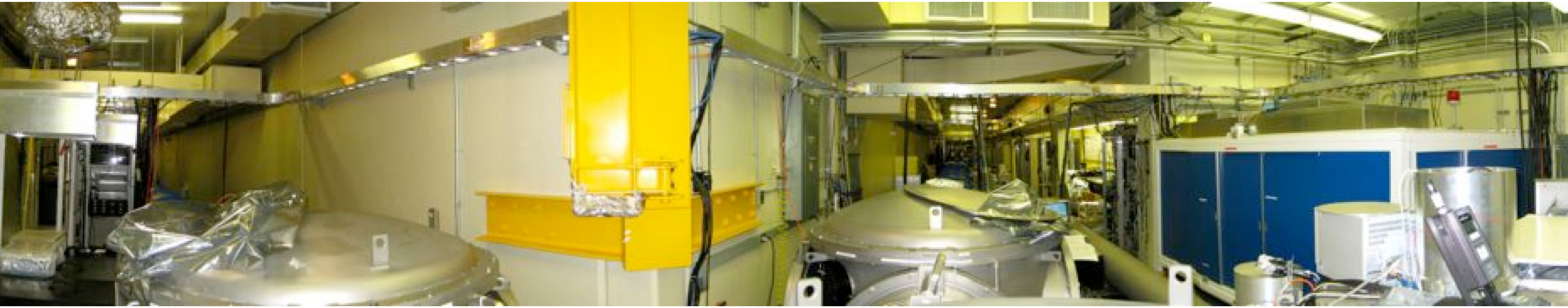
Mariner

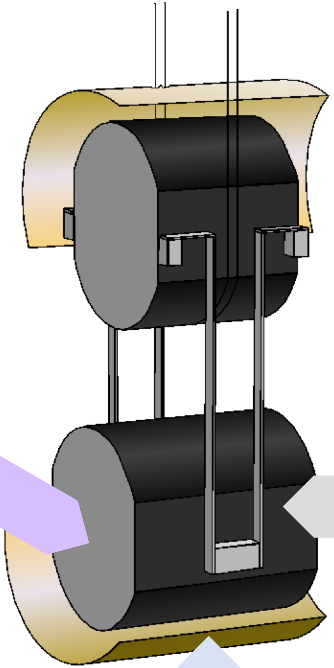


LIGO Voyager Prototype
at the Caltech 40 m Lab

Christopher Wipf
for Mariner Team

Voyager

Adhikari et al, CQG 37 165003 (2020)



① Amorphous silicon coating

- Reduces coating noise. Prospect of a **4–7x** reduction from aLIGO level
- Favors **2 µm** wavelength

② Crystalline silicon substrate

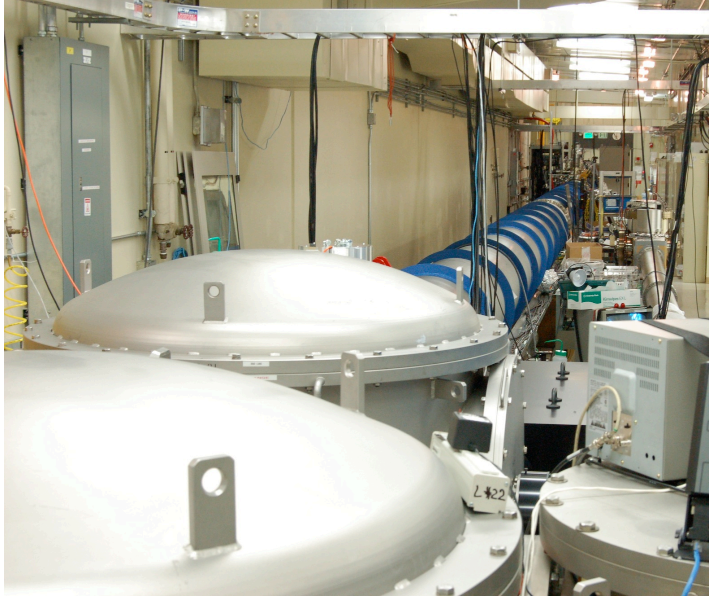
- Improves quantum noise. **200 kg** mass, **3 MW** power
- High thermal conductivity, ultra-low expansion at **123 K**

③ Radiative cooling

- Remains efficient at **123 K**
- Suspension design not constrained* by cryogenics

