Angular Sensor with a Coupled Cavity for Gravity Gradient Sensing

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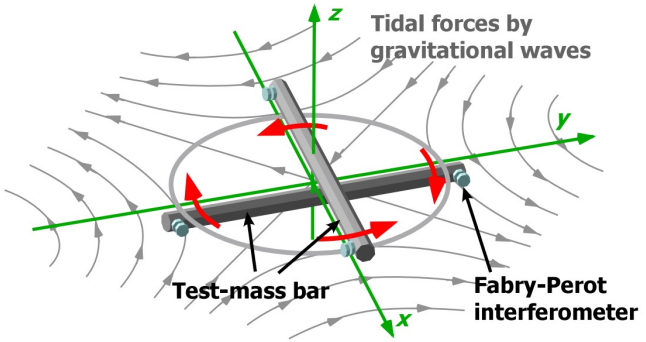
Gravity gradient sensor TOBA

- TOBA: TOrsion-Bar Antenna
- Two bars rotate
  by gravity gradient
- Using torsion pendulums
  → Sensitive to low frequency (~0.1 Hz)



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

Development plan

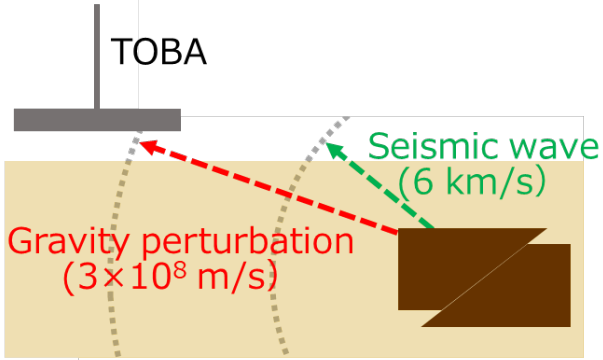
Phase-I	Phase-II	Now Phase-III	Final
Principle test		Noise reduction	Observation
$10^{-8}/\sqrt{\text{Hz}}$ (Established)		$10^{-15}/\sqrt{\text{Hz}}$ (Design)	$10^{-19}/\sqrt{\text{Hz}}$ (Design)
20 cm bar		35 cm bars	10 m bars
Room temp.		Cryo. temp. (4 K)	Cryo. temp. (4 K)

