

Cryogenic Monolithic Torsion Pendulum Made of Silicon for Gravity Gradient Sensing

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Masaki Ando

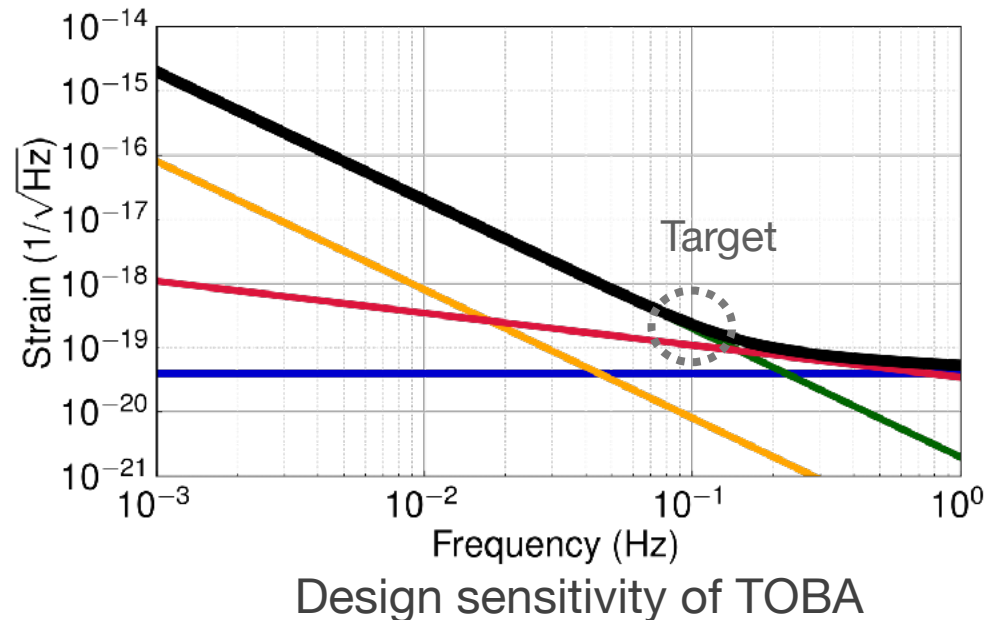
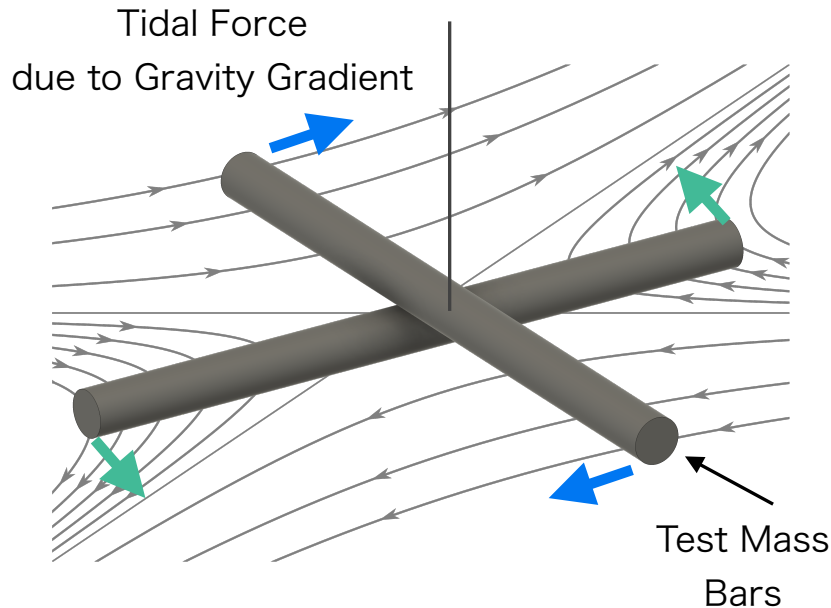
The Univ. of Tokyo

