

先進的な防振技術による 巨視的量子系の実現

Enabling Macroscopic Quantum Systems through Advanced Vibration Damping Technology

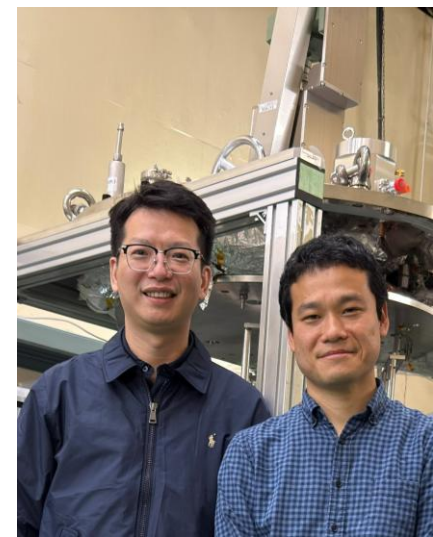


Yuta Michimura

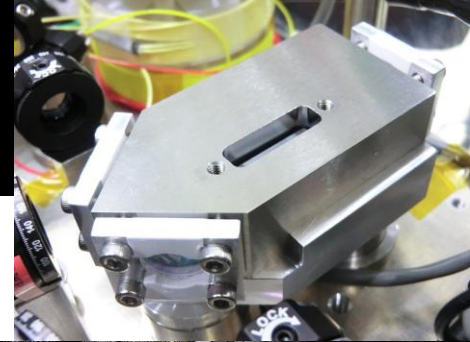
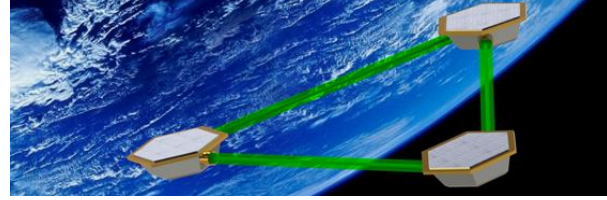
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道村 唯太



1987 — Yokohama, Kanagawa

2014 —
2015 ← PhD in Physics



Assistant Professor at
Department of Physics,  UTokyo



2022 —
2024 — Research Scientist at
LIGO Lab, Caltech



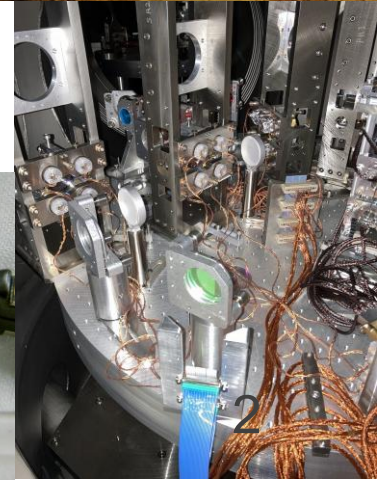
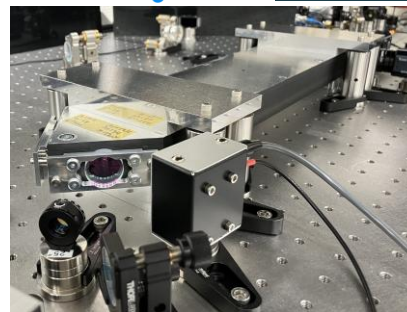
2024 — Associate Professor at
RESCEU,  UTokyo



