Direct measurement of coating thermal noise toward multi-wavelength gravitational-wave observation

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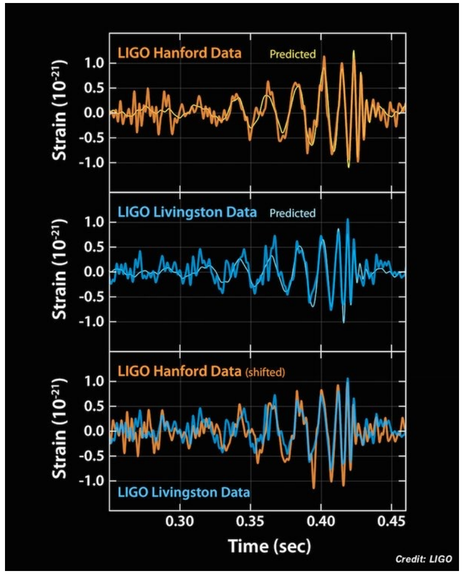
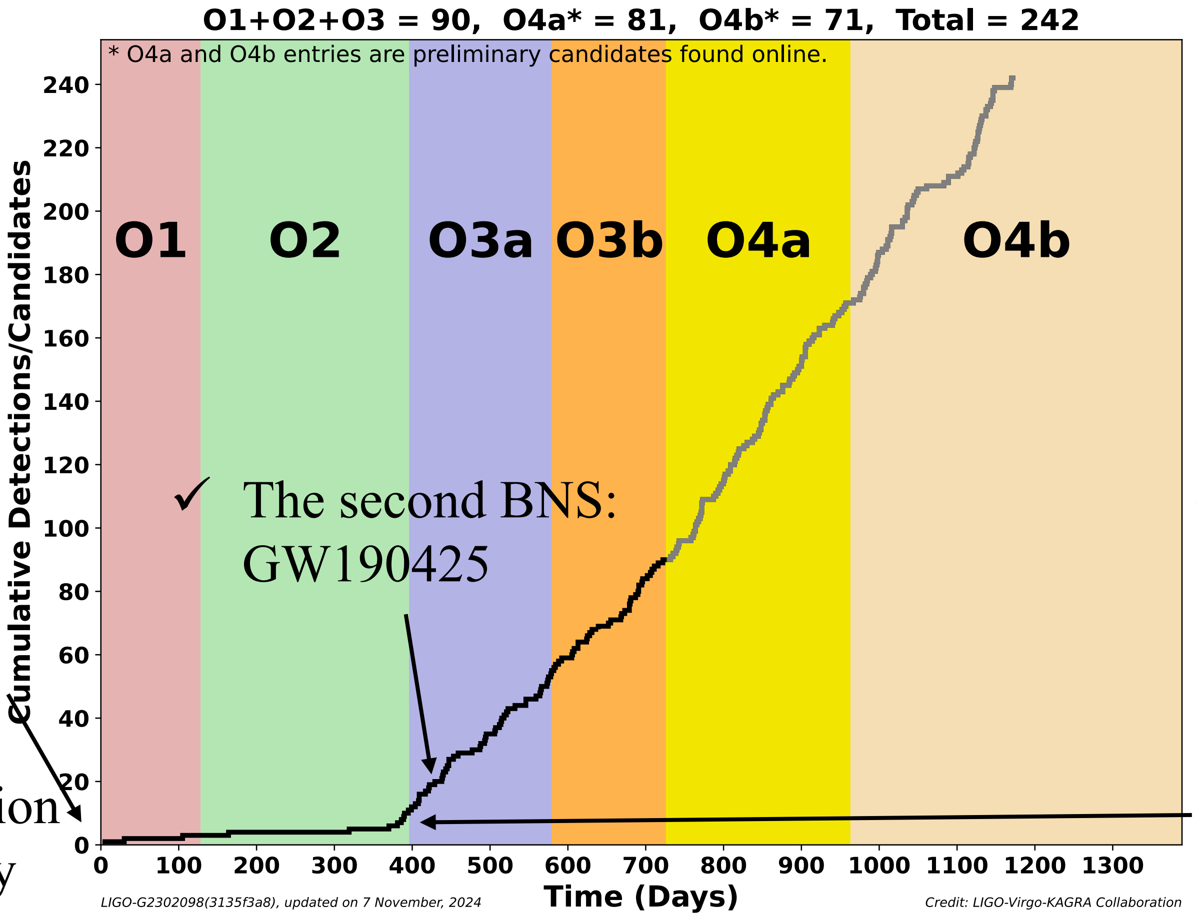
GW observation and multimessenger

