LISA on table, an electro-optical simulator for space based gravitational observatories

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Outline

1. Gravitational waves

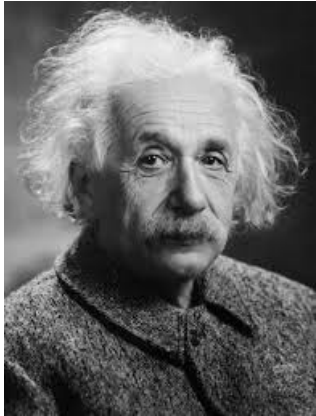2. Gravitational waves detectors

3. LISA

4. LISA on table

Outline

1.Gravitational waves

2.Gravitational waves detectors

3.LISA

4.LISA on table

Gravitational waves

Predicted by Albert Einstein in his General Relativity Theory.

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}$$

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

$$\Box \overline{h}_{\mu\nu} = -\frac{16\pi G}{c^4} T_{\mu\nu}$$

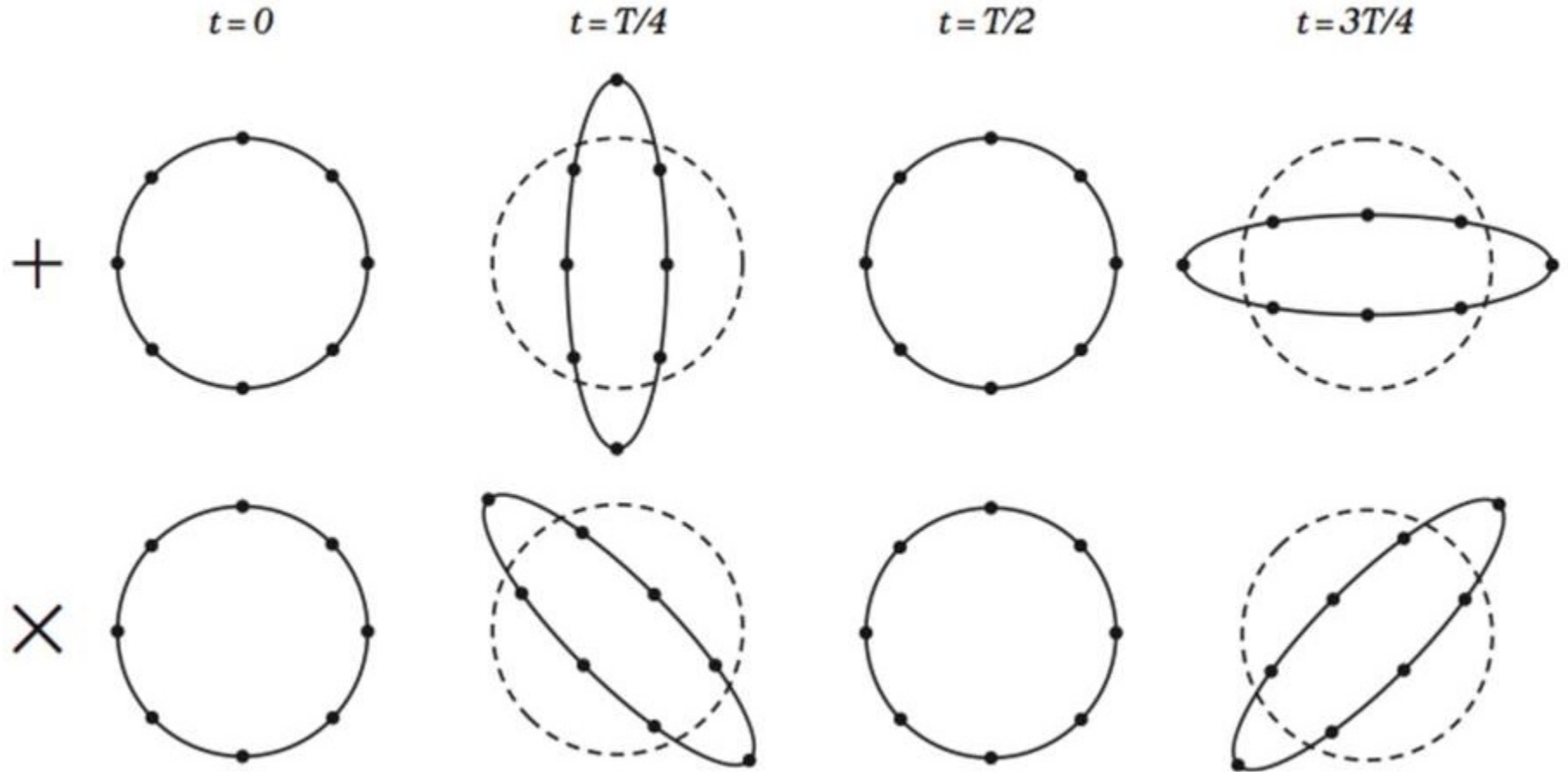Two different polarisations x and +, order of magnitude : 10^(-21)

Gravitational waves are produced by massive aspheric accelerated systems and violent mass changes:

- Coalescing binaries (black holes, neutron stars),
- Magnetars,
- Supernovae...