Today

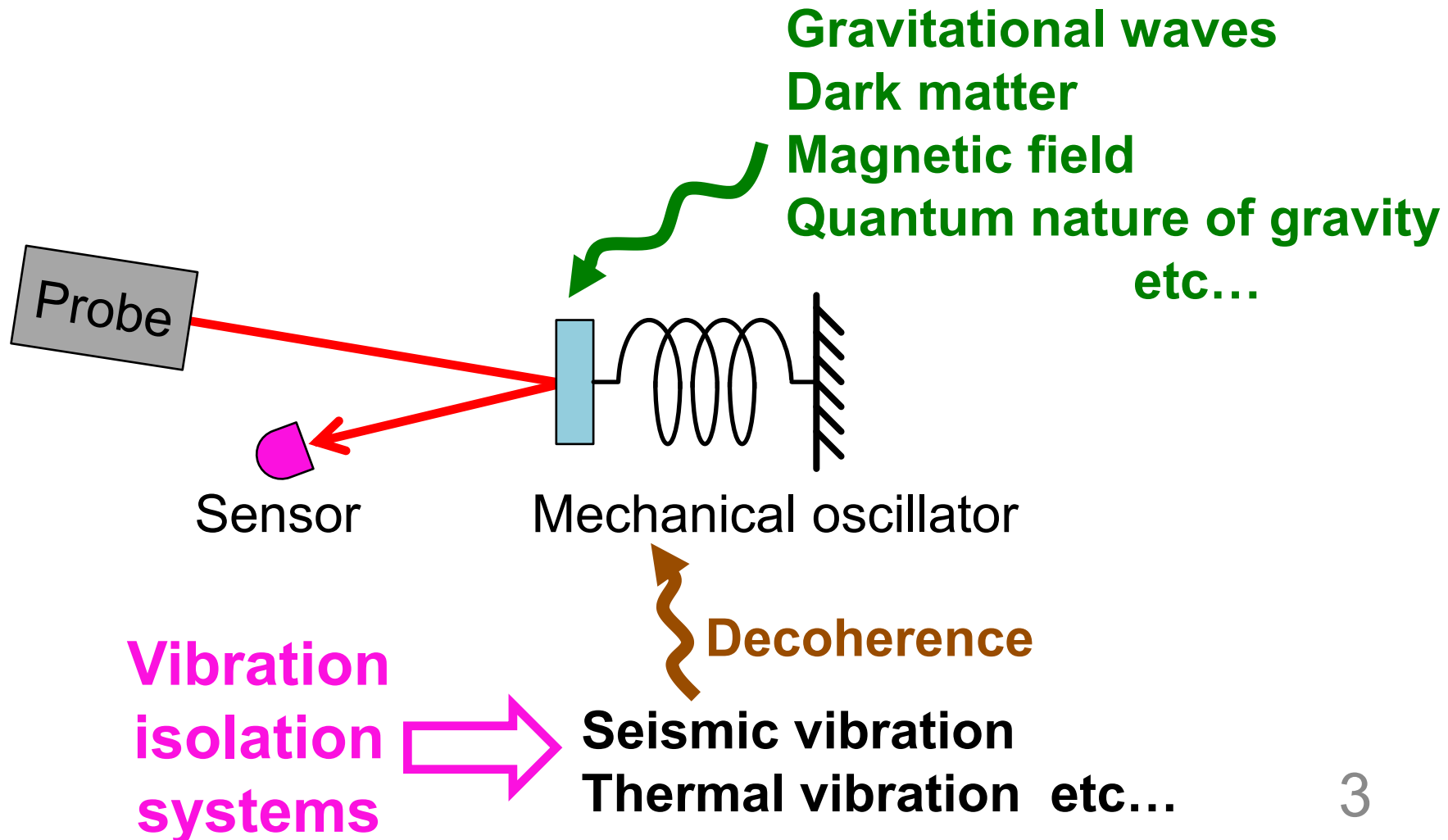


創発の研究支援事業
Pusion Oriented REsearch for disruptive Science and Technology



Overview of the Project

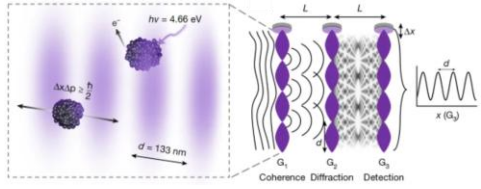
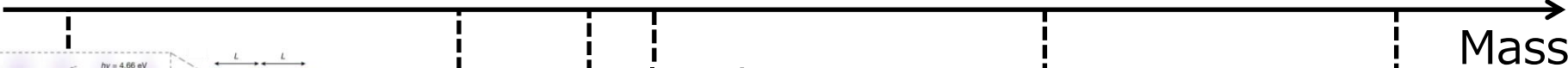
- Develop **vibration isolation systems** for realizing macroscopic quantum systems