*i.e. the suspension is not required to conductively extract any heat

Mariner



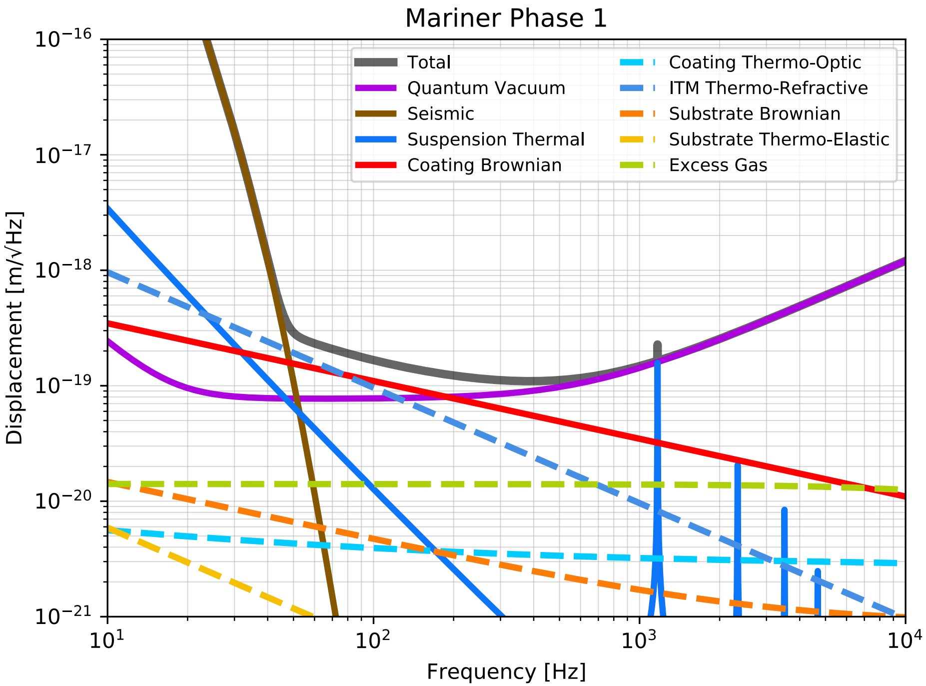
- Voyager-like prototype in the Caltech 40 m Lab
- (Phase 0: balanced homodyne for A+)
- Phase 1: cryo silicon FPMI
- Phase 2: ~Voyager DRFPMI

Will Test	Won't Test
Silicon optics	Quad suspensions
123 K operation	Active seismic isolation
Pre-stabilized laser at 2 μm	High power
Arm length stabilization at 1.4 μm	Big beam spots
Sensing & control (DRFPMI, balanced homodyne)	Thermal compensation
Maybe squeezing?	Filter cavities