Gravitational waves

The effect of a gravitational wave on a set of free falling particles:

$t = 0$ $t = T/4$ $t = T/2$ $t = 3T/4$
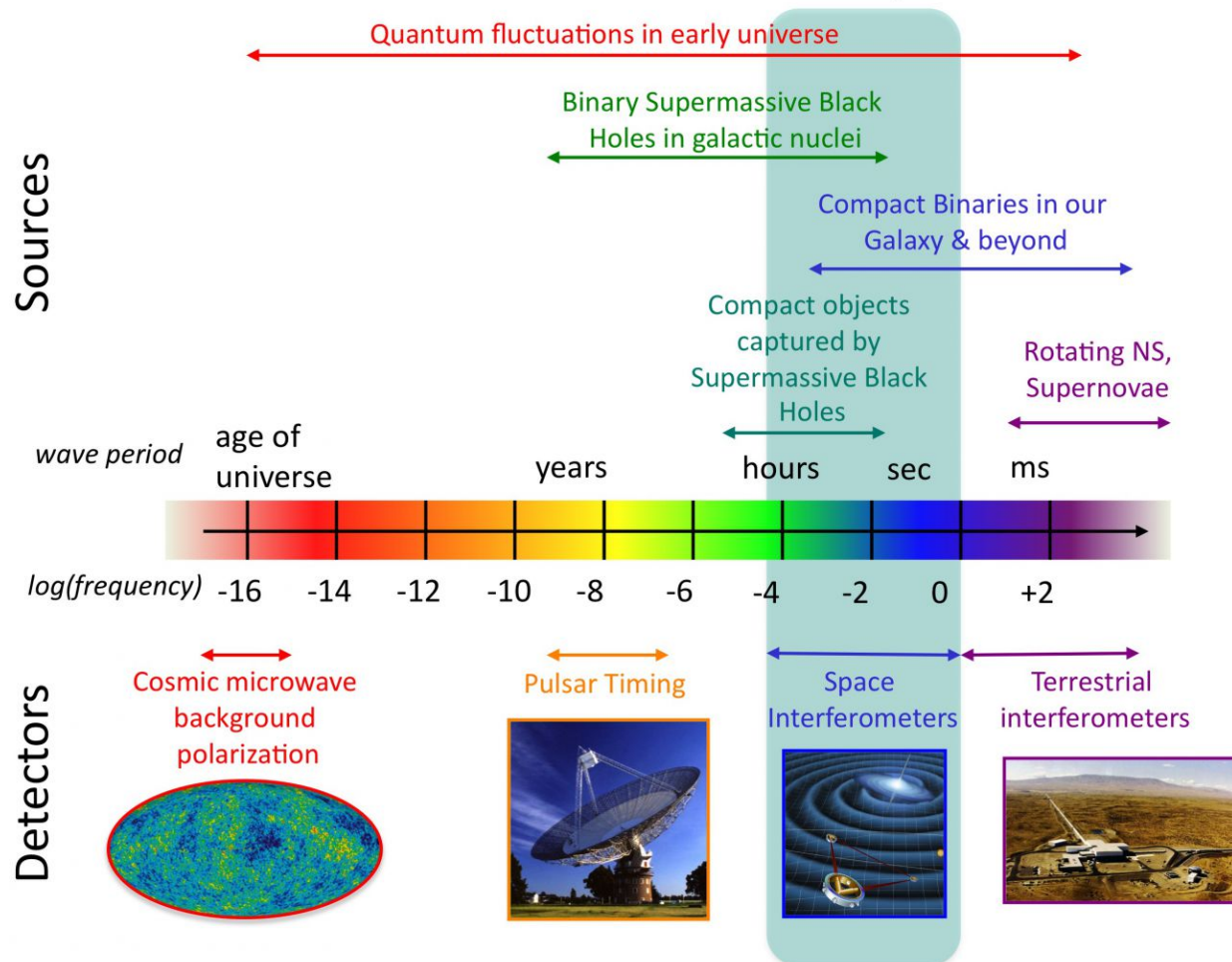
Outline