Quantum and Gravity Experiments

Quantum →

← **Gravity**

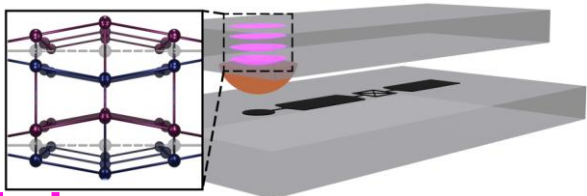


sodium nanoparticles,
 $3e-19 \text{ g}$
[Pedalino+ \(2026\)](#)
Interference



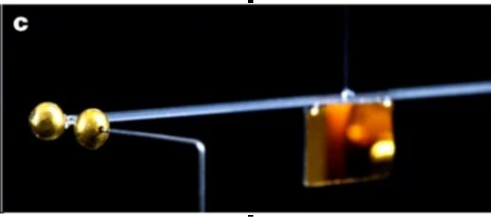
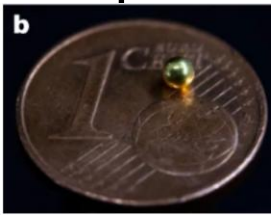
cantilever, 50 ng
[Cripe+ \(2019\)](#)

Backaction

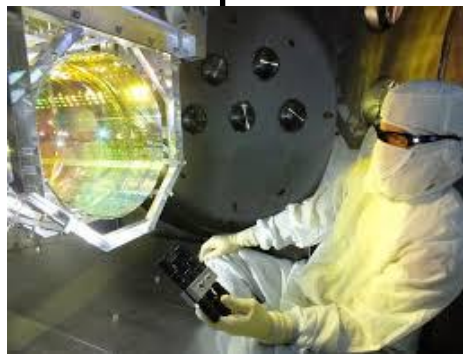


Cat state acoustic wave, 16 μg
[Bild+ \(2023\)](#)

Planck mass
 22 μg



torsion pendulum, 90 mg
[Westphal+ \(2021\)](#)



LIGO, Virgo, KAGRA, ~20-40 kg

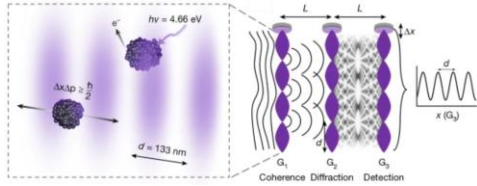
Quantum and Gravity Experiments

Quantum

Quantum regime of gravity

Gravity

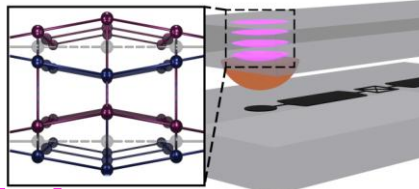
Mass



sodium nanoparticles, $3e-19$ g
[Pedalino+ \(2026\)](#)
Interference



cantilever, 50 ng
[Cripe+ \(2019\)](#)
Backaction



Cat state acoustic wave,
[Bild+ \(2023\)](#)

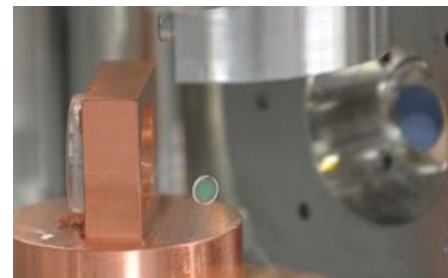
Planck mass
 22 μ g



Our focus: 0.1-10 mg scale



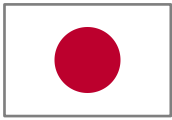
optical levitation,
 ~ 0.2 mg



suspended disk, 7 mg
[Matsumoto+ \(2019\)](#)



suspended bar, 10 mg
[Komori+ \(2020\)](#)



Japan Team

- **Motivation**

- Gravitational waves (KAGRA)
- Dark matter (axions, vector bosons)
- Quantum nature of gravity