Science of TOBA

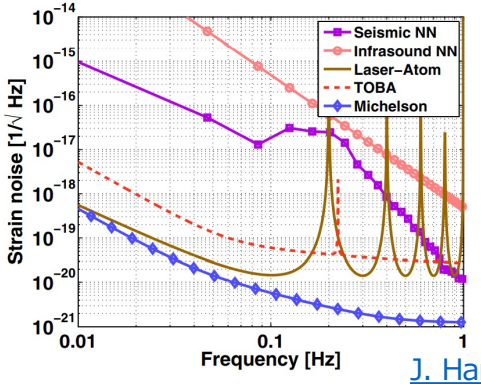
Geophysics

- Earthquake alert

  More than 10 sec earlier than now



- Newtonian noise

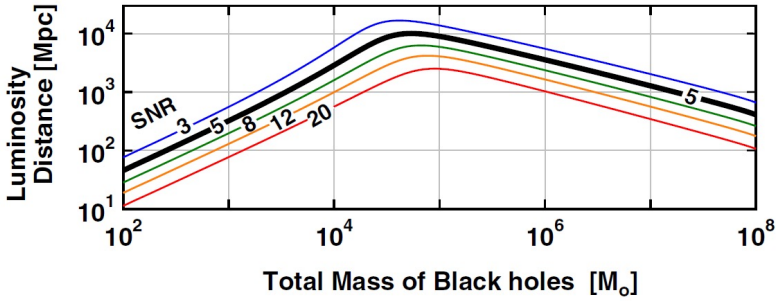


J. Harms+ (2013)

Astrophysics

- Intermediate mass black holes binary merger

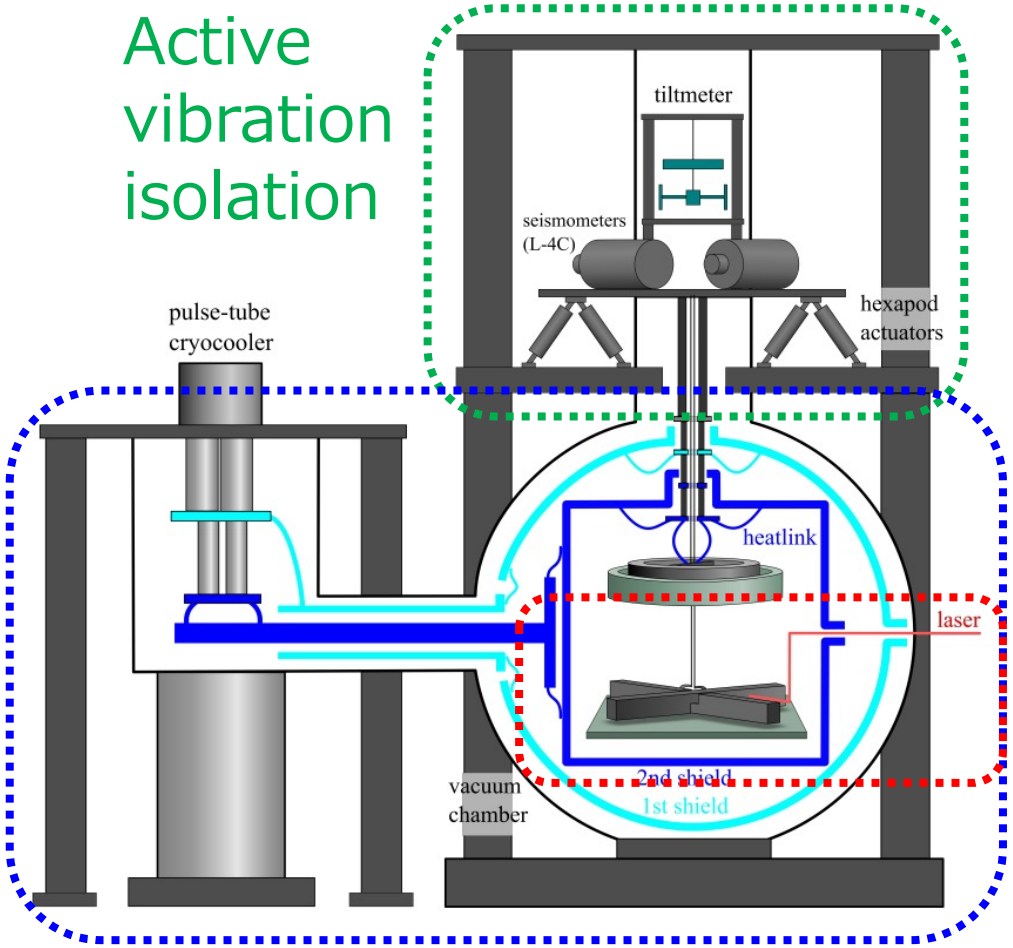
  Within ~10 Gpc



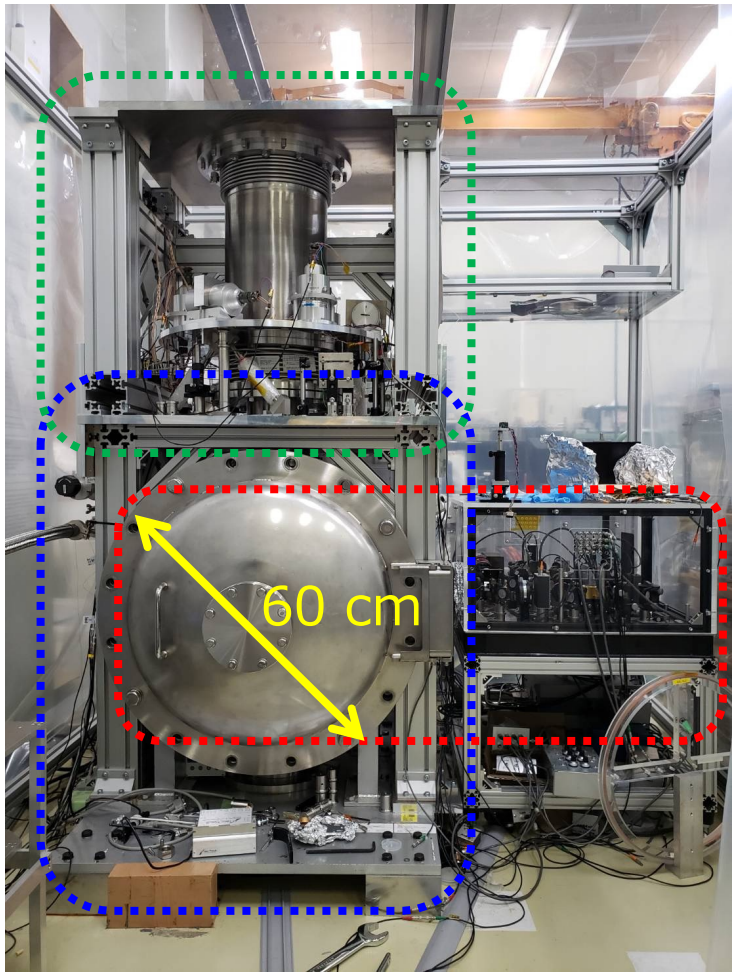
- Gravitational wave stochastic background

Configuration of TOBA

Active vibration isolation