- ➢Growing population but only two binary neutron star merger events

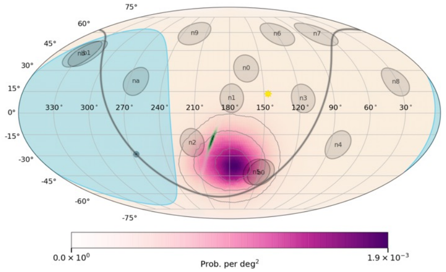
PRL 116, 061102 (2016)



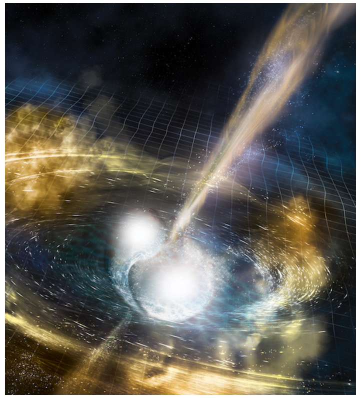
✓ The First observation of GW from binary black hole merger



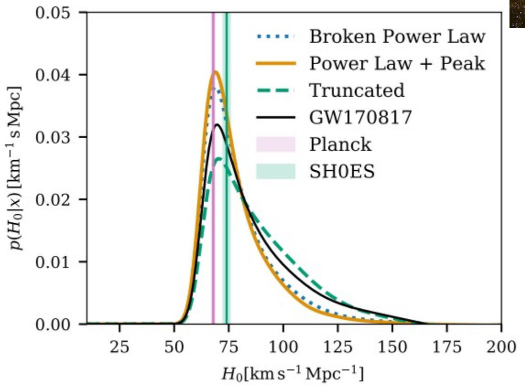
✓ The second BNS: GW190425



PRL 119, 161101 (2017)



Credit: LIGO



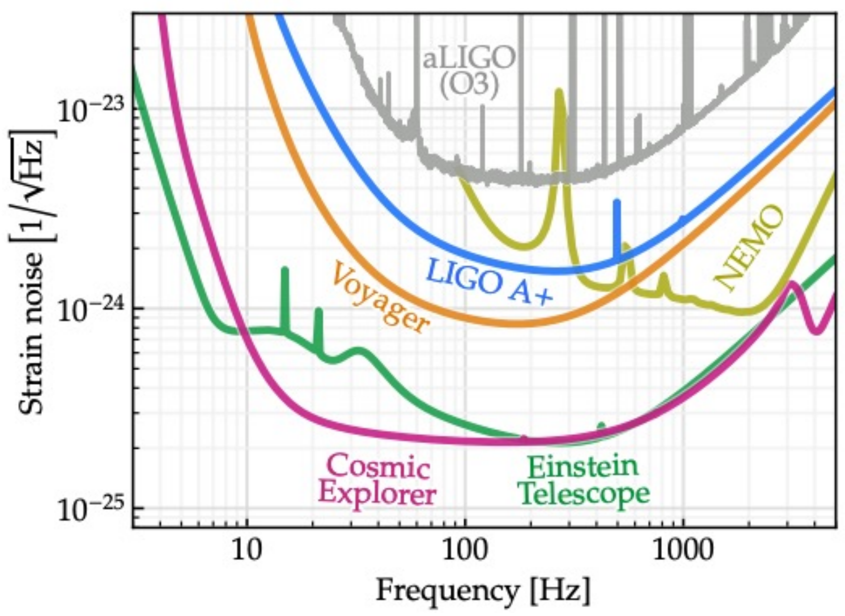
ApJ 909, 218 (2021)