Gravitational waves detectors

The Gravitational Wave Spectrum

Sources

Quantum fluctuations in early universe

Binary Supermassive Black Holes in galactic nuclei

Compact Binaries in our Galaxy & beyond

Compact objects captured by Supermassive Black Holes

Rotating NS, Supernovae

wave period

age of universe — years — hours — sec — ms

log(frequency) -16 -14 -12 -10 -8 -6 -4 -2 0 +2

Detectors

Cosmic microwave background polarization

Pulsar Timing

Space Interferometers

Terrestrial interferometers

Gravitational waves detectors

Ground detectors:

- LIGO (x2), USA
- Virgo, Italy
- KAGRA, Japan
- Einstein Telescope
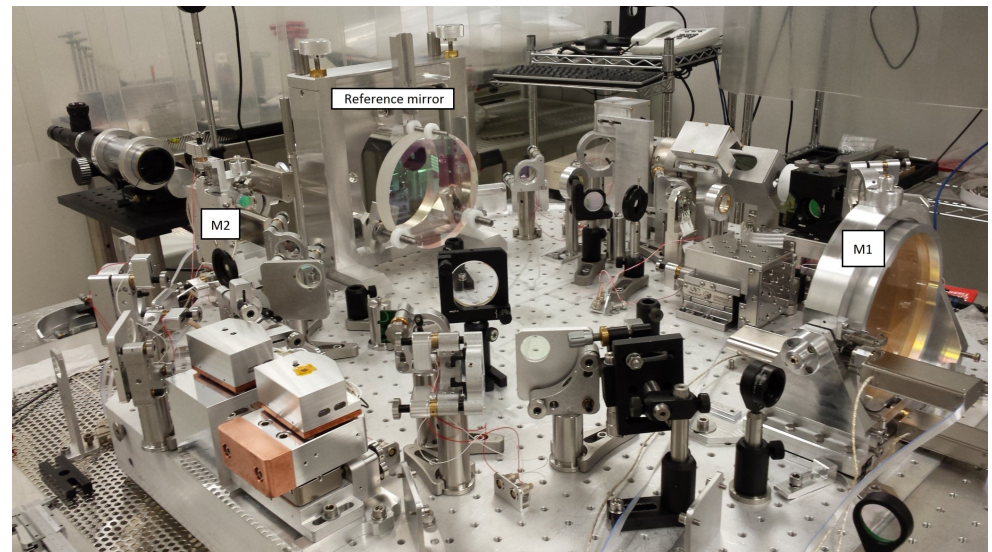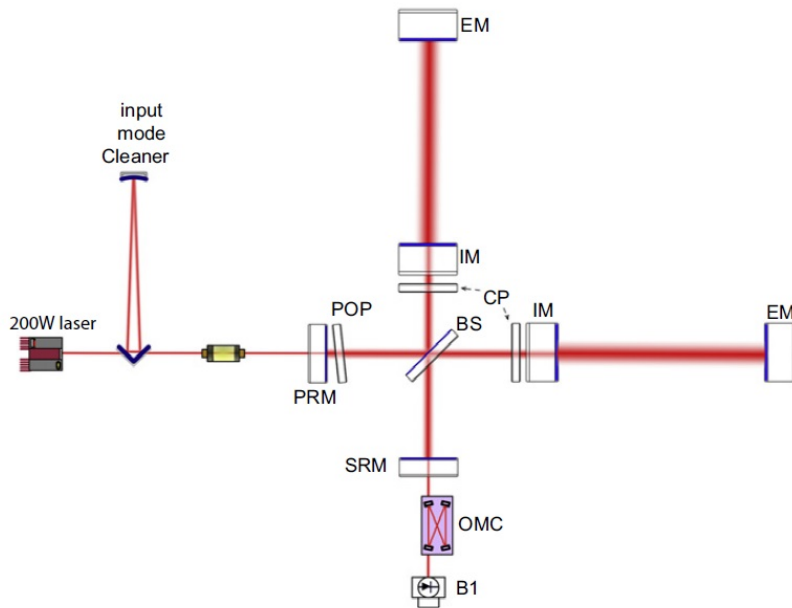
First Detection

