Torsion-Bar Antenna for Early Earthquake Alert

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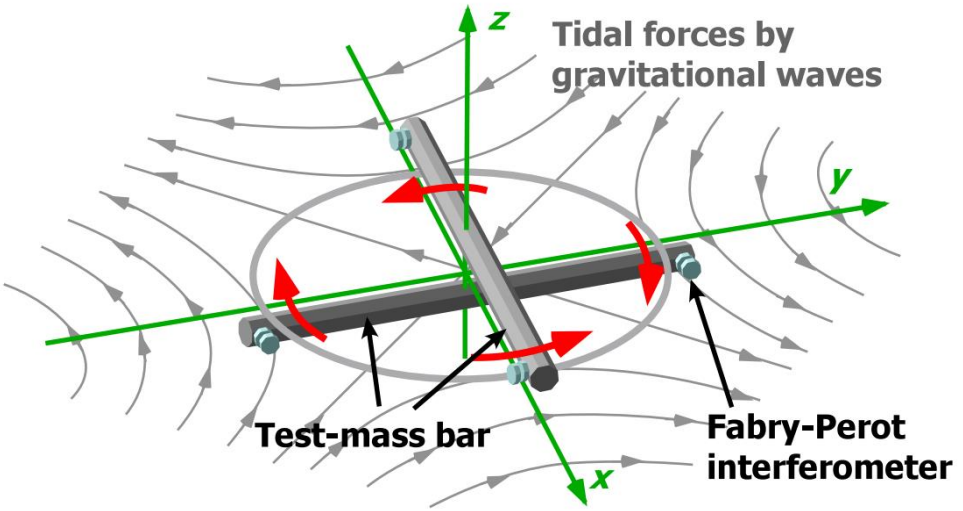
TOBA: TOrsion-Bar Antenna

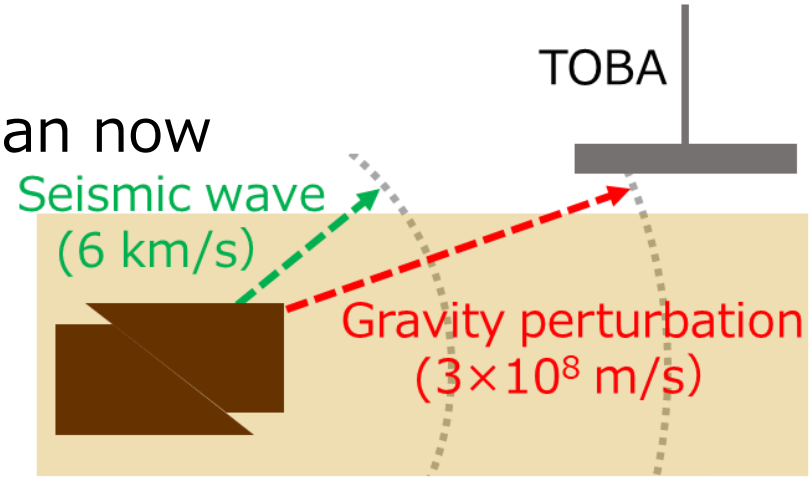
- Gravity gradient sensor
- Consists of two bars suspended horizontally
- Aim to detect the torsional rotation by gravity gradient
- Target sensitivity: 10^{-15} /√Hz between 0.1 – 10 Hz



M. Ando+,
PRL 105, 161101 (2010)

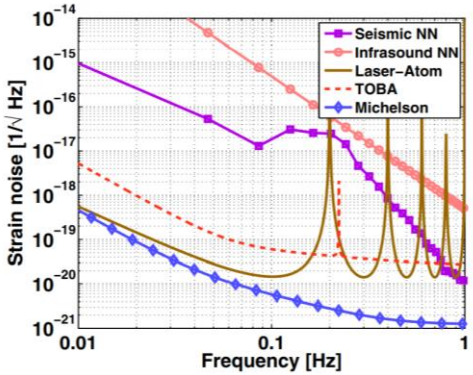
Science of TOBA

- Earthquake alert
  - More than 10 sec earlier than now



- Gravitational waves from intermediate-mass black holes binary merger
  - Within ~1 Mpc