- **Expertise**

- Laser interferometry
- Optomechanics
- Vibration isolation



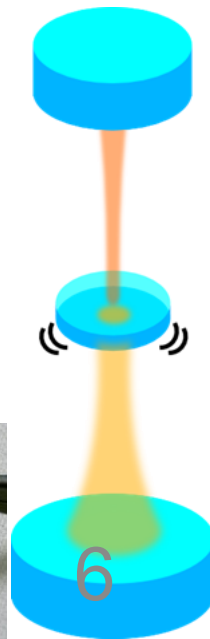
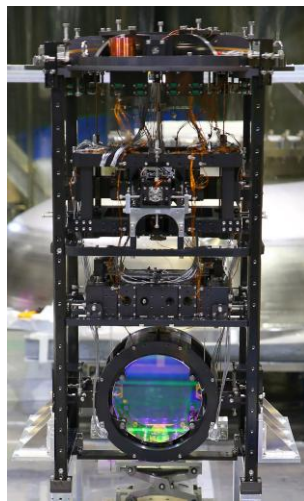
Michimura (PI)
 UTokyo



Komori (Co-I)
 NAOJ
National Astronomical
Observatory of Japan



Ando (Collab.)
 UTokyo





Singapore Team



Wang (PI)



Assad (Co-I)



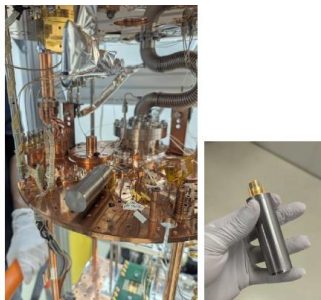
Lam (Collab.)

- **Motivation**

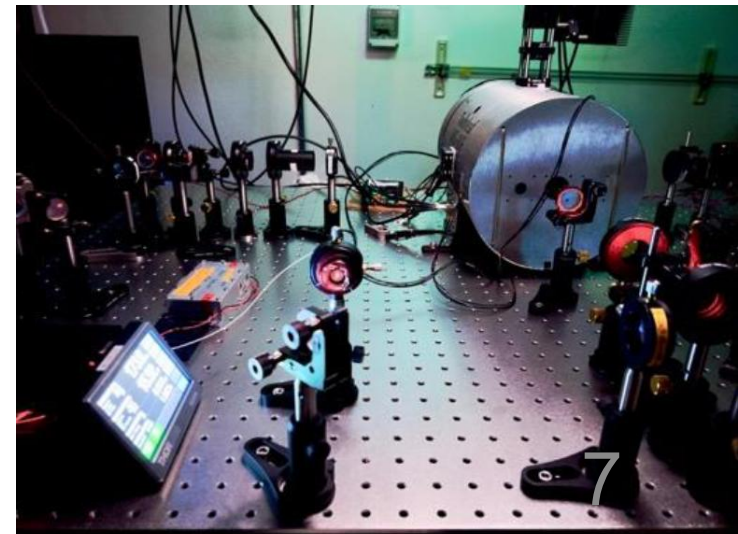
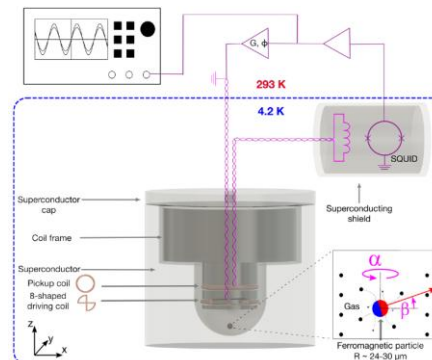
- Quantum ground state cooling
- Ultrahigh sensitivity sensing
 (magnetic field, cryogenic vacuum gauge, etc.)
- PNT (Positioning, Navigation, and Timing)
- Dark matter (axions)
- Gravity sensing

- **Expertise**

- Magnetometry (atomic, precessing ferromagnetic)
- Superconducting levitation
- Quantum system control
- Optical coherent levitation



3 Channel SQUID readout



Research Topics

- **Realization of optical levitation of mirrors**

- Proposed in 2017 YM, Y. Kuwahara+, Optics Express **25**, 13799 (2017)

- Proof of concept experiment done

- T. Kawasaki, ..., YM, PRA **102**, 053520 (2020)

- Mirror fabrication on-going (with LMA)

- M. Croquette, ..., YM+, AVS Quantum Science **5**, 014403 (2023)

- Supported by ANR-JST CREST (2018-2024) and

- France-Japan JSPS Birateral Collaborations (二国間交流, 2025-2027)