- First detection by LIGO on september 14, 2015

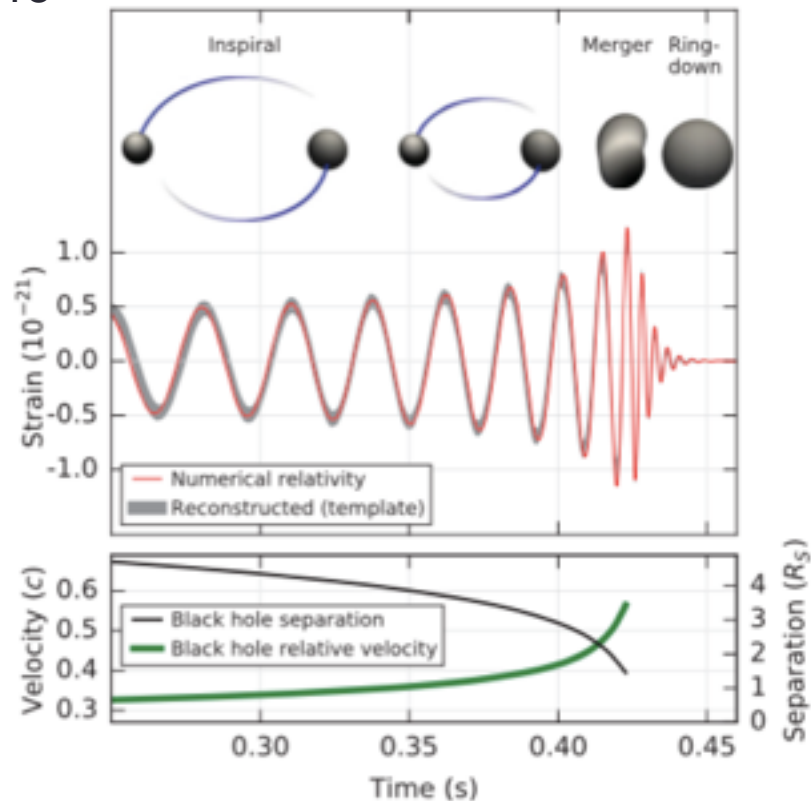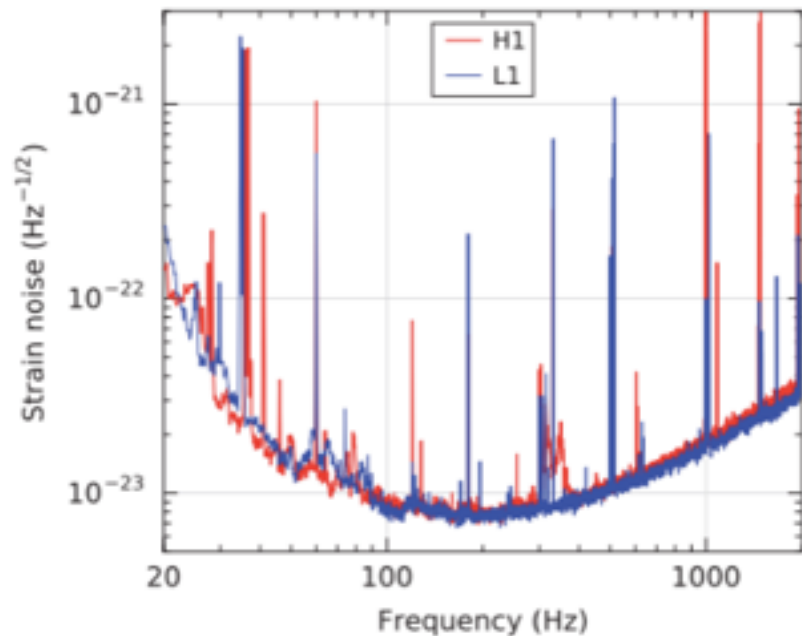- Binary black holes merger

Primary black hole mass $36^{+5}_{-4} M_\odot$

Secondary black hole mass $29^{+4}_{-4} M_\odot$

Final black hole mass $62^{+4}_{-4} M_\odot$

B.P. Abot *et al.,* Observation of Gravitational Waves from a Binary Black Hole Merger, PRL 116, 061102 (2016)

Outline

LISA

Mentioned in the 90s, launch in 2034, ESA-(NASA) mission.