17/12/20 3rd IFQMS

Torsion Bar Antenna (TOBA)

TOBA : TOrsion-Bar Antenna

- Gravity gradiometer using two torsion pendulums
- Resonant frequency of torsion pendulum \sim mHz
→ Sensitive to **low frequency** (~ 0.1 Hz)
- Target sensitivity $h \sim 10^{-19} / \sqrt{\text{Hz}}$ @ 0.1 Hz with **10 m** bars



Science of TOBA

TOBA

Astrophysics

IMBH Binary
Merger

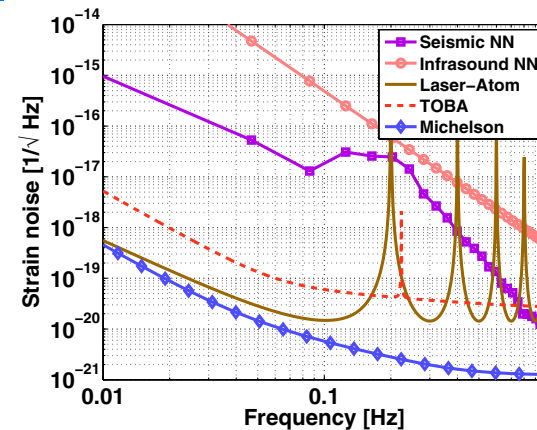
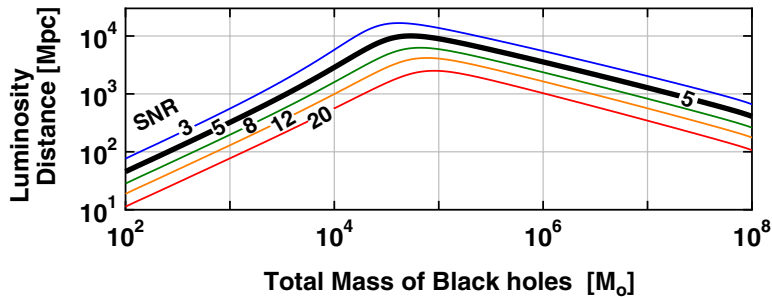
GW Stochastic
Background

Geophysics

Newtonian
Noise

Earthquake
Alert

10 Gpc for $10^5 M_{\odot}$



M. Ando+ (2010)

J. Harms+ (2012)

Development Plan

• Phase-I
(2009)

Phase-II
(2015)

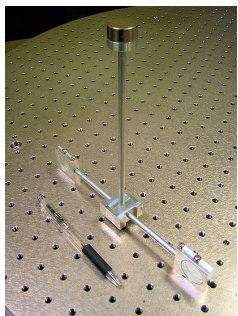
**Phase-III
(Now)**

Final
(Target)

Principle Test

$10^{-8}/\sqrt{\text{Hz}}$ @ 0.1 Hz
(Established)

- Room Temp.
- 25cm TM(s)

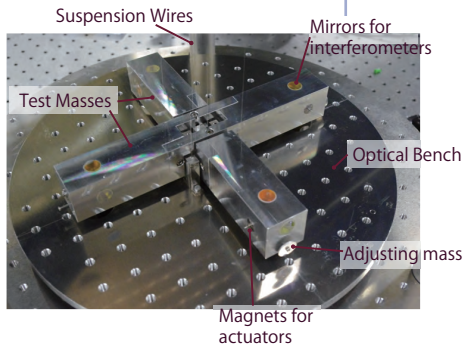


M. Okada
Master Thesis

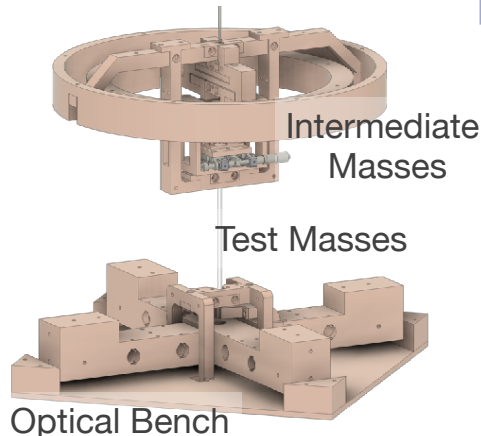
Cryogenic Test

$10^{-15}/\sqrt{\text{Hz}}$ @ 0.1 Hz
(Design)