Phase-III

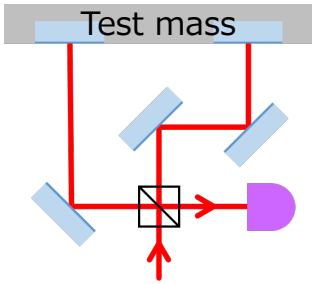
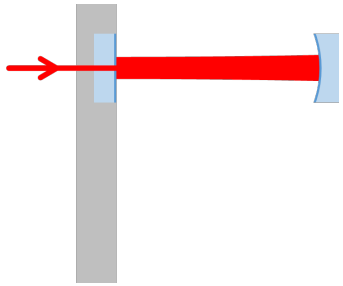
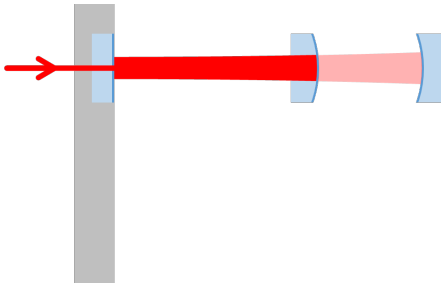


Cryogenic suspension

Optical readout (This talk)

Angular sensors for TOBA

- Need highly-sensitive angular sensor to readout test mass rotation (Requirement for Phase-III: 5×10^{-16} rad/$\sqrt{\text{Hz}}$)

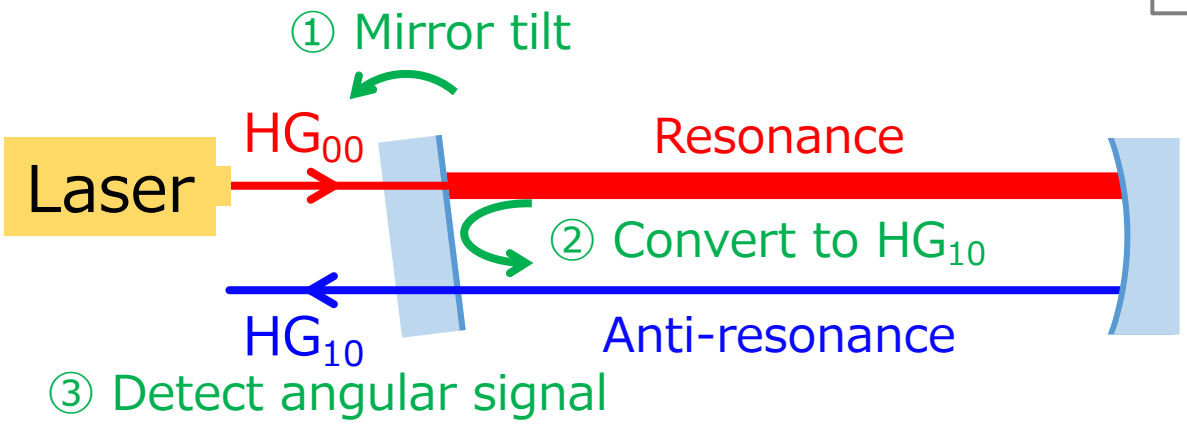
	Michelson interferometer	Wavefront sensor	Coupled wavefront sensor
			