Three satellites separated by few millions km, forming an equilateral triangle.
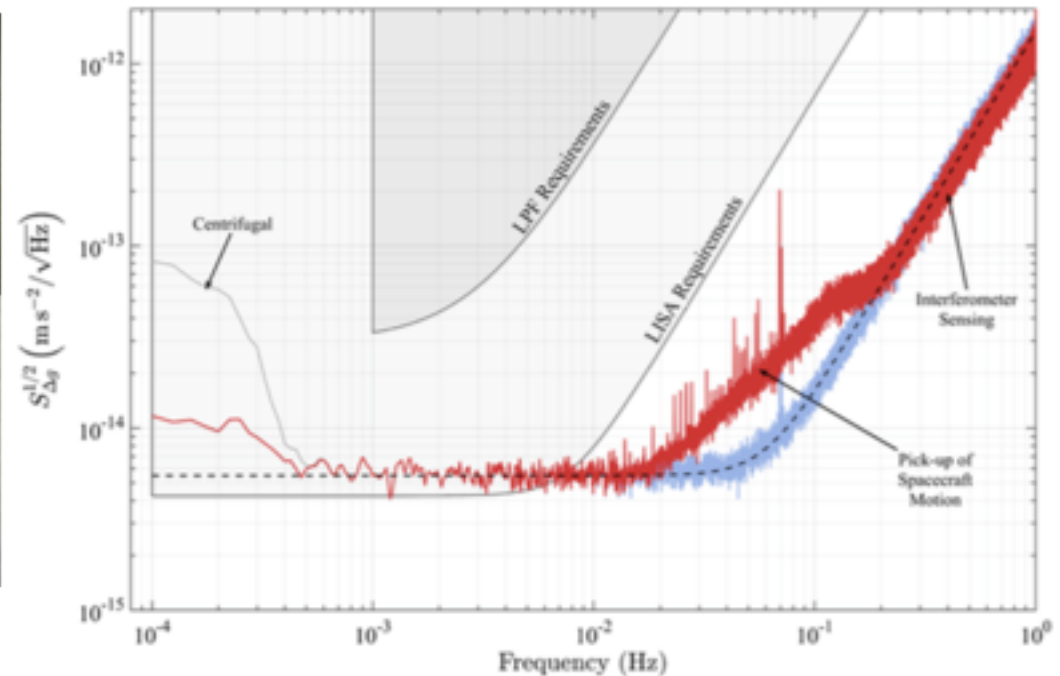