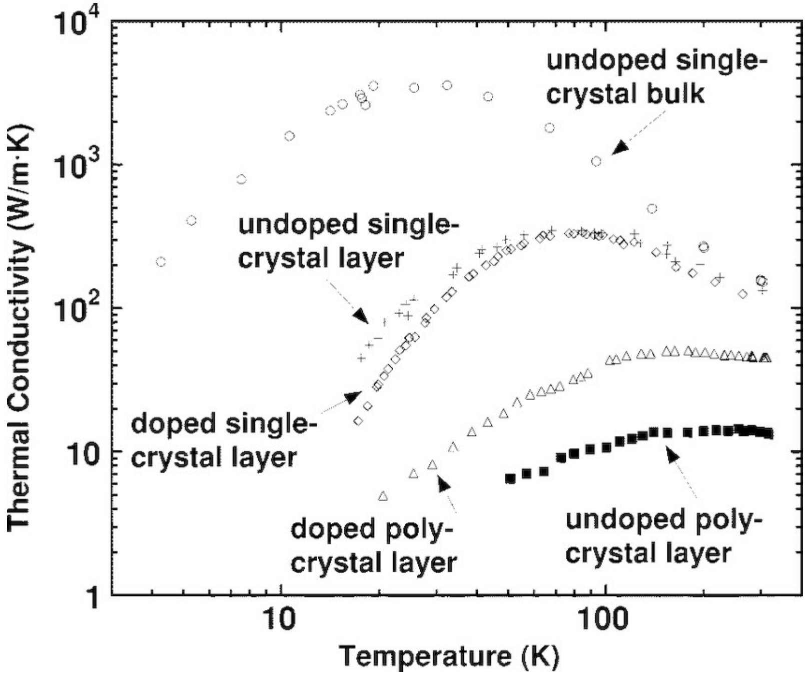
- improved material properties (for <u>some</u> materials); : high thermal conductivity of mirror substrate allows for much greater circulating laser power
- decreased thermal noise $\propto \sqrt{T}$

But: new challenges related to cryogenics, different wavelength!

Current cryogenic GW detector concepts:

KAGRA, Einstein Telescope (ET), LIGO Voyager

for comparison:
fused silica @RT
~1 W/(m K)



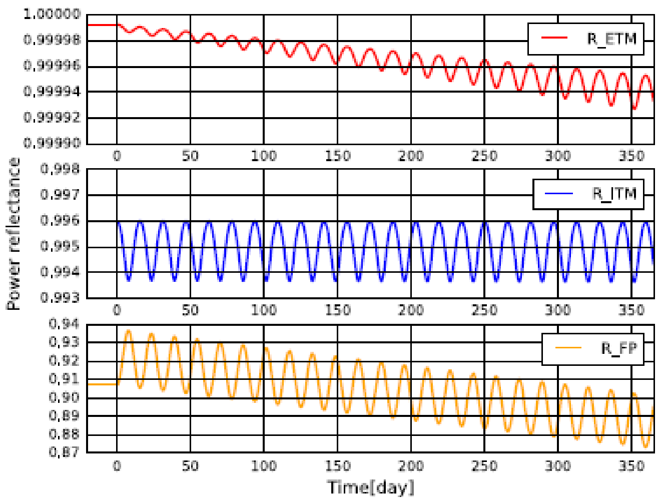
from:
McConnell et al., *J. Microelectromech. Syst*. **10**, 360 (2001)

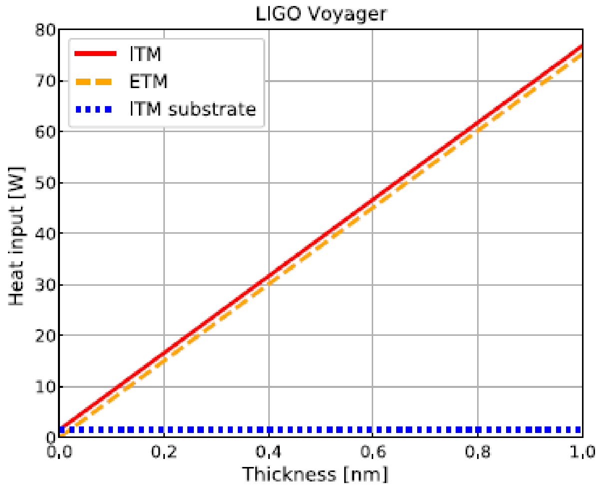
An Uninvited Guest Among the Coating Layers...