Sensitivity			
Freq. noise			
Trans-coupling			
Thermal noise			
Linear range			

Coupled wavefront sensor

Wavefront sensor

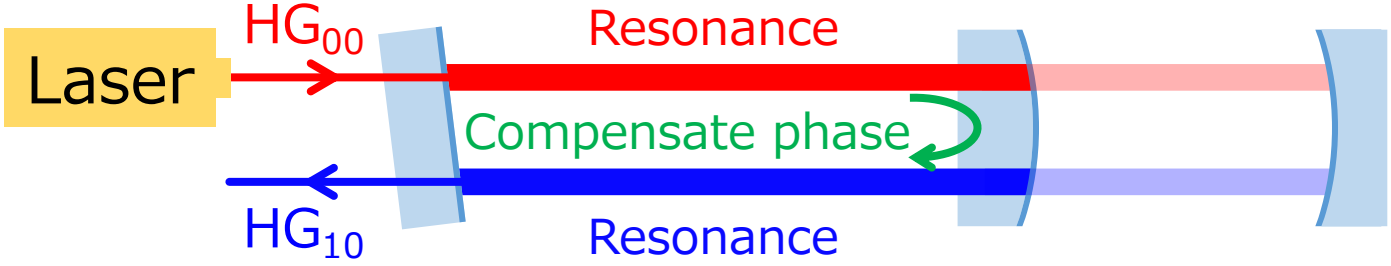
- Angular sensor with optical cavity
- Detect HG_{10} mode as angular signal

Laser spatial modes



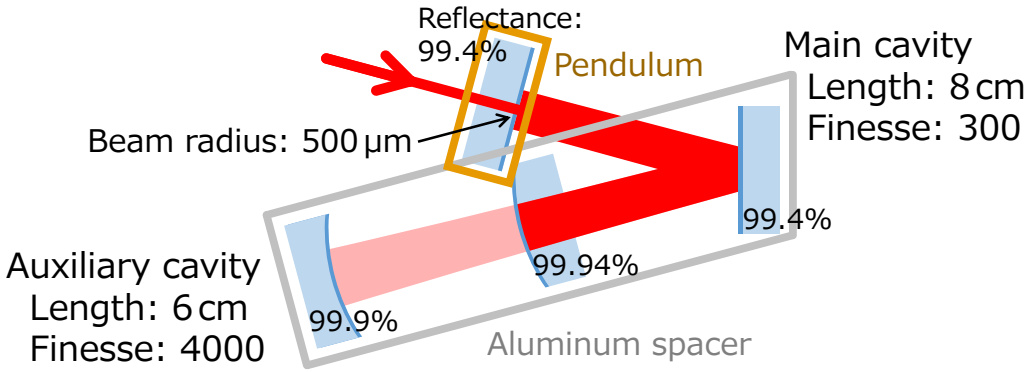
Coupled wavefront sensor

- Wavefront sensor with coupled cavity
- HG_{10} mode can be amplified in main cavity