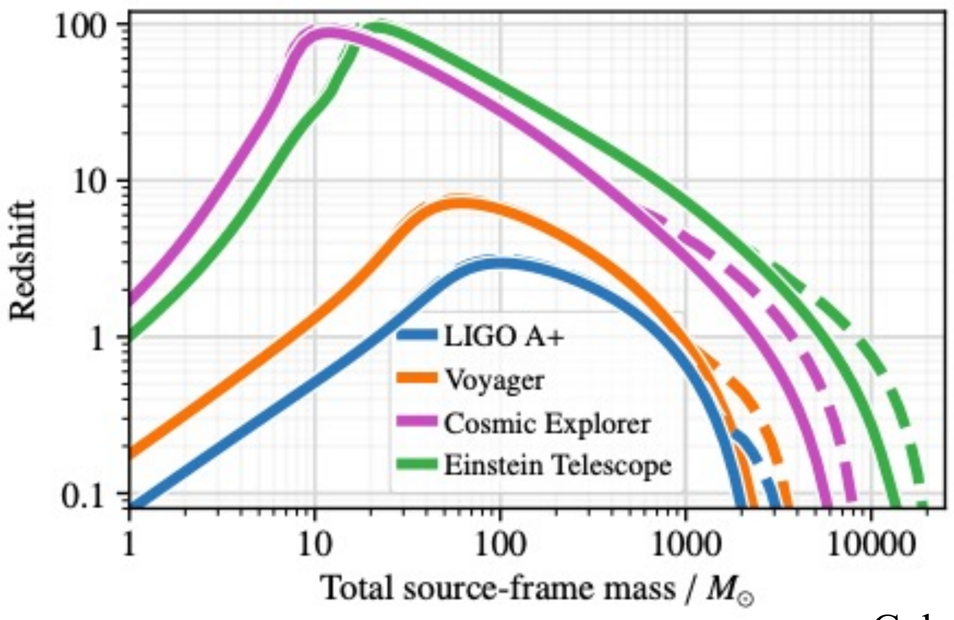
✓ The First BNS merger

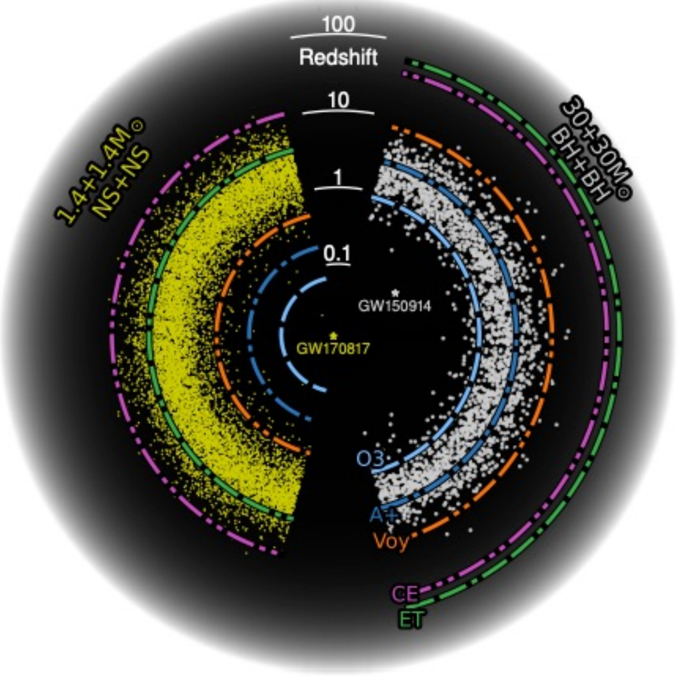
✓ Hubble constant measurement, etc

Next-generation GW-detectors

- ➢GW detector network will enter the multi-wavelength era
- ➢In 2030s, detector sensitivities will be improved by an order of magnitude
  - Cosmic Explorer in US (40 km) and Einstein Telescope (10 km) in Europe