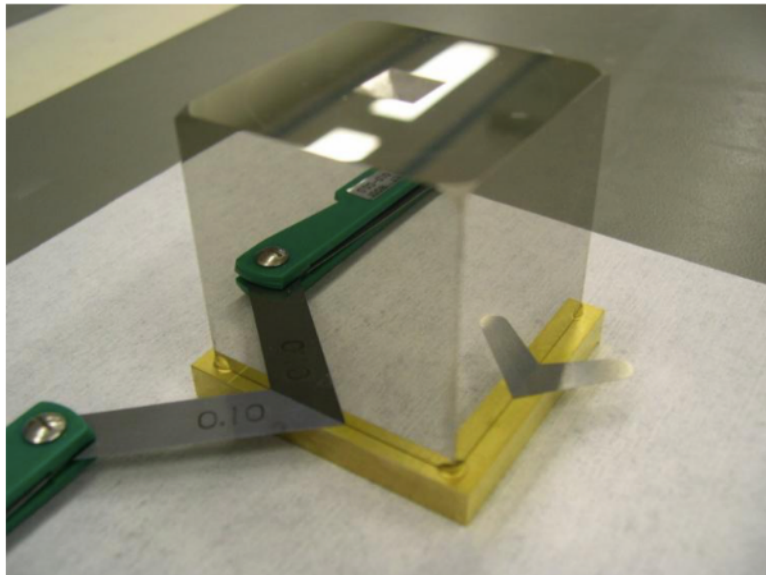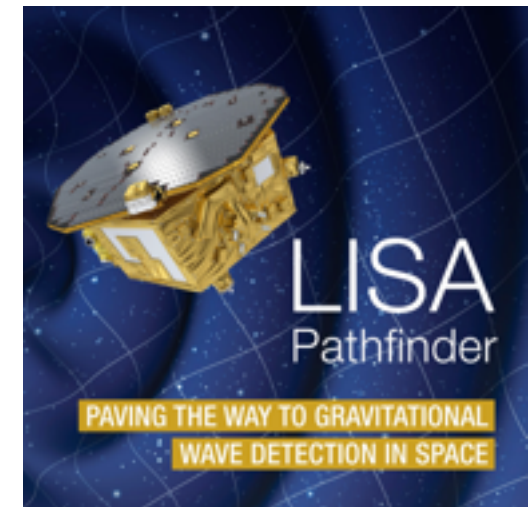
Orbital configuration:
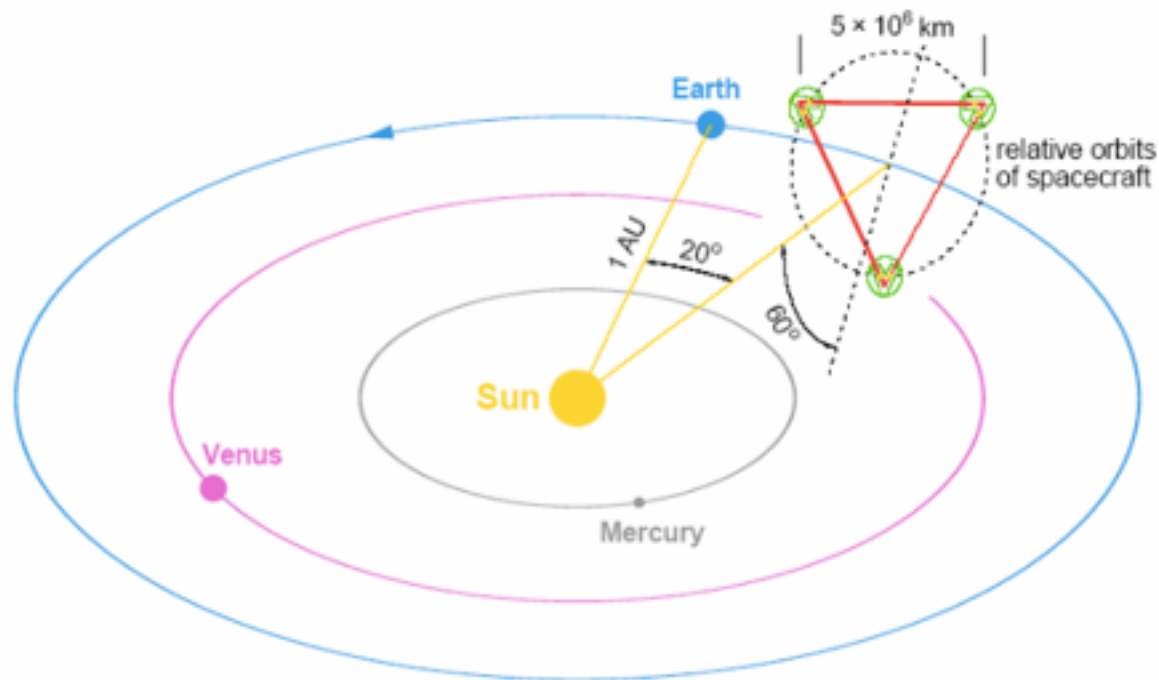
LISA