Observed in KAGRA: freezing-out of residual gas on cold test mass surfaces

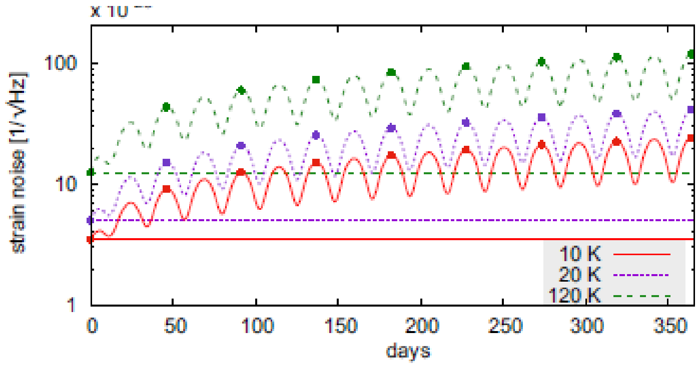
- mostly **amorphous water ice** from room-temperature parts of the vacuum system
- can be reduced, but will always need a clear line of sight to the RT parts of the vacuum system
- **affects optical and mechanical properties** (reflectivity, loss, absorption, thermal noise, scatter, ...)
- water ice has **very strong absorption** around 1550nm and 2000nm