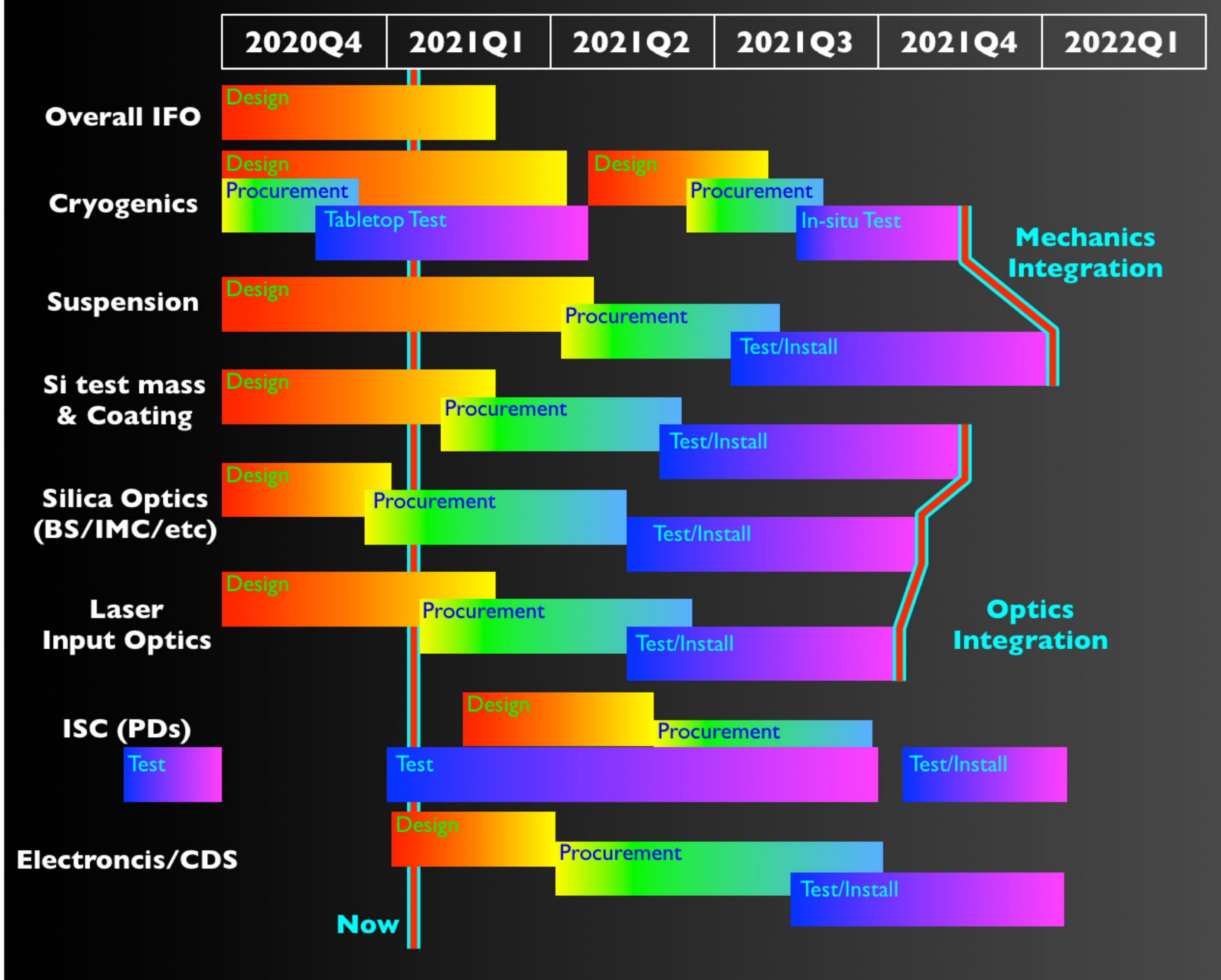
Goals

Phase 1

- Demonstrate 2 μm cryo silicon suspended mirror interferometry
- Develop 2 μm electro-optics
- Low-vibration radiative cooling, steady-state temperature control
- Investigate icing (use ALS as diagnostic?)

