Torsion-Bar Antenna for Low-Frequency Gravitational-Wave Observation

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Abstract

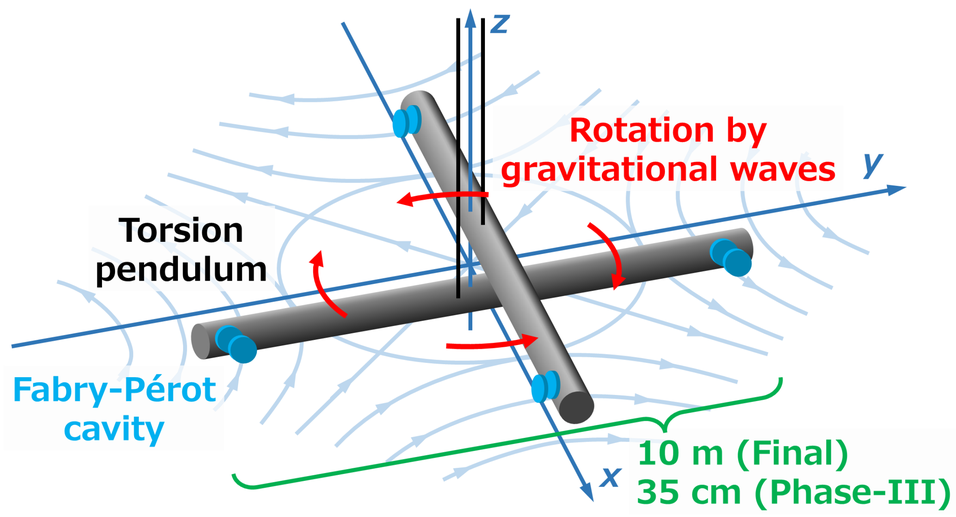
Torsion-Bar Antenna (TOBA) is a ground-based detector using torsion pendulums being developed to observe gravitational waves (GWs) in frequencies between 1 mHz and 10 Hz. The low resonant frequency of the torsion pendulum enables observation in this frequency band on the ground. The final target of TOBA is to achieve the sensitivity of 10^{-19} /√Hz at 0.1 Hz with 10 m-scale bars.

We are developing a prototype detector, Phase-III TOBA, to investigate technical noises. In this work, we constructed a combined system of the optics for torsional rotation measurement and the suspension including the torsion pendulums. We show the results and future plans.

1. TOBA: Torsion-Bar Antenna

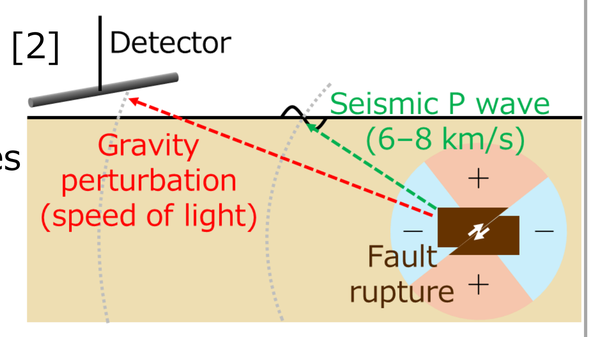
Principle [1]

- Ground-based GW detector
- Composed of two torsion pendulums
  - The resonant frequency of torsional motion is low (~1 mHz)
    → Good sensitivity in 0.1 Hz-10 Hz even on the ground
- Detect the differential rotation of bars with Fabry-Pérot cavities



Scientific targets

- GWs emitted from intermediate-mass black hole binary mergers
  - Within ~1 Mpc (Phase-III TOBA)
  - Within ~10 Gpc (Final TOBA) [1]
- Newtonian noise
  - First direct detection (Phase-III) [2]
- Earthquake alert
  - Within 10 sec for M7 earthquakes far from 100 km (Phase-III) [3]