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





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

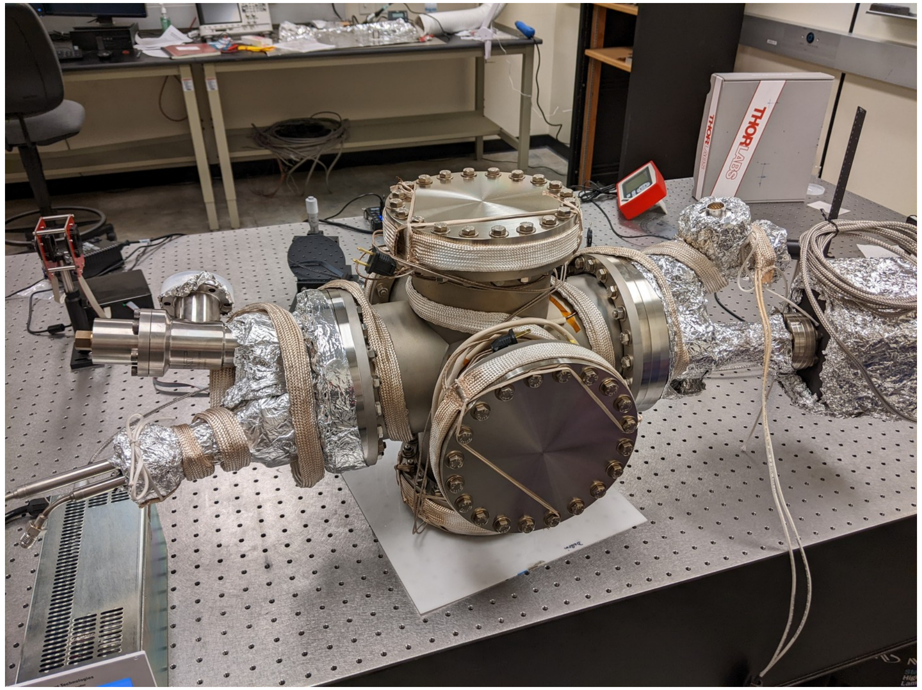


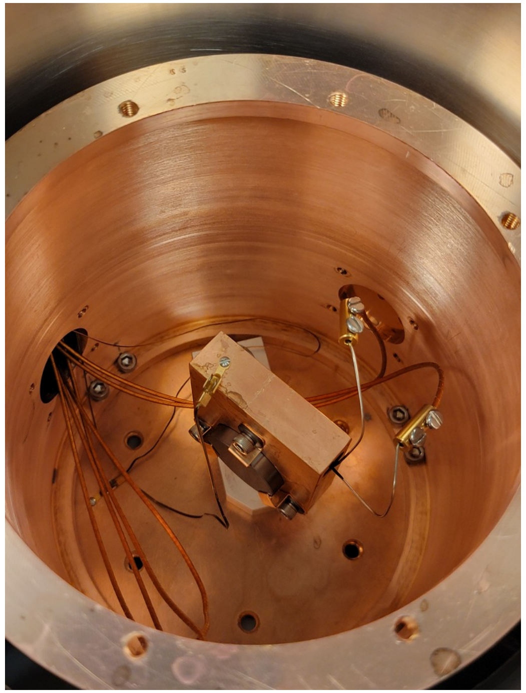
from J. Steinlechner, I. Martin, *Phys. Rev. Res.* **1**, 013008 (2019)

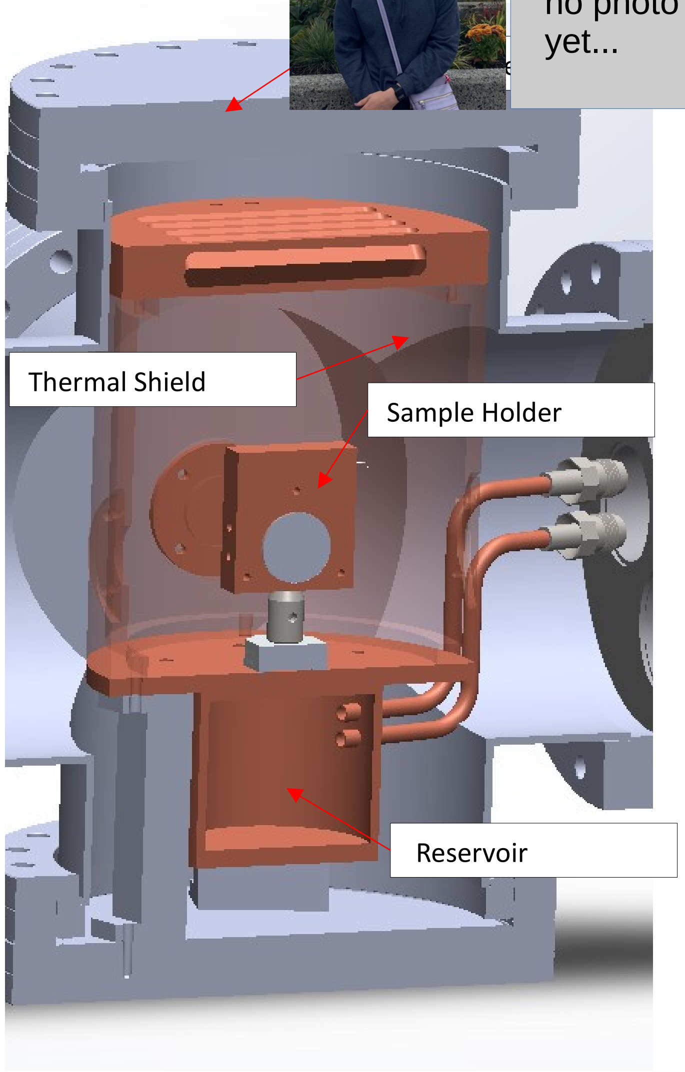
This calculation appears to overestimate the absorption in ultrathin layers – but still: maximum tolerable ice layer for LIGO Voyager estimated to be around 20-30nm!

The WWU Optical Cryostat

Idea: build a clean, modular, LN_2-cooled cryostat with versatile optical access for a systematic study of ice layers on optical surfaces (and other things).