- **Cryo. Temp. (4K)**
- 35cm TMs



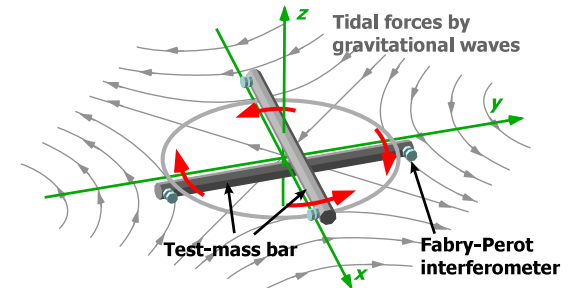
A. Shoda
Ph.D Thesis



Goal

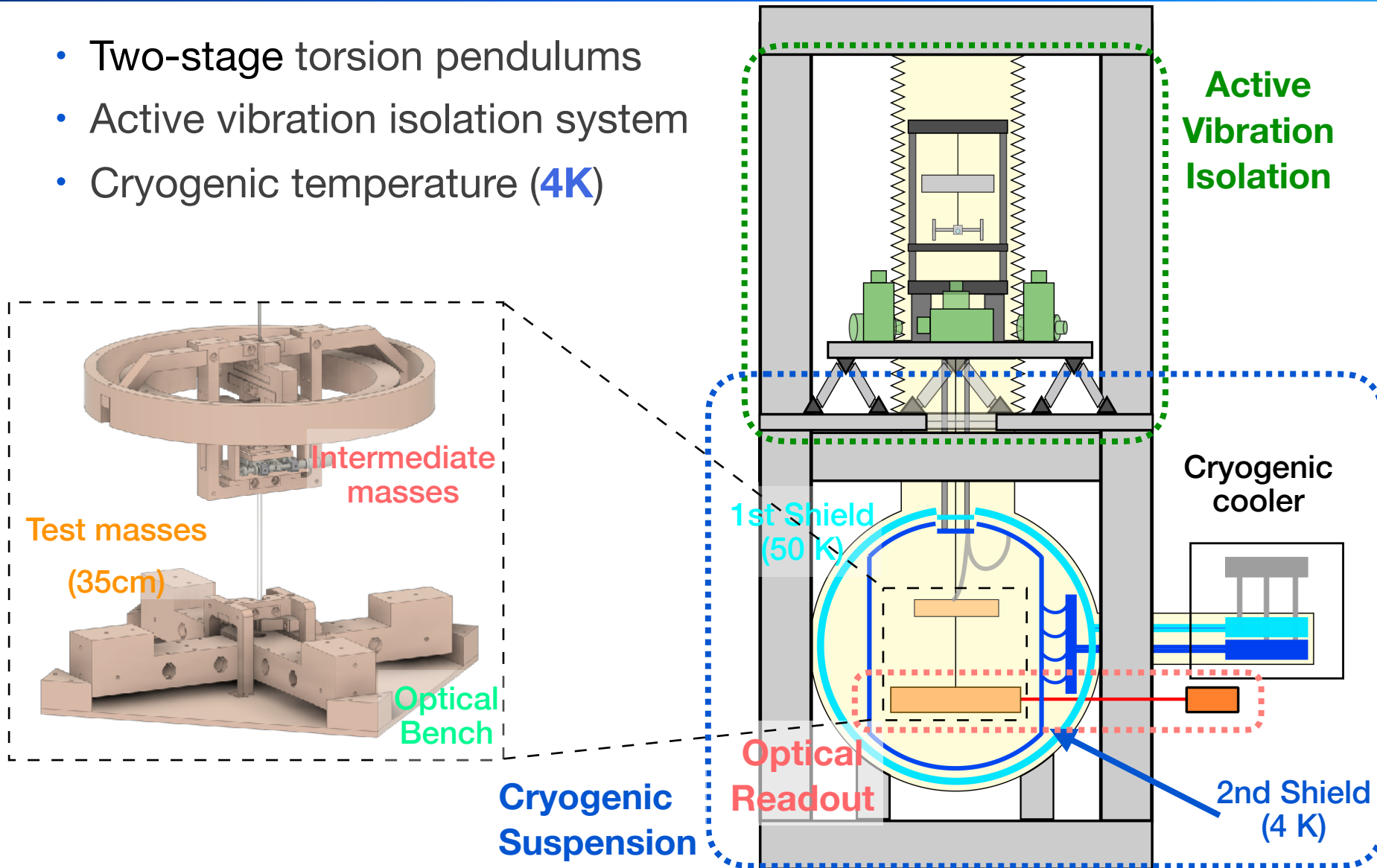
$10^{-19}/\sqrt{\text{Hz}}$ @ 0.1 Hz
(Target)