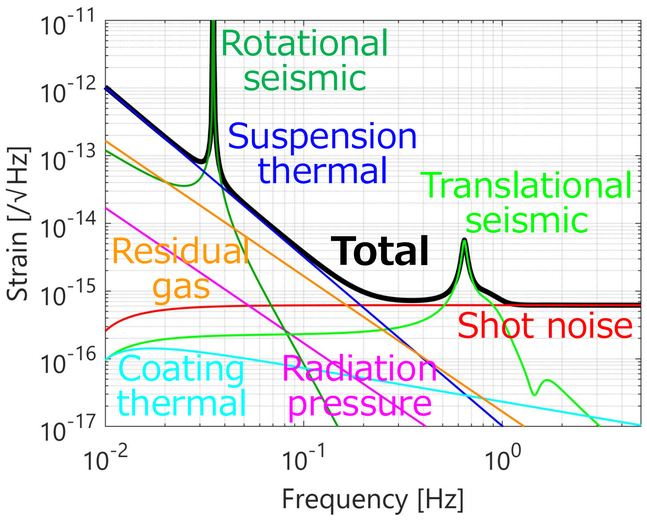


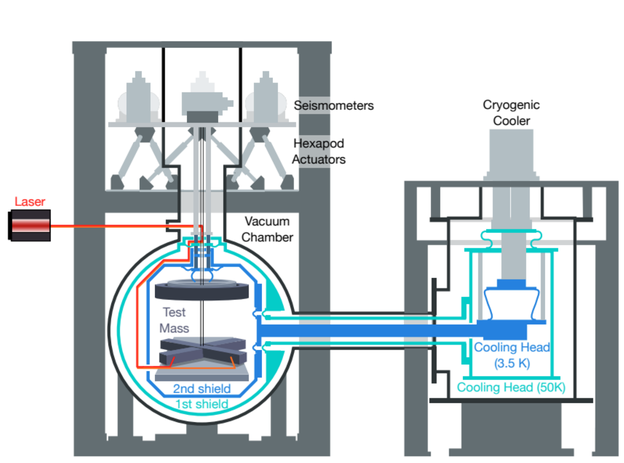
2. Phase-III TOBA

Development roadmap of TOBA [4, 5]

Phase-I (2009)	Phase-II (2015)	Phase-III (now)	Final (future)
Principle test		Technical demonstration	Observation
10^{-8} /√Hz (Established) 20 cm bars Room temp.		10^{-15} /√Hz (Target) 30 cm bars Cryo. temp. (4 K)	10^{-19} /√Hz (Target) 10 m bars Cryo. temp. (4 K)

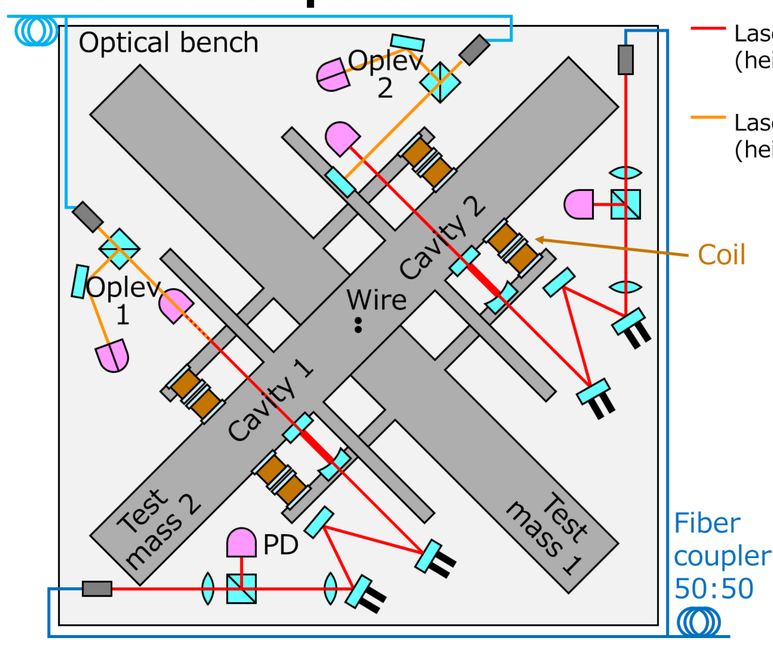
Design sensitivity of Phase-III TOBA [5]