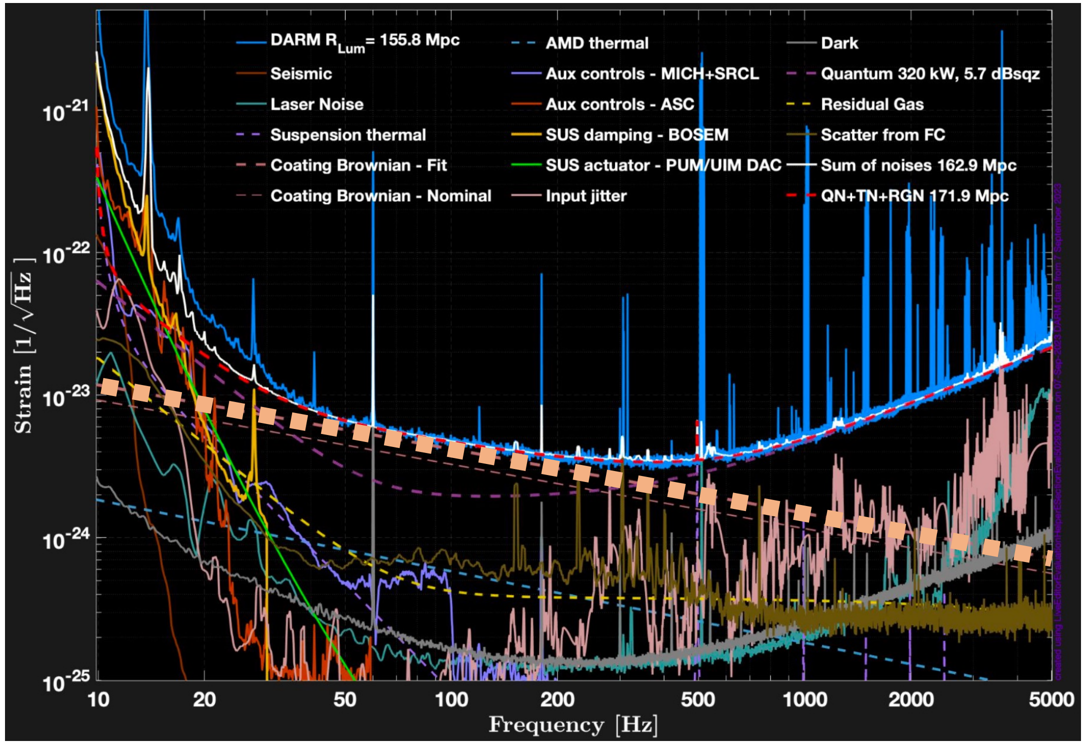


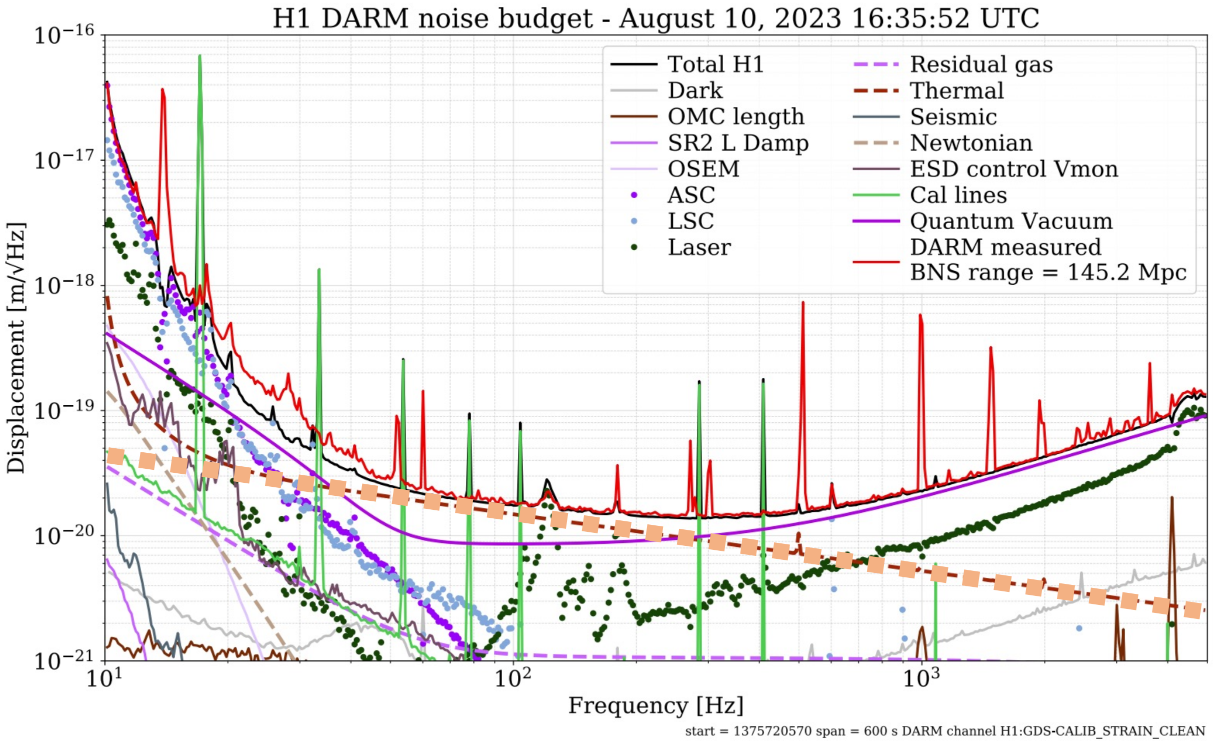
Galaxies 10, 90 (2022)

Motivation

➢Mysterious noise of aLIGO in both sites

O4a sensitivity

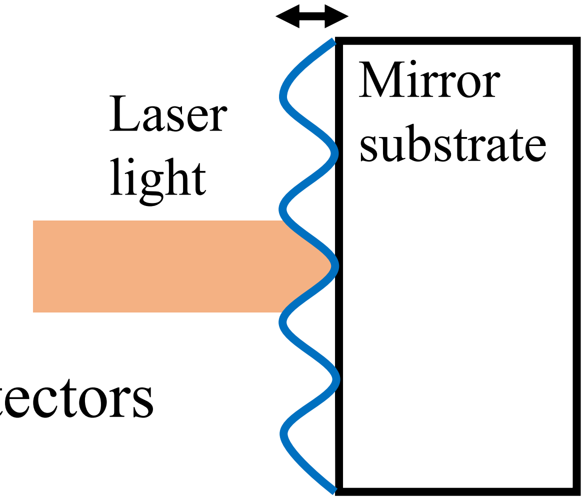




➢It is highly likely due to coating thermal noise of mirrors, worse than expected

Coating thermal noise

- Brownian motion of the coating layers
  - Calculated by fluctuation dissipation theorem (FDT)
  - The coating fluctuation cannot be distinguished from the mirror motion caused by GW signals
  - Fundamental sensitivity limit of current and future GW detectors