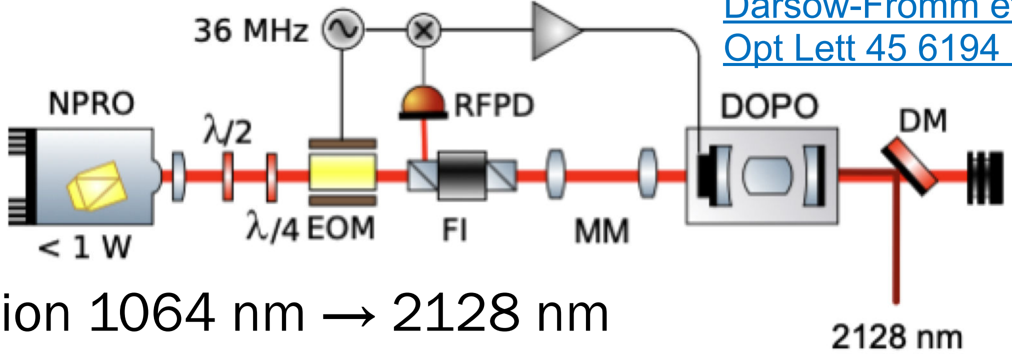


Timeline

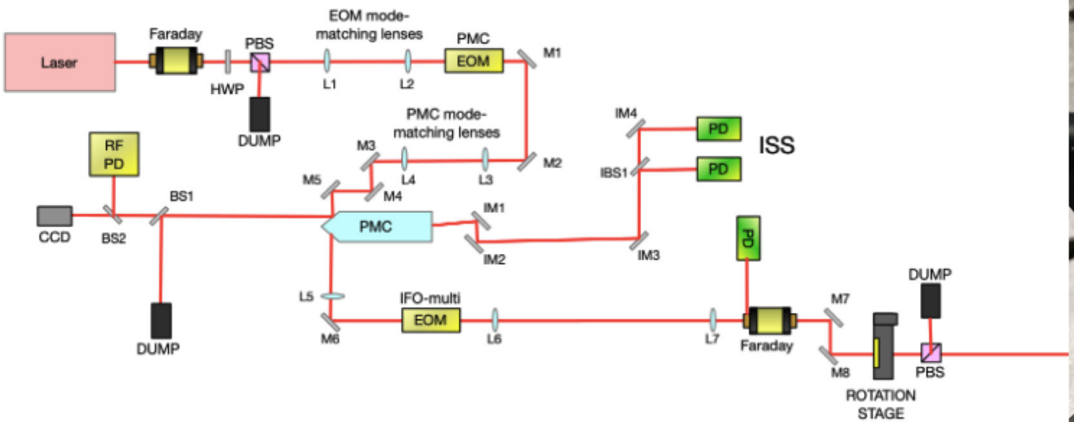

2020Q4
2021Q1
2021Q2
2021Q3
2021Q4
2022Q1
Overall IFO
Design
Cryogenics
Design
Procurement
Tabletop Test
Design
Procurement
In-situ Test
Mechanics Integration
Suspension
Design
Procurement
Test/Install
Si test mass & Coating
Design
Procurement
Test/Install
Silica Optics (BS/IMC/etc)
Design
Procurement
Test/Install
Laser Input Optics
Design
Procurement
Test/Install
Optics Integration
ISC (PDs)
Test
Design
Procurement
Test
Test/Install
Electroncis/CDS
Design
Procurement
Test/Install
Now

Laser for 2 μm

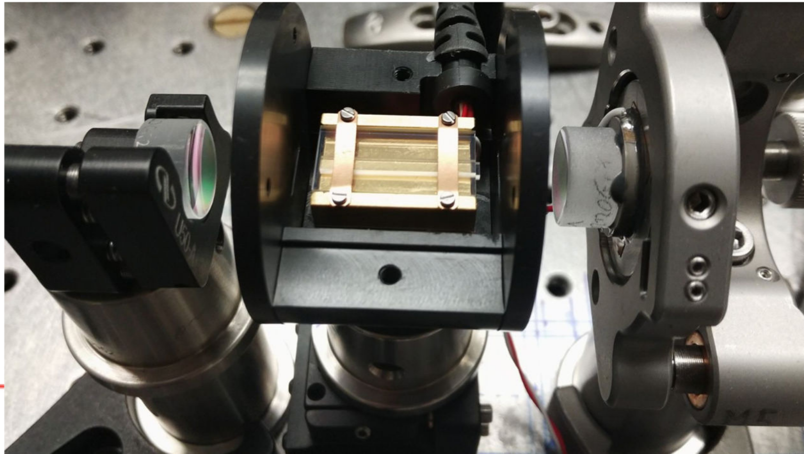
[Darsow-Fromm et al, Opt Lett 45 6194 (2020)]



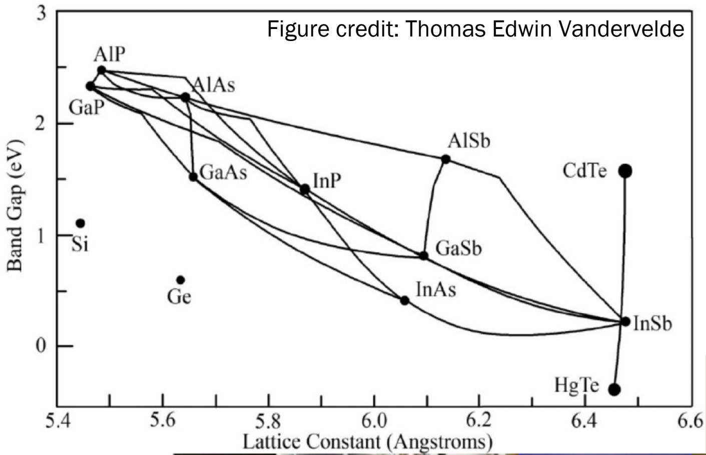
- Parametric down-conversion 1064 nm → 2128 nm
- Reuse existing NPRO laser and stabilization servos
- Degenerate OPO with PPKTP crystal in a linear cavity
- ~1 W pump will yield several hundred mW



F Salces Carcoba



Photodetectors for 2 μm



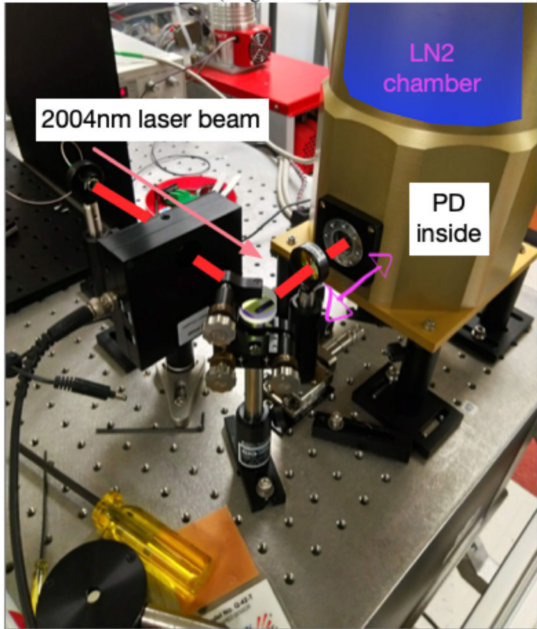
Requirements

- High QE (>99%)
- Spatially uniform, linear response up to ~3–5 mW
- ~100 kHz bandwidth
- Low dark noise (<3 pA/rtHz from 10–1000 Hz)
- 1–3 mm diameter