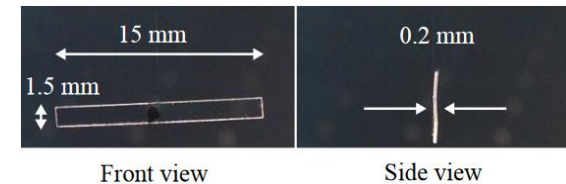
← Levitation technology from **Singapore team**

- **Feedback cooling of a suspended bar**

- Best torque sensitivity in 2020

- K. Komori, ..., YM, M. Ando, PRA **101**, 011802(R) (2020)

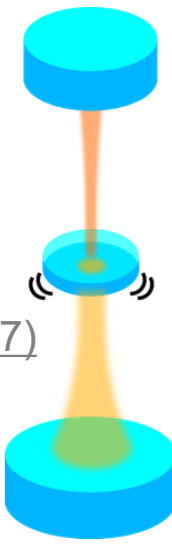
- Upgrade on-going



- **Development of vibration isolation systems**

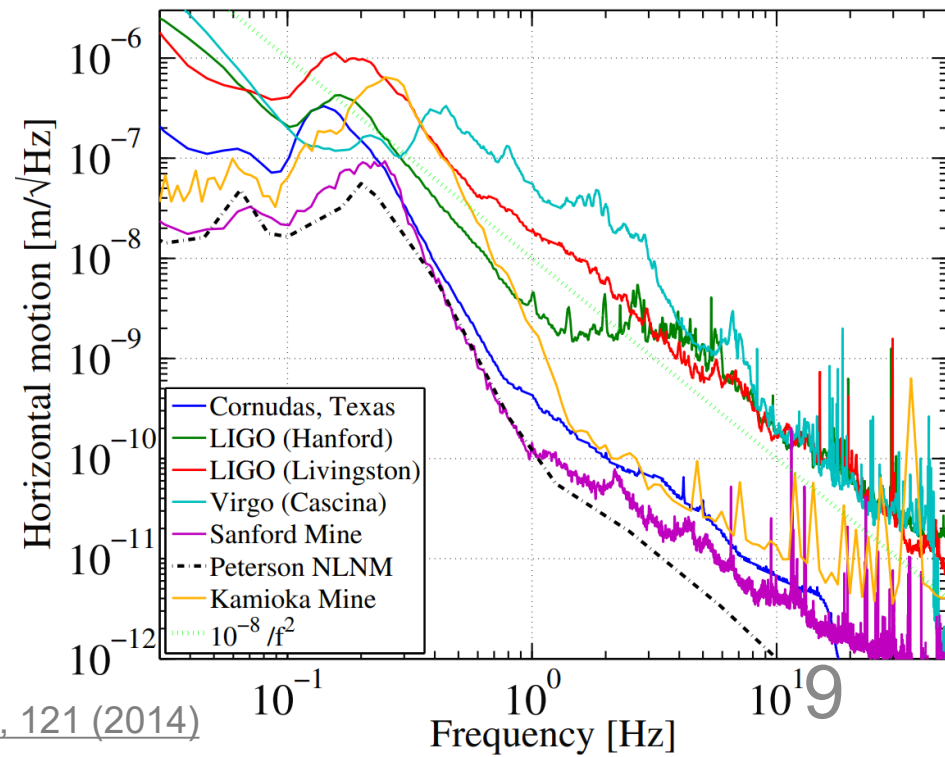
- Needed for both Singapore and Japan platforms