Simplified scheme of the constellation:
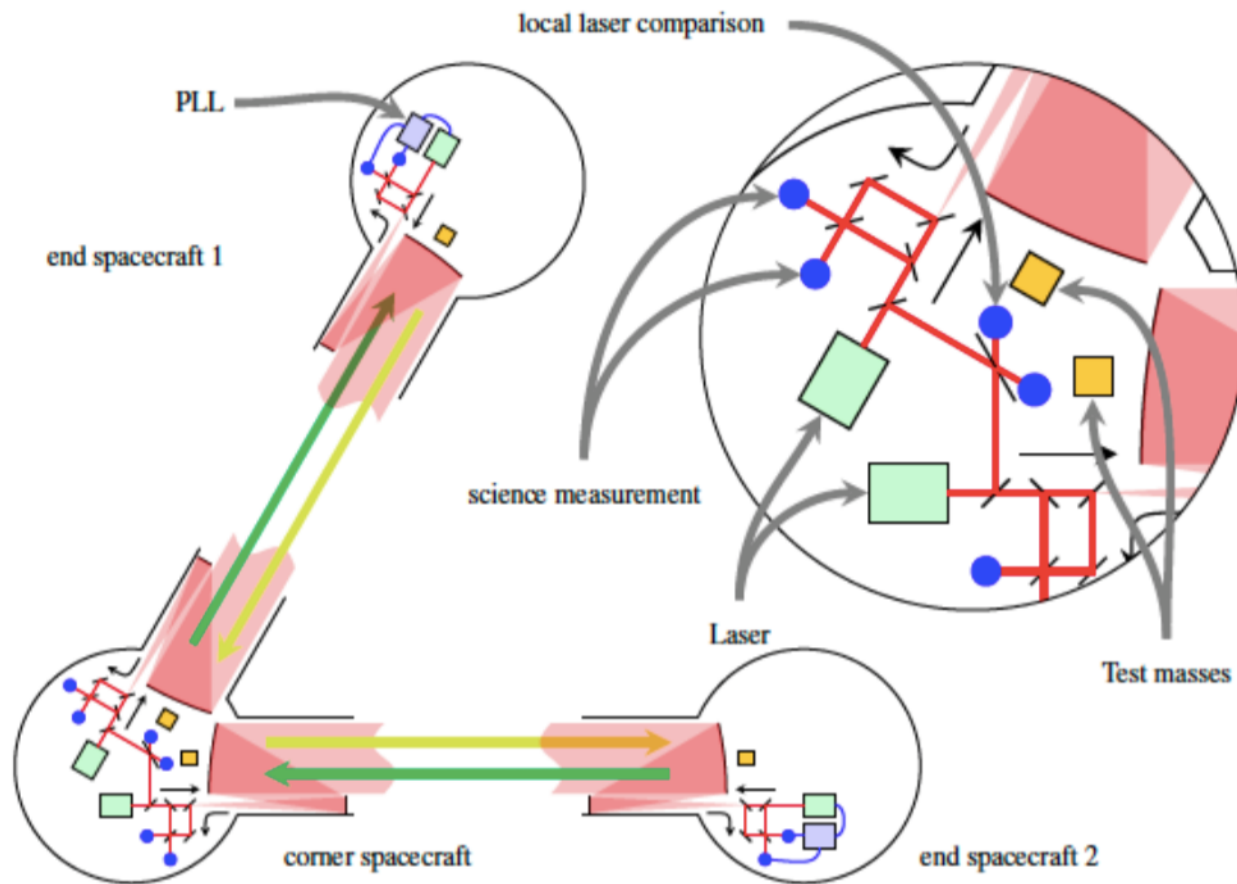
LISA Pathfinder