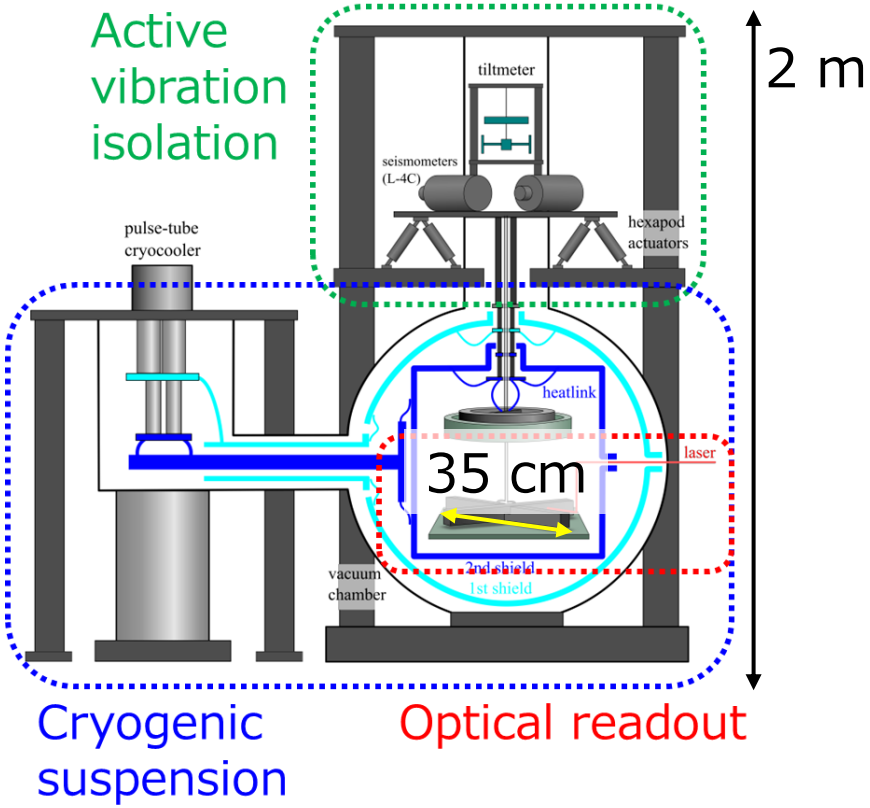
- Newtonian noise
  - First direct detection



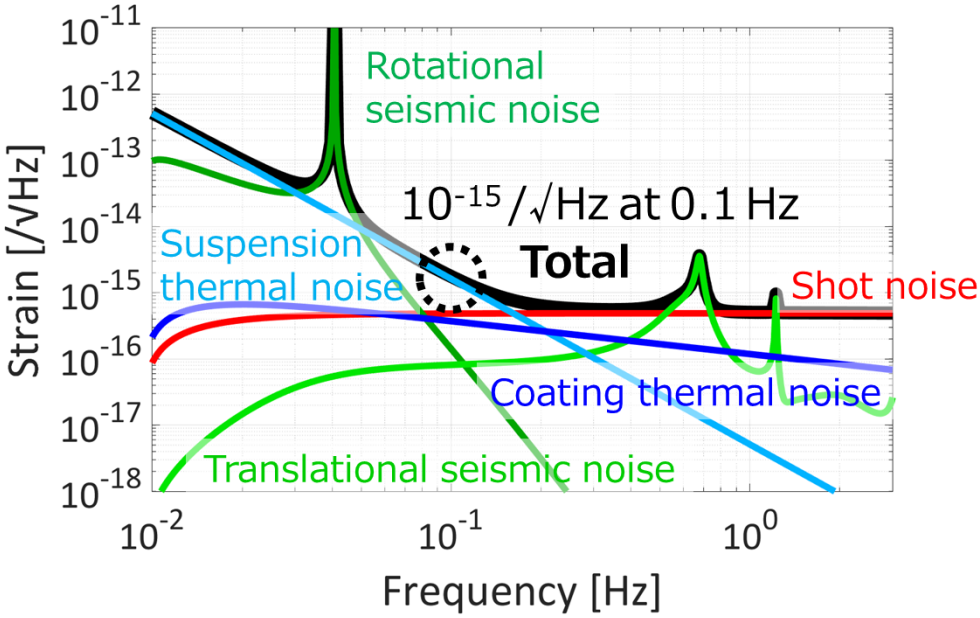
J. Harms+ (2013)