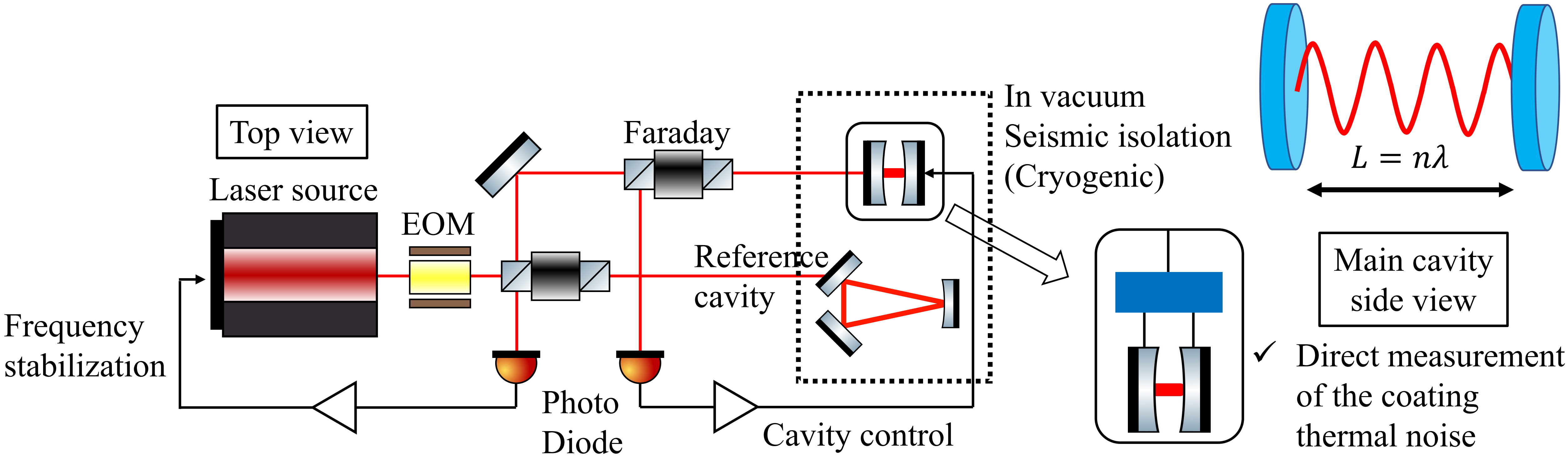
- Coating materials
  - Current: dielectric multilayer film (SiO_2/Ta_2O_5)
  - Potential candidate in future: crystalline coating (AlGaAs)

Thorlab

- Issues
  - Only one setup for direct measurement of the coating thermal noise
  - No works in cryogenic temperature (for KAGRA, CE and ET)

Our experiment

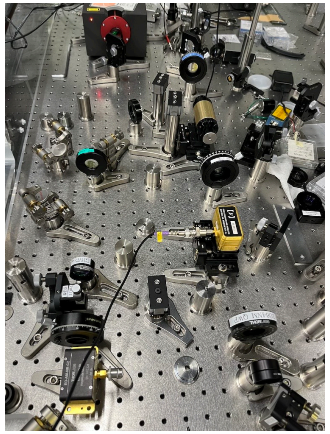
- Goals
  - Measurement of the coating thermal noise for some candidates
  - Giving implications which coating we should use in future detectors