- Launched in 2016
- Demonstrates the feasibility of the drag-free principle
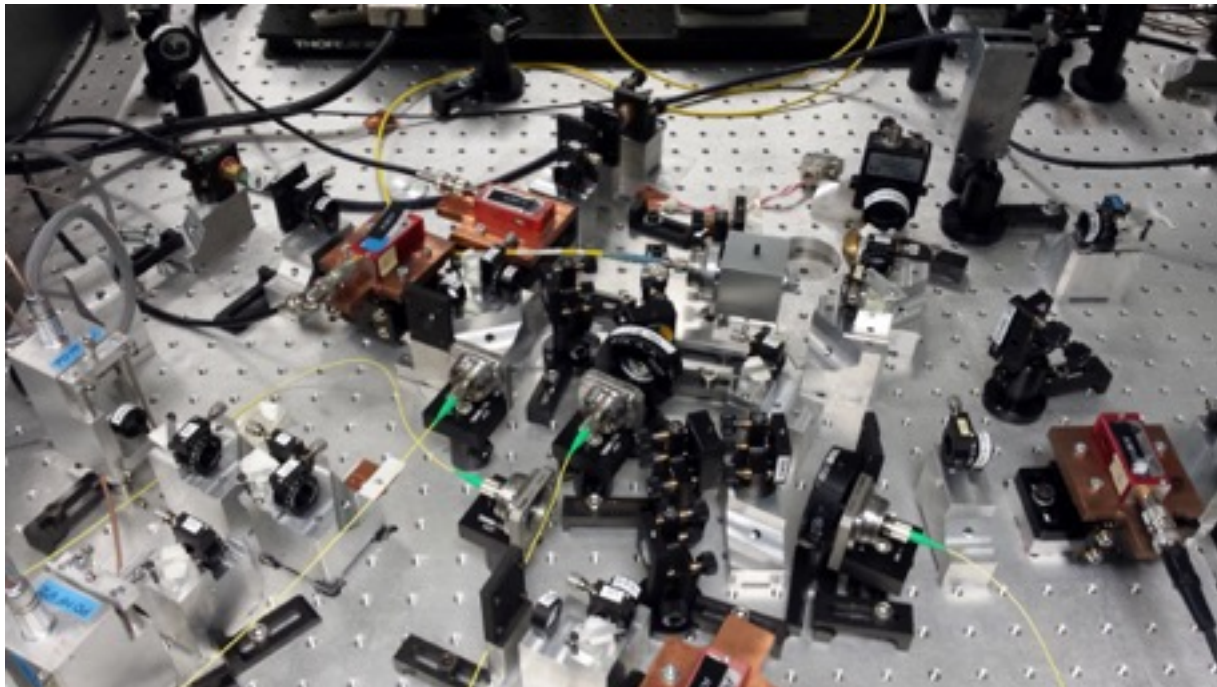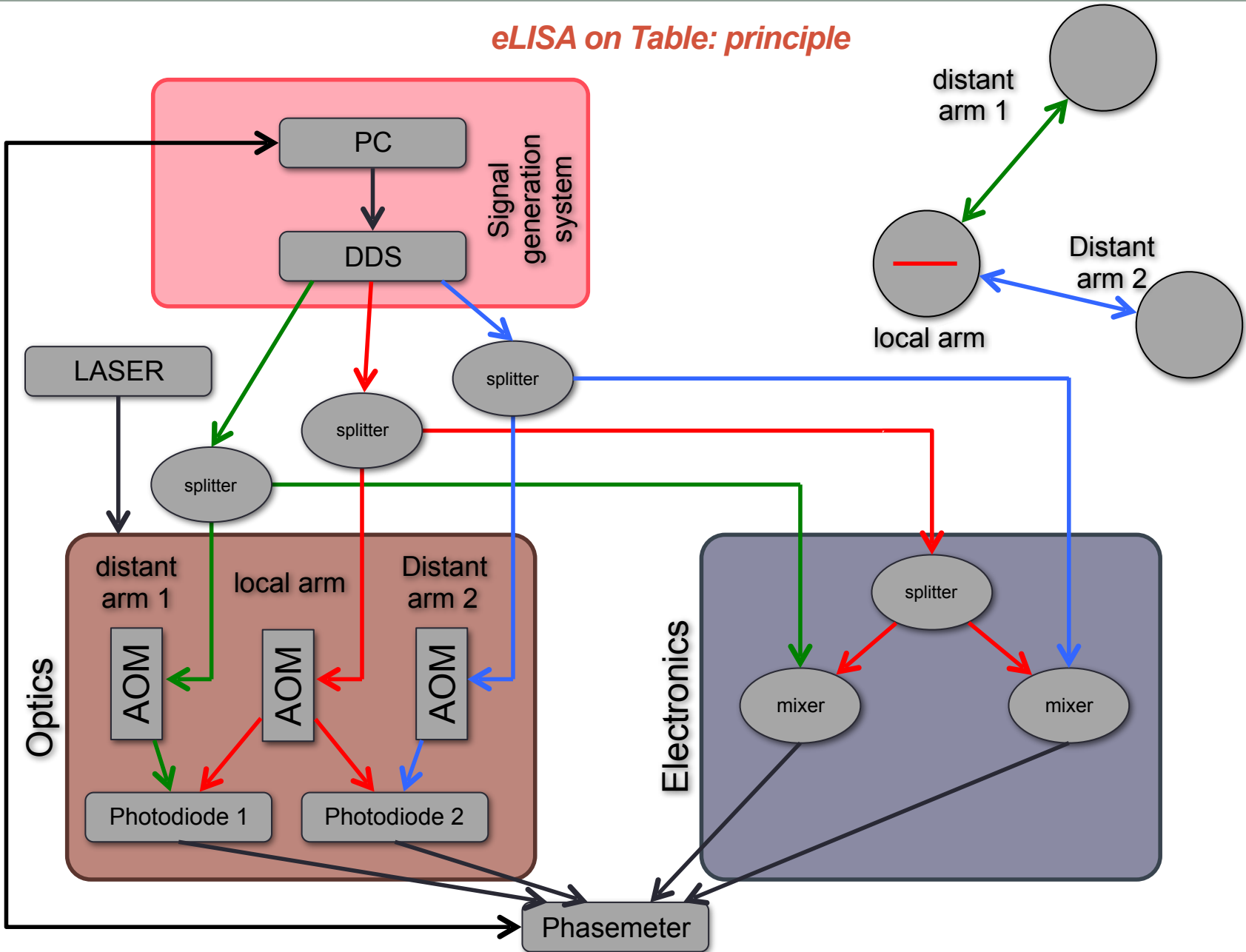- Residual acceleration of test masses beyond LISA requirements

PRL 116, 231101 (2016)

Outline

LISA on Table

- Optical and electronic simulator of LISA.

- Objectives: to test the noise reduction techniques experimentally, to test instruments (photodiodes, phasemeter, …) in a representative acquisition chain.