Oli del Rio

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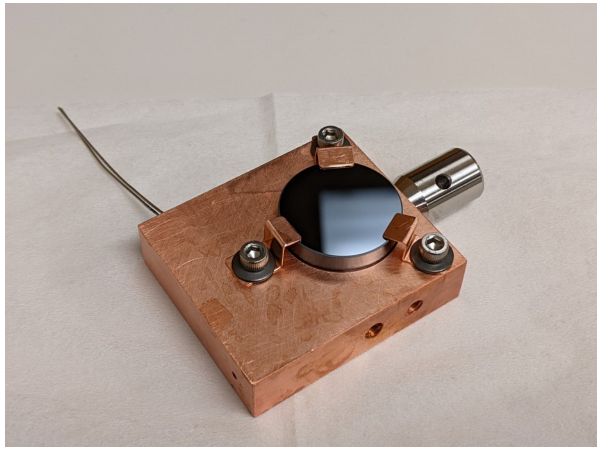
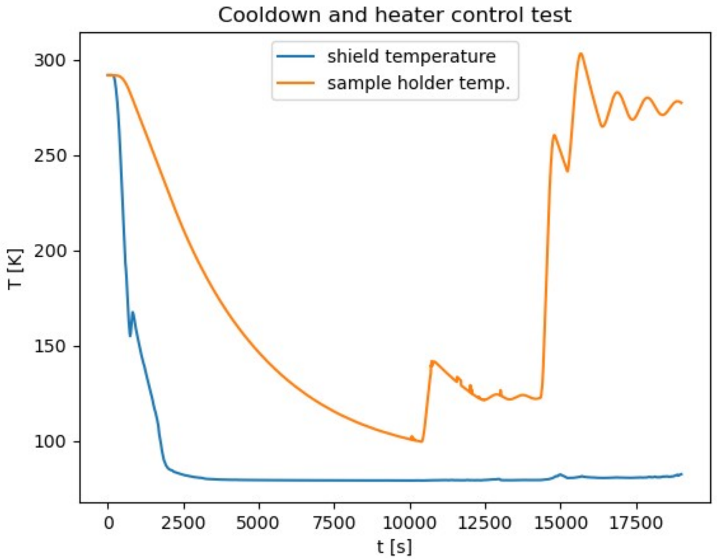
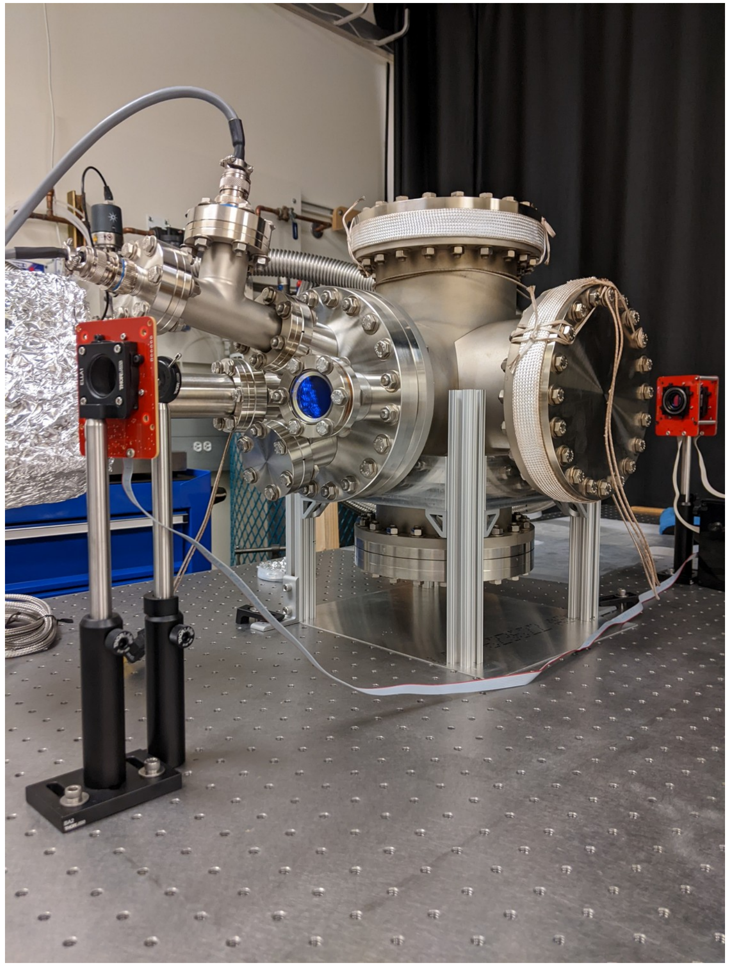
The WWU Optical Cryostat: Testing