- **Cryo. Temp. (4K)**
- **10m TMs**

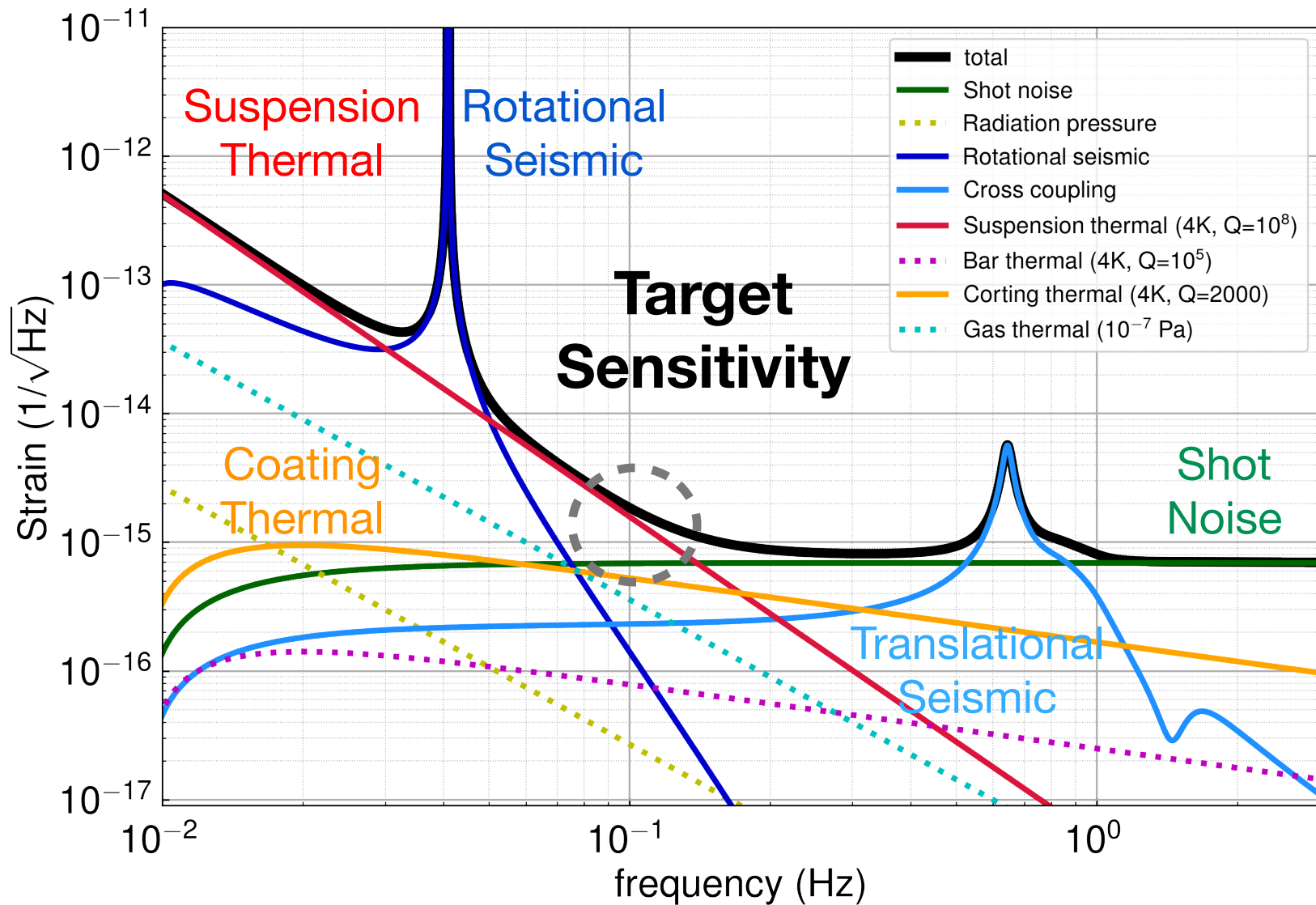


Overviews of Phase-III TOBA

- Two-stage torsion pendulums
- Active vibration isolation system
- Cryogenic temperature (**4K**)