Candidates

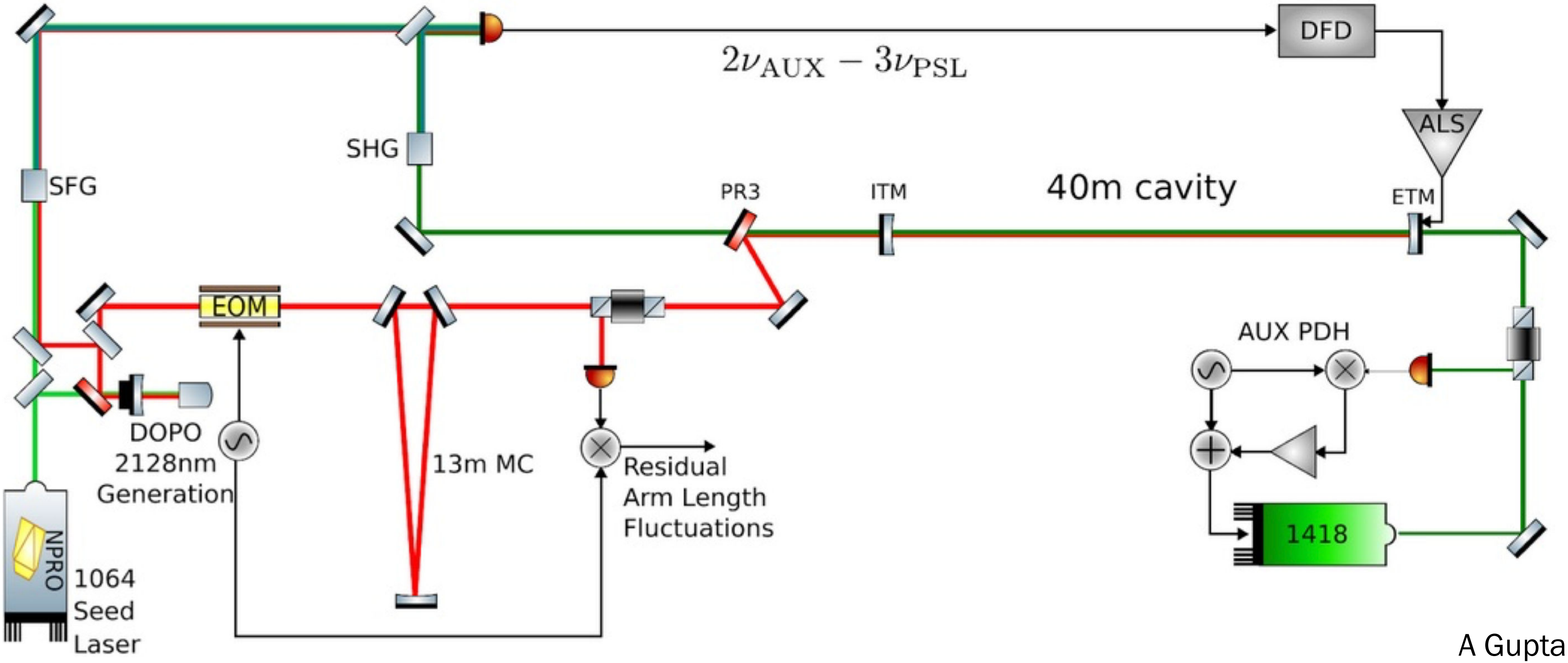
- Extended InGaAs (from Laser Components) [lattice mismatch]
- InAsSb (from Jet Propulsion Laboratory)
  - QE of v1 diodes ~80%
- HgCdTe (University of Western Australia) [very tunable bandgap]

Cryogenic testing of detector samples underway (77–300 K)