⇒ Joint design with **Singapore team**



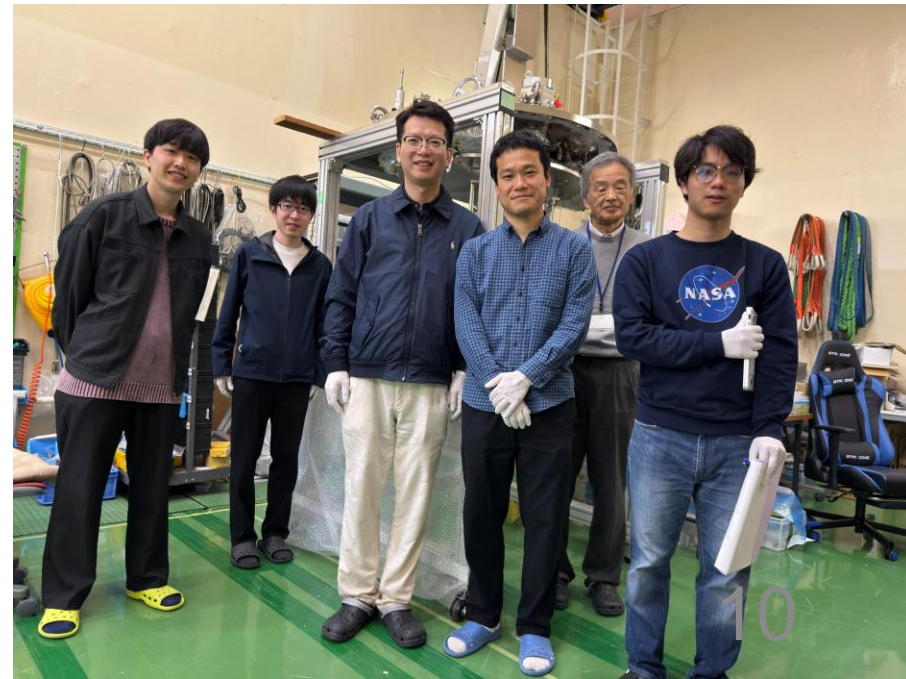
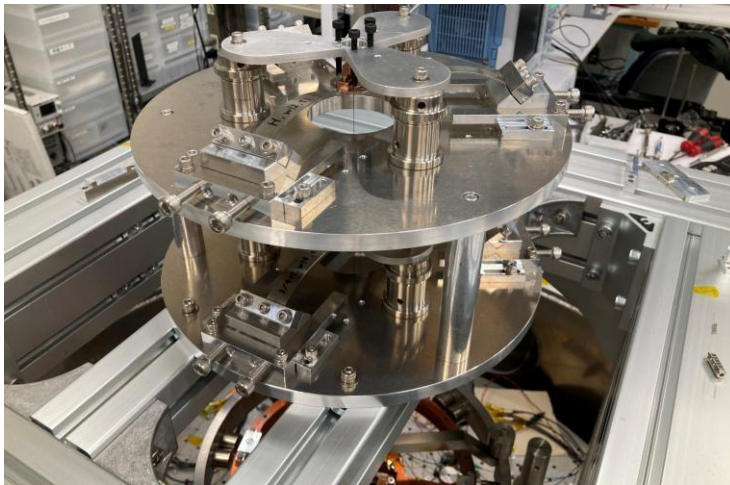
Vibration Isolation Requirements

- Ground-state cooling of mg-scale oscillators
 - 2×10^{-17} m/ $\sqrt{\text{Hz}}$ at 100 Hz
- Magnetic field sensing beyond standard quantum limit with a superconducting levitation sensor
 - $\sim 1 \times 10^{-9}$ m/ $\sqrt{\text{Hz}}$ at 0.1-10 Hz
 - **1/100** from typical seismic noise
 - Active vibration isolation technology can be used



Kick-off Meetings and Lab Visits

- Tao Wang visited Tokyo in **April 20-24**
 - Kick-off meeting
 - Visited KAGRA cryogenic suspension test facility at KEK
- Japan team will visit Singapore in **June 1-4**



Exchange Plans

- **Annual workshops**

- Provide presentation opportunities for ECRs
- In both Tokyo and Singapore for FY2026
- In Singapore for FY2027
- In Tokyo for FY2028

- **Long-term exchange visits**

- Hands-on experience for ECRs
- 1-2 months in FY2027
- 2 from Tokyo to Singapore
- 2 from Singapore to Tokyo

Summary

- This funding opportunity has initiated a **completely new collaboration** between Singapore and Japan
 - Already become active through a kickoff workshop
 - Also providing strong inspiration and experience for ECRs
 - Hoping to establish a long-term partnership connecting gravitational-wave instrumentation and quantum sensing
- **Main research topics**
 - Realization of **optical levitation** of mirrors
 - **Feedback cooling** of a suspended bar
 - Development of **vibration isolation systems**
- **Key collaborative goal**
 - Joint development of a vibration isolation system capable of reducing vibration noise by **a factor of 100**