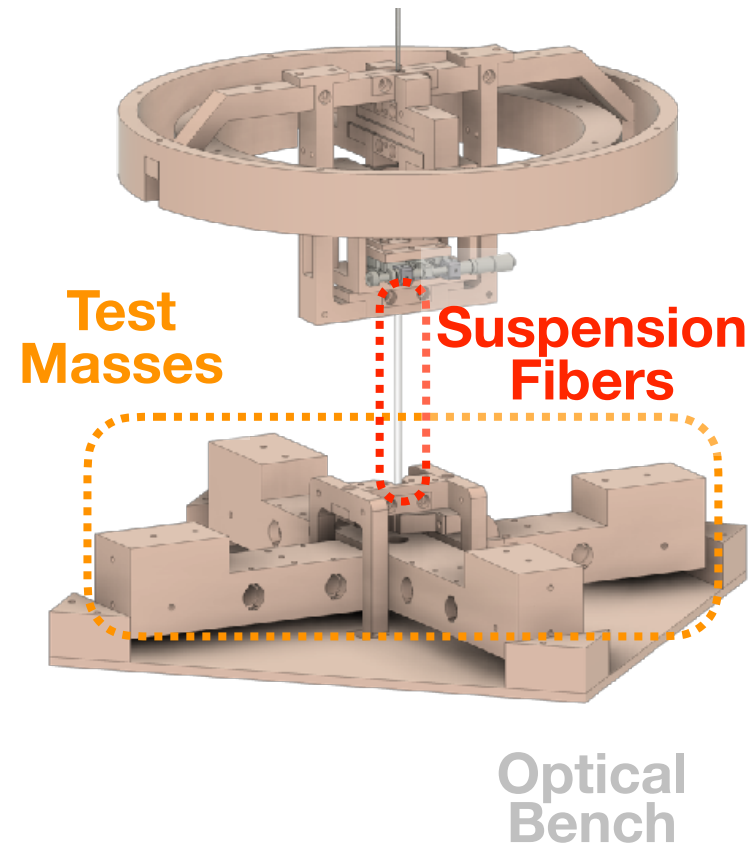
Target Sensitivity of Phase-III TOBA



Silicon Suspension System

Test masses and suspension wires are made of silicon

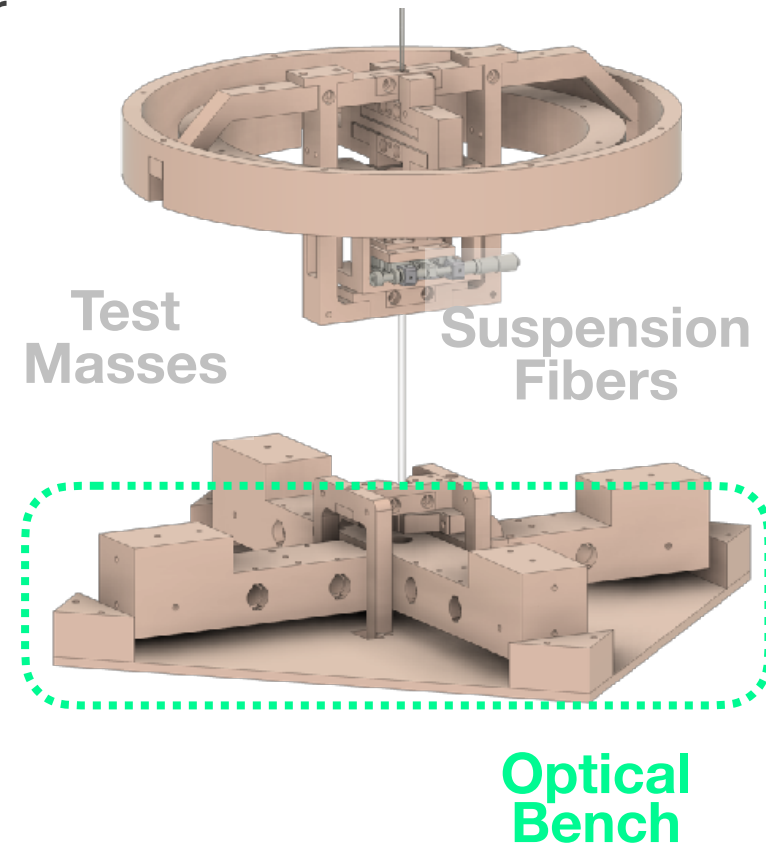
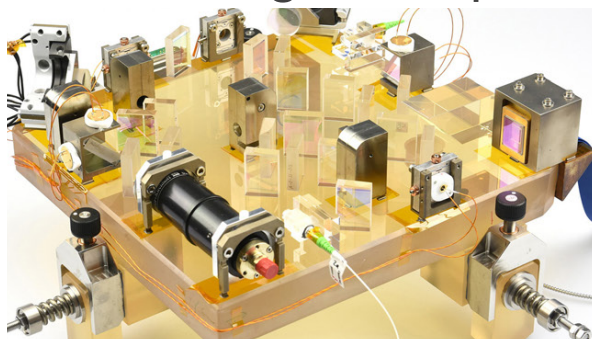
- **Good thermal conductivity**
 - ▶ Cooling test masses effectively
- **Small electrical conductivity**
 - ▶ Reduce induced current coupling
- **Extremely small mechanical loss**
 - ▶ Reduce thermal noise (Brownian motion)
- With a simplified setup (BuCu fires, Cu test masses) we succeeded in cooling the test masses down to 6K



Monolithic Interferometer

Optical system: Monolithic interferometer

- Every optics glued on a base plate
 - ▶ Reduce effects from environmental disturbances (vibration, temperature, ...)
- Main optics and the base plate are made of silicon
 - ▶ Decrease thermal contraction during cooling to keep the alignment



An example figure of monolithic interferometer

[Chwalla et. al. \(2016\)](#)

Current Status & Future Plan

Monolithic Interferometer

- Testing some components at cryogenic temperatures
 - ▶ Photodiodes
 - ▶ Glues
- Now designing optical layout

Silicon Suspension System

- Ordered a bulk silicon sample for test masses
- Silicon fibers will be delivered soon
- Considering suspension parameters