A Brooks, R Bhatt

Fractional Harmonic Arm Length Stabilization



A Gupta

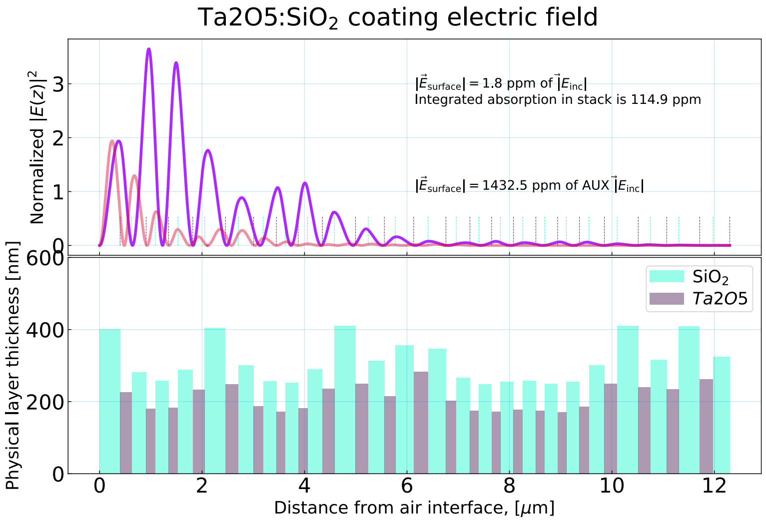
Core Optics

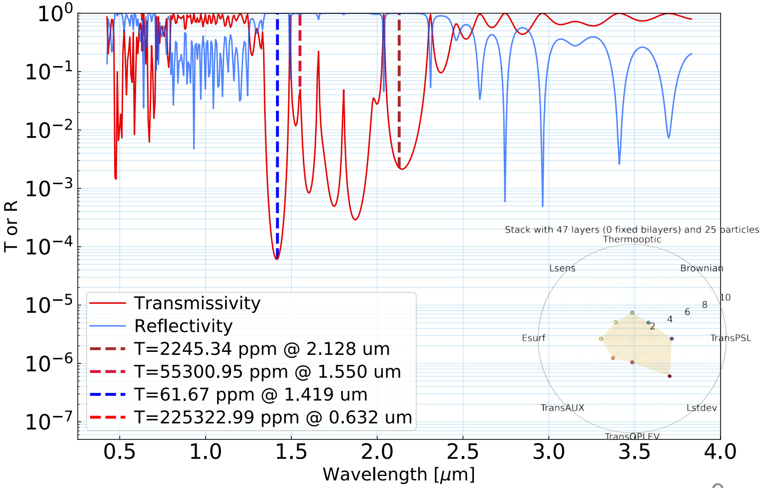
Substrates

- Float-zone Si to be used in phase 1
- Testing new magnetic-Cz Si samples to prepare for phase 2

Coatings

- Silica/tantala for phase 1; amorphous Si for phase 2
- Dichroic designs for new arm length stabilization scheme with 1.4 μm light
- Elevated silica absorption from impurities near 2128 nm