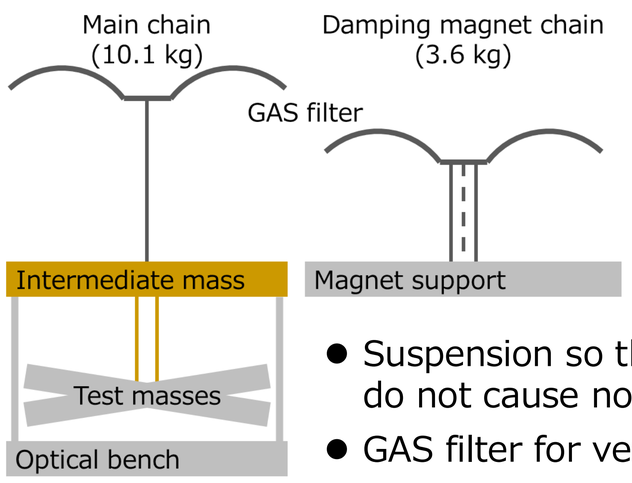
3. Development of optics and suspension

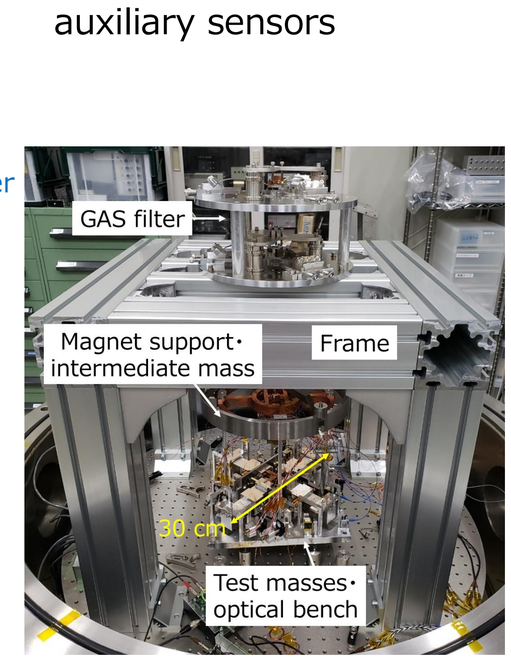
Readout optics



- Differential Fabry-Pérot cavities between two test masses
- Optical levers as auxiliary sensors

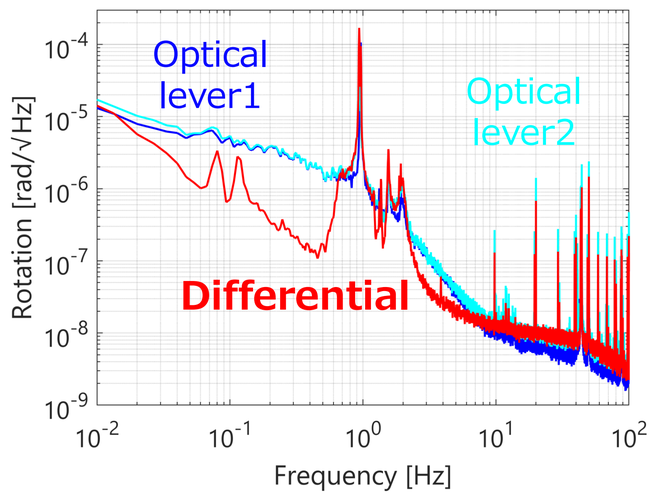
Suspension





- Suspension so that vibrations of the optical bench do not cause noise
- GAS filter for vertical vibration isolation

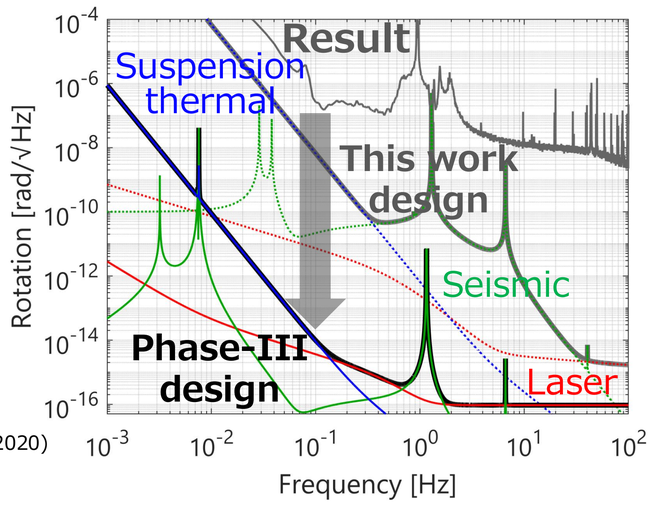
Results [6]



- Common mode rejection between two test masses
- Above 4 Hz, sensor noise is dominant
- In 0.1 Hz-4 Hz, significant correlation with vertical seismic noise

4. Summary & Future plans

- We are developing TOBA to detect GW in 0.1 Hz-10 Hz
- Current prototype: Phase-III TOBA
- We constructed a combined system of optics and suspension
- Rotation measurement with optical levers
- We will lock the cavities
- We will replace test masses made of silicon and operate at cryo. temp.



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