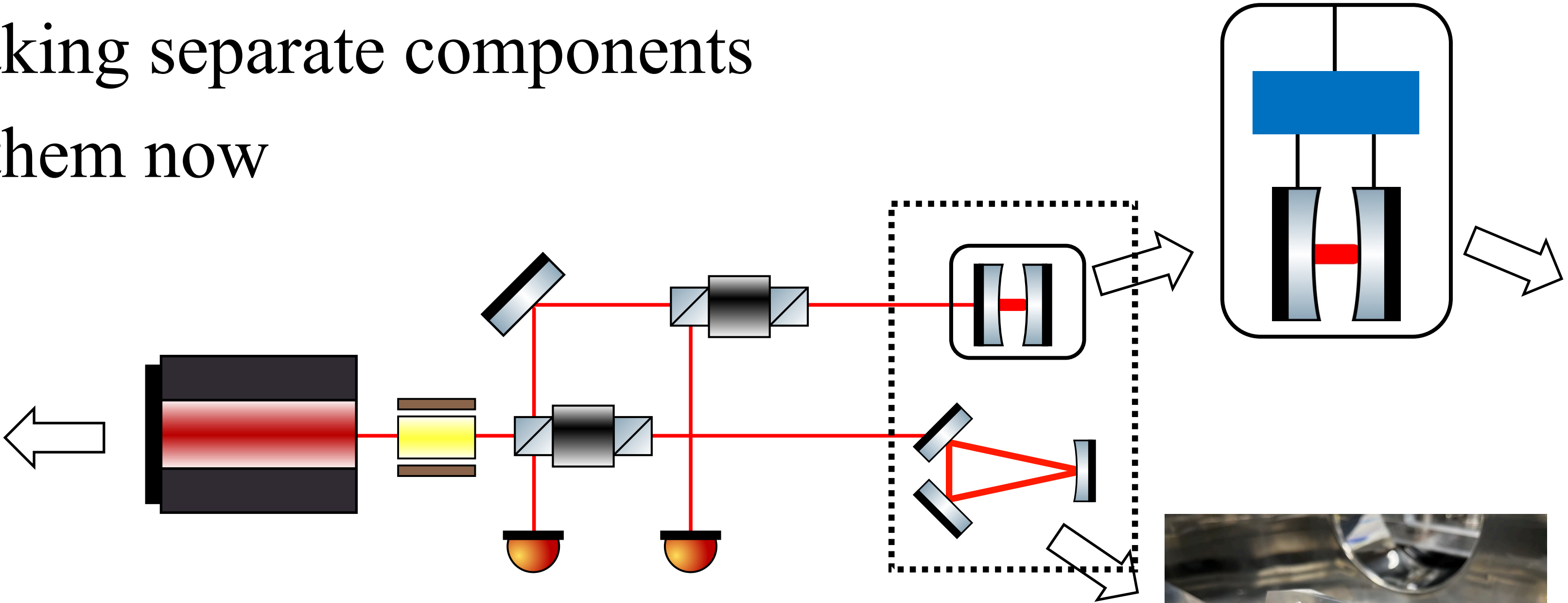


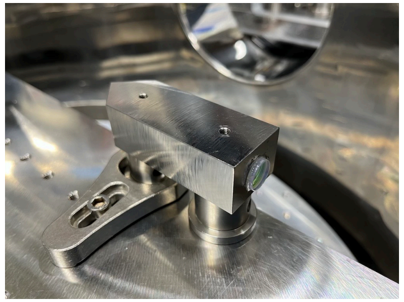
✓ Direct measurement of the coating thermal noise

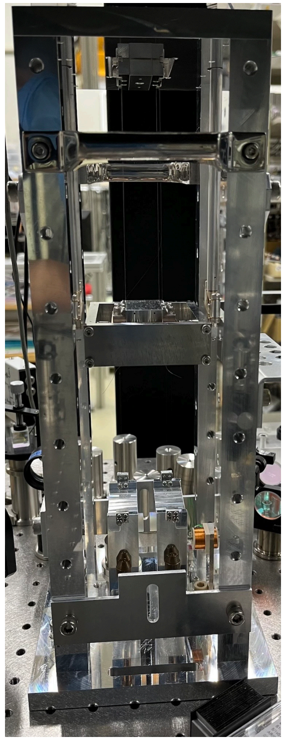
Current status

- ➢Finished making separate components
- ➢Integrating them now









- ➢Future
  - Completing the whole setup construction
  - Measurement of AlGaAs coating thermal noise in room temperature
  - Measurement of SiO_2/Ta_2O_5 and AlGaAs in cryogenic temperature

Summary

- The BBH population is drastically increasing, but we need more BNS and multimessenger events
- Coating thermal noise will be one of fundamental issues for current and future GW detectors
- We aim at direct measurement of the coating thermal noise
- Construction of the setup in room temperature almost completed