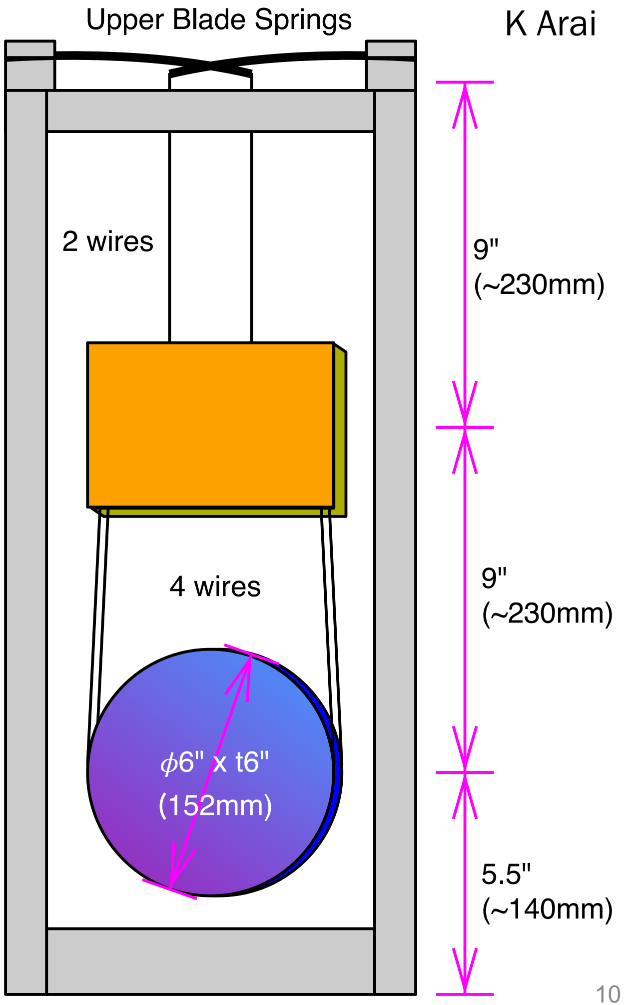




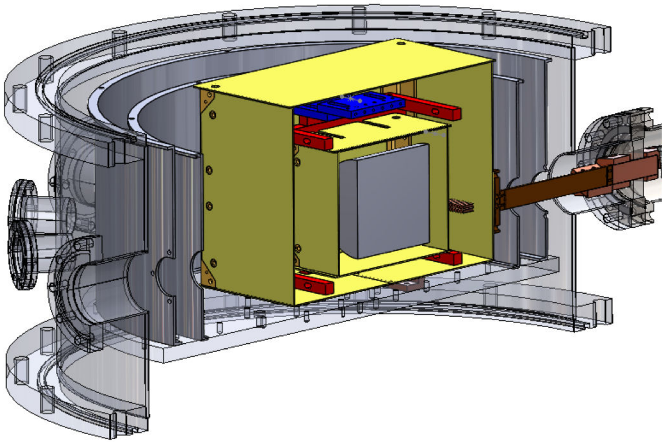
F Salces Carcoba

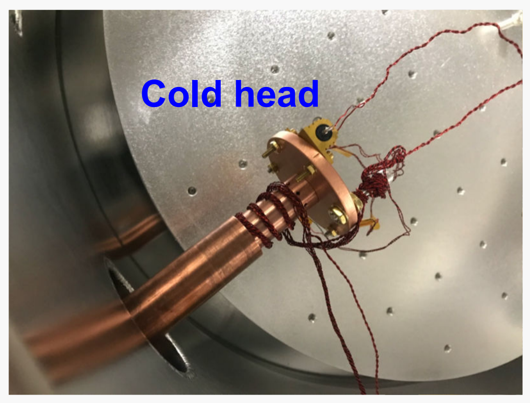
Suspensions

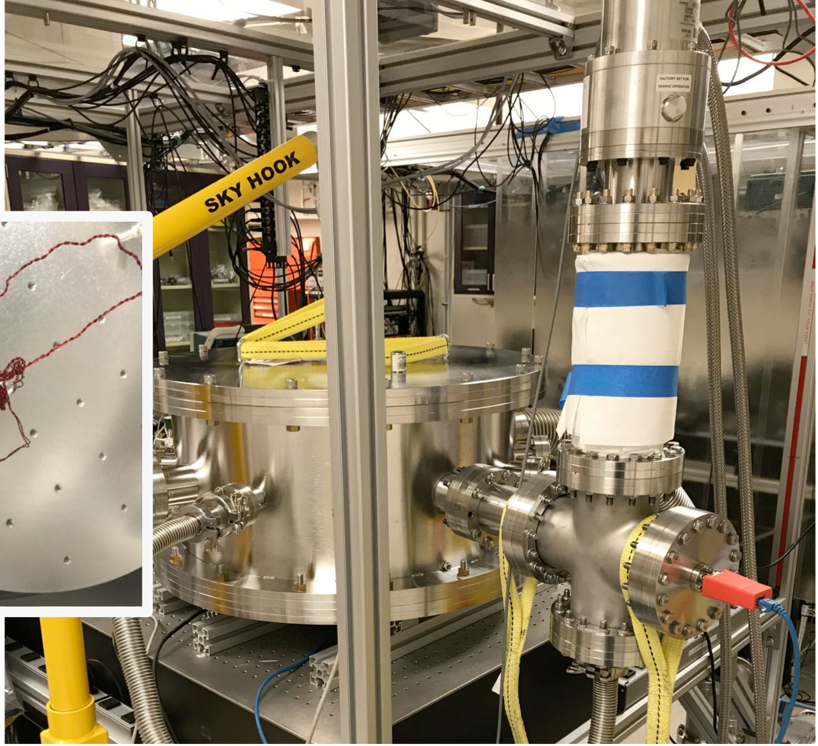
- 2-stage metal wire suspension for phase 1
  - Seismic isolation
  - Alignment/damping on intermediate stage
  - Fast actuation on test mass
- Actuate with cryo coil/magnet OSEMs
  - SmCo magnets are OK (KAGRA experience)
  - Cryo BOSEM development (in collaboration with University of Birmingham)
- Monolithic suspension upgrade in phase 2
  - Si suspension ribbons and blade springs