Development of TOBA

Configuration



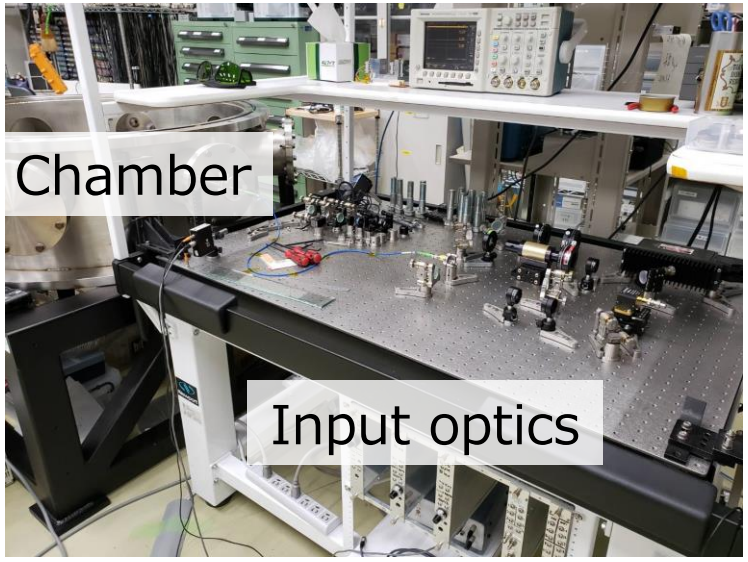
Target sensitivity

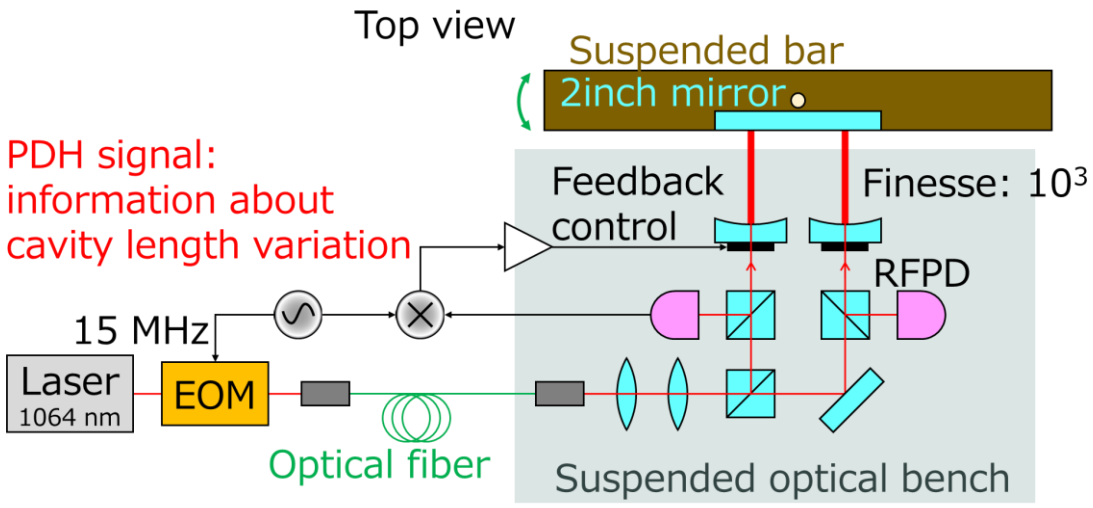


- Successfully cooled the bars to 6 K T. Shimoda, Ph.D. thesis (2019)
- Next step: develop torsion pendulums and readout optics to achieve the target sensitivity

Experimental status

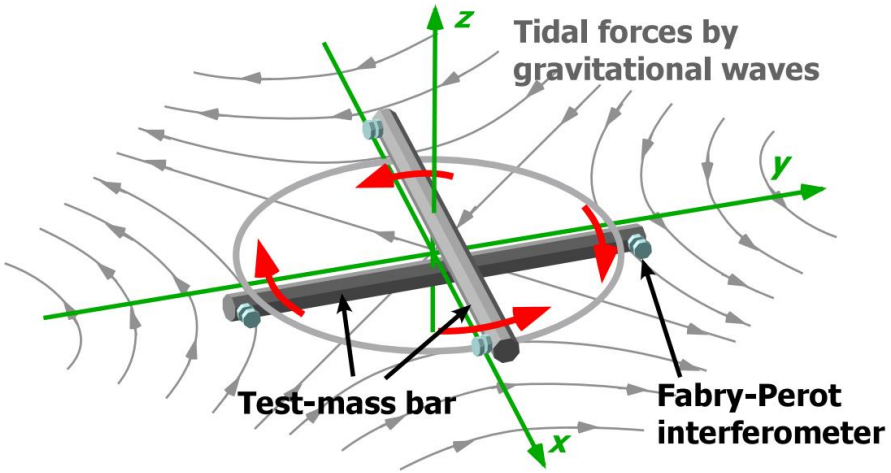
- Start to develop the torsion pendulums and readout optics in vacuum at room temp.
- Measure the rotation from the subtraction of PDH signals of two Fabry-Perot cavities
- Finished drawing the design, purchasing cavity mirrors, and building input optics
- Plan to assemble parts as soon as they arrive