- cryostat setup complete and successfully tested:
  - achieved ~5x10^{-9} mbar vacuum (ion pump, no vibration)
  - demonstrated operation between about 90K and room temperature @ sample holder

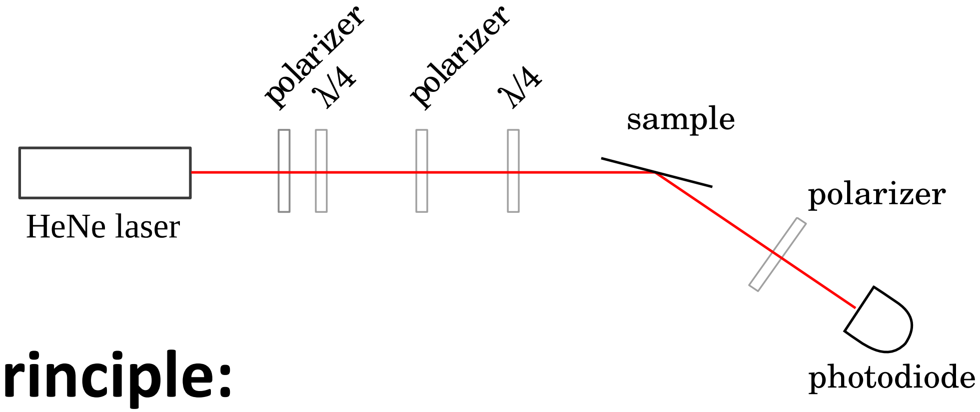


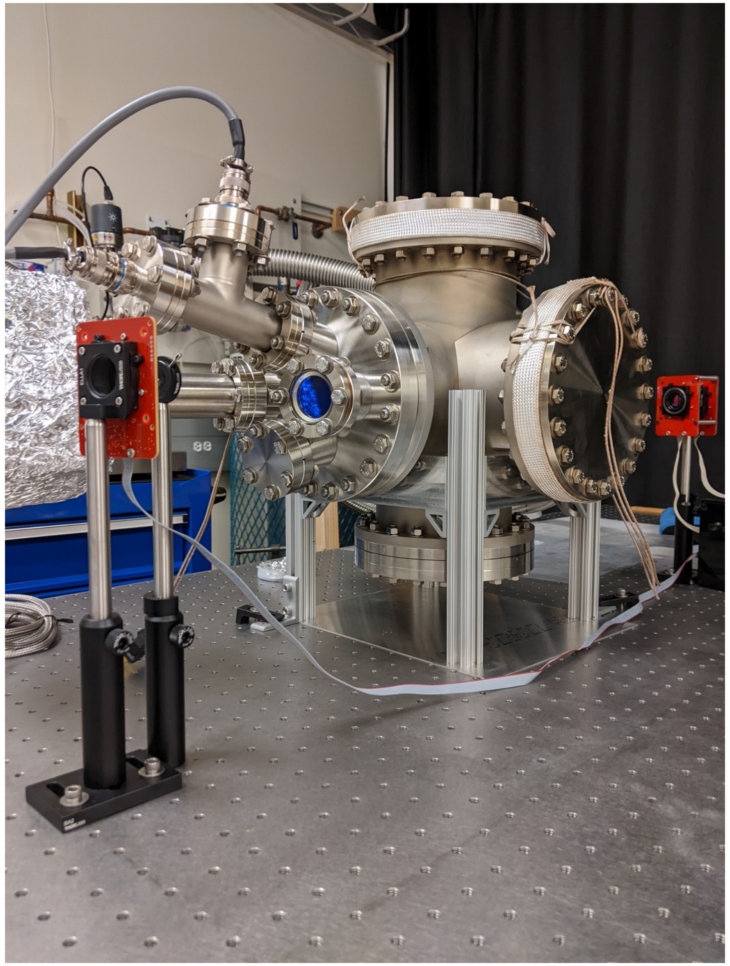




Monitoring layer thickness by ellipsometry

- can measure sub-nanometer layers!





Principle:

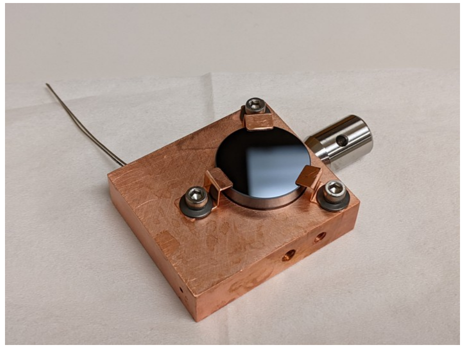
- measure ratio of complex reflection coefficients $\rho = r_p / r_s = \tan\psi \; e^{i\Delta}$