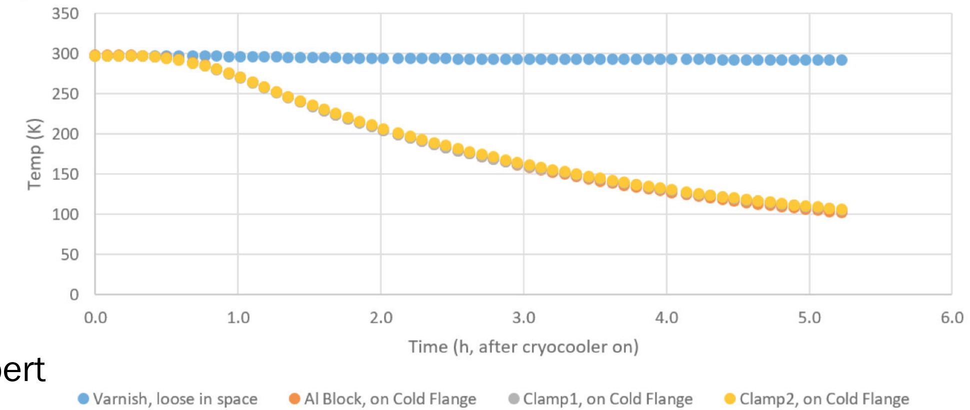


Cryo Engineering









- Cryo-shielded test chamber + GM cryocooler (45 W @ 60 K)
- First cooldowns underway

S Appert

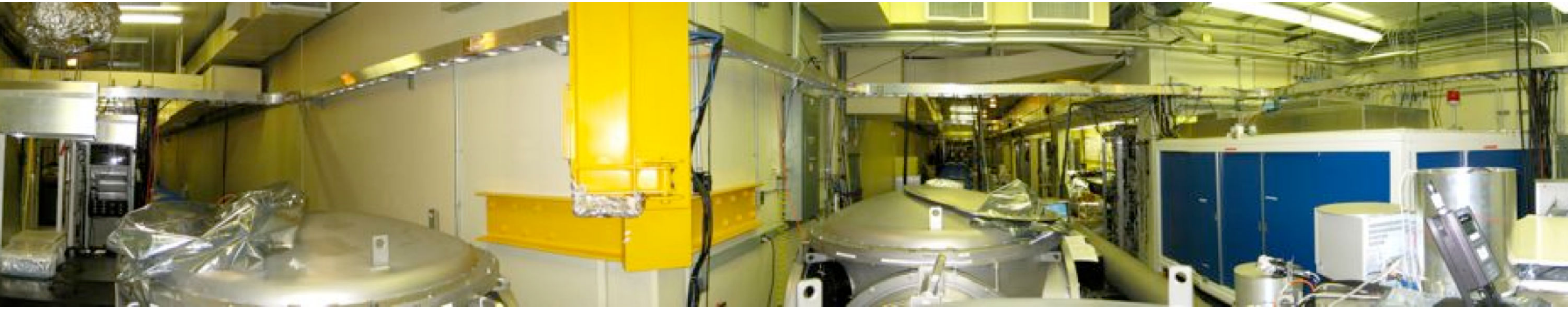
Research Opportunities & More Resources

1. 35 W laser amplifier for 2 microns
2. EOM for 2 microns with resonant modulation capability and a 35 W power handling capacity
3. low absorption glass to meet the BS requirements
4. process to anneal large pieces of silicon to trap the Oxygen and lower the 2 micron absorption coefficient to 5 ppm/cm.
5. low noise, low absorption HR mirror coating for 2 microns
6. ALS (1.4-3 microns, phase locked with carrier)
7. High QE Photodiode for 2 microns
8. How to handle the ice formation on the HR surfaces of the mirrors?
9. Damping of Parametric Instabilities: beyond the "Mushrooms" approach
10. 2-micron squeezer (10 dB measured in a homodyne detector)
11. Quadruple Suspension
12. Seismic Isolation Platform
13. Optical Rigid Body: lock all platforms with lasers
14. Dynamic RoC actuator for test masses
15. UHV compatible 2um Faraday isolator

- Chat channels
  - chat.ligo.org (Voyager channel)
  - cryoifo.slack.com
- Voyager telecons
- Wiki pages
  - Mariner
  - Voyager
- Voyager White Paper

Credits

Rana Adhikari, Stephen Appert, Koji Arai,
Radhika Bhatt, Aidan Brooks, **Anchal Gupta,**
Shruti Jose Maliakal, Aaron Markowitz, Raymond Robie,
Francisco Salces Carcoba, Nina Vaidya



Caltech

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