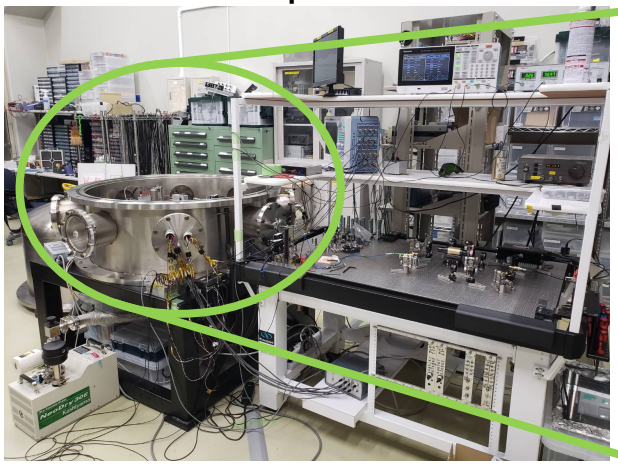


Experimental status & plans

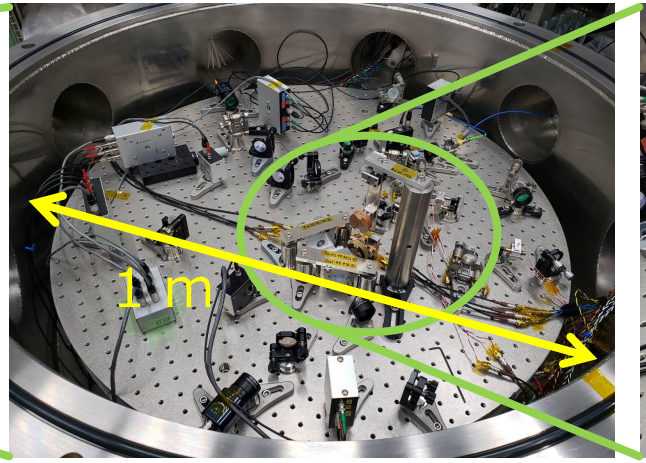
- Finished the design and construction of optical system



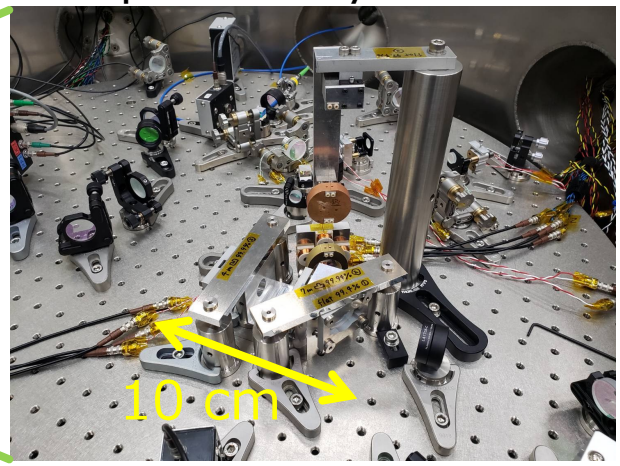
Whole setup



Vacuum chamber

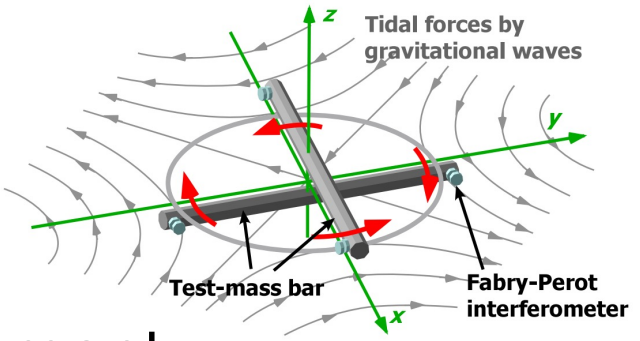


Coupled cavity



- Plan to control cavities and confirm angular signal amplification

Summary



- TOBA is gravity gradient sensor using torsion pendulums
- Phase-III TOBA is under development

- Coupled wavefront sensor is proposed as angular sensor for TOBA
- Experimental demonstration is ongoing