- compare to model of the surface layers

  → fit model parameters to match!

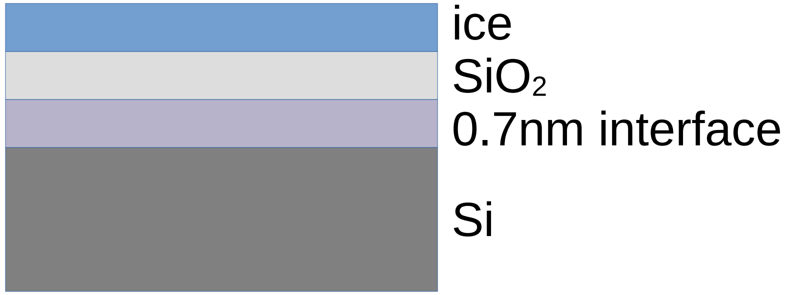
Looking for ice!

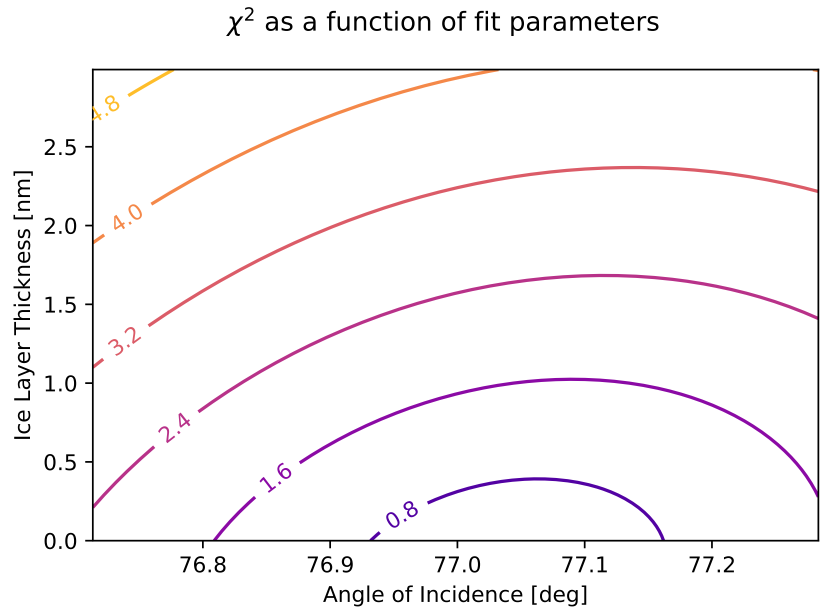
- at RT (no ice): fit oxide layer thickness and angle of incidence → $d = 2.23(05)\ \mathrm{nm}$
- cool down, measure ρ over time: change in first few hours, then plateau
  - best fit ice layer thickness: $< 0.65\ \mathrm{nm}$
  - explain change from RT? → fit n, k:

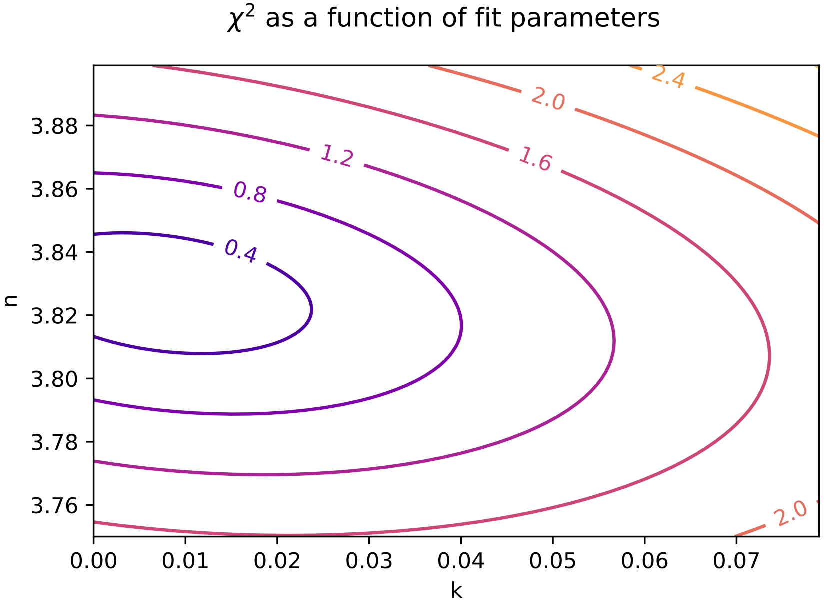
$$n = 3.827(44)\ \mathrm{nm} \quad k = 0.008(42)\ \mathrm{nm}$$



Model:





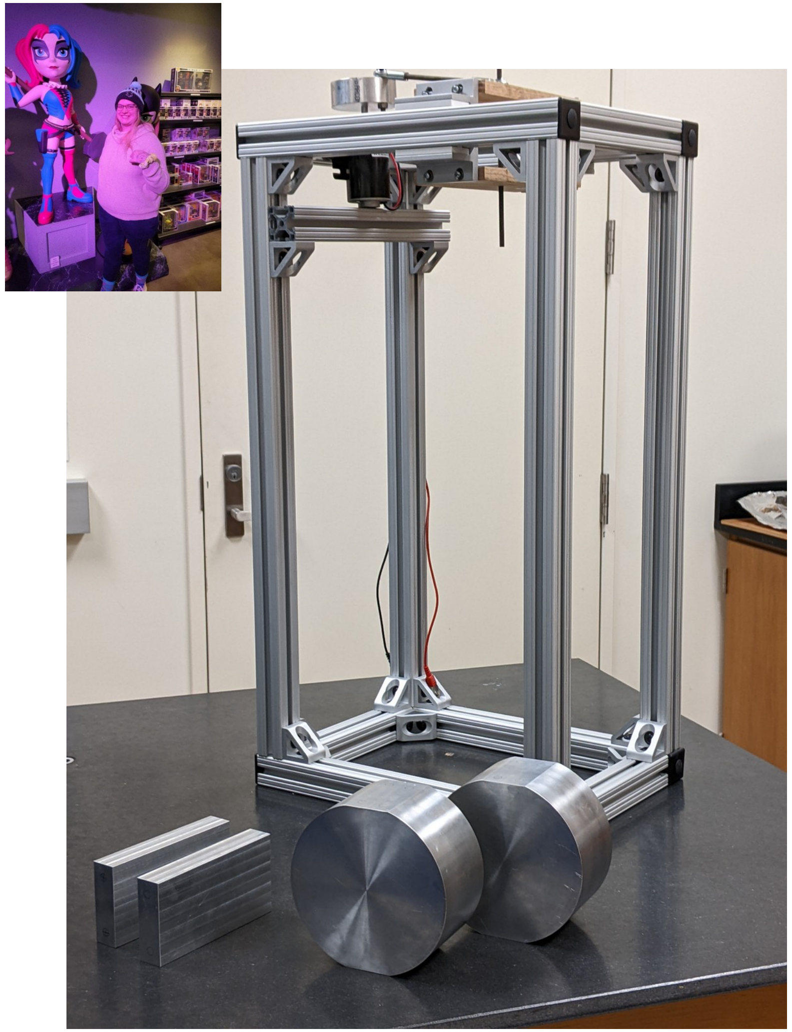


Optical Cryostat: Next Steps

- so far no sign of ice formation found in clean system (over ~1.5 days); repeat test with worse vacuum (no bakeout)!
- reduce liquid nitrogen consumption rate to enable longer experiments
- add precise dosing mechanism for water vapor
- correct for viewport birefringence (currently just increasing error) and reexamine angular errors
- start exploring ice layers!
- ice removal with laser?
- uses beyond ice layers?

Oli del Rio and *Leah Vizmeg* are working on this project.

Interactive quad suspension model for LExC

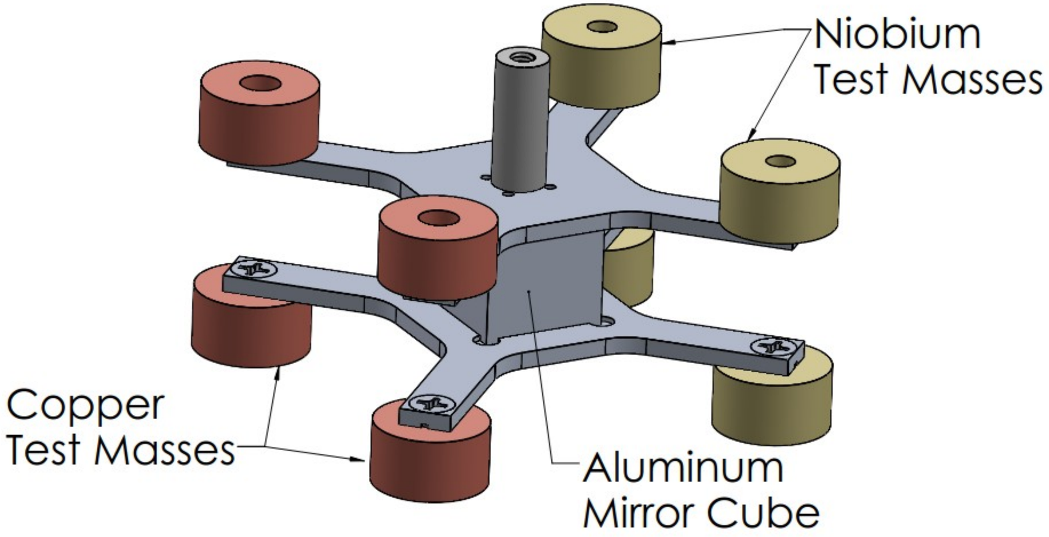


Veronica Russ is building an interactive model of an aLIGO quad suspension system for LExC:

- demonstrate passive isolation by moving suspension point with fixed amplitude but variable frequency
- would like to have a large enough amplitude for a visually impressive demonstration
- portable size for other uses (traveling exhibit)

Other Things: WEP Test with Superconductors

In collaboration with the University of Washington Eotwash group: a test of the weak equivalence principle (WEP) with superconducting test bodies, using a cryogenic torsion balance.



Thank you for your attention!

Questions?

LIGO @ Western Students:

- Oli del Rio
- Veronica Russ
- Leah Vizmeg

just graduated:

- Jackson Larsen
- Douglas Slater

Funding for this project is provided by the National Science Foundation under grant award no. 2208090.