Summary

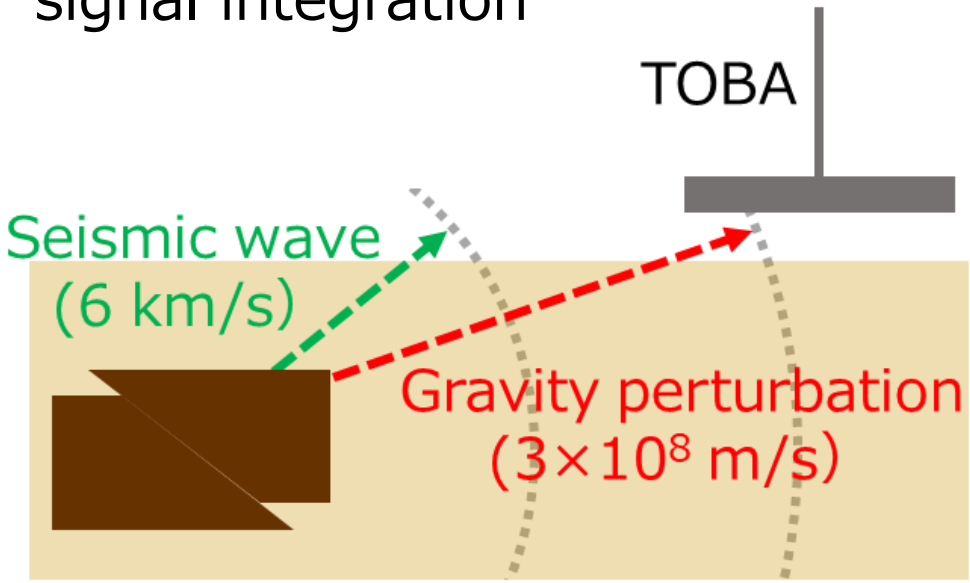
- TOBA is a gravity gradient sensor using torsion pendulums
- Science of TOBA
  - Earthquake early warning
  - Gravitational waves from intermediate-mass black hole mergers
- Development of torsion pendulums and readout optics is ongoing



Extra slides

Earthquake alert

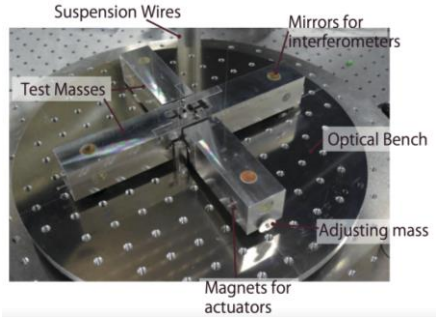
- Current systems: read Primary-wave (6 km/s) and alert before Secondary-wave (4 km/s) arrive
- TOBA: read gravity perturbation (speed of light) due to density fluctuation by fault rupture
- TOBA can alert within 10 sec for M7 earthquake at a distance of 100 km
  - Takes 10 seconds for signal integration



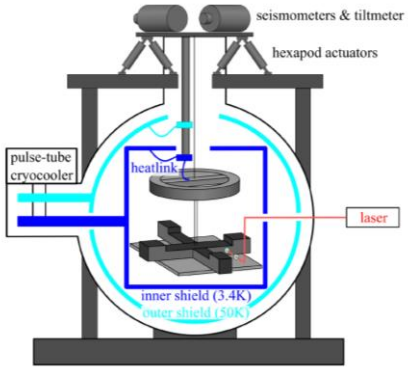
Development roadmap of TOBA

Now

Phase-I	Phase-II	Phase-III	Final
Principle test		Technical demonstration	GW observation
10^{-8} /√Hz (Established)		10^{-15} /√Hz (Target)	10^{-19} /√Hz (Target)
~20 cm bars		35 cm bars	10 m bars
Room temp.		Cryo. Temp. (4 K)	Cryo. Temp. (4 K)



K. Ishidoshiro+, PRL 106, 161101 (2011)
A. Shoda+, PRD 95, 082004 (2017)



T. Shimoda+, Int. J. Mod. Phys. D 29, 1940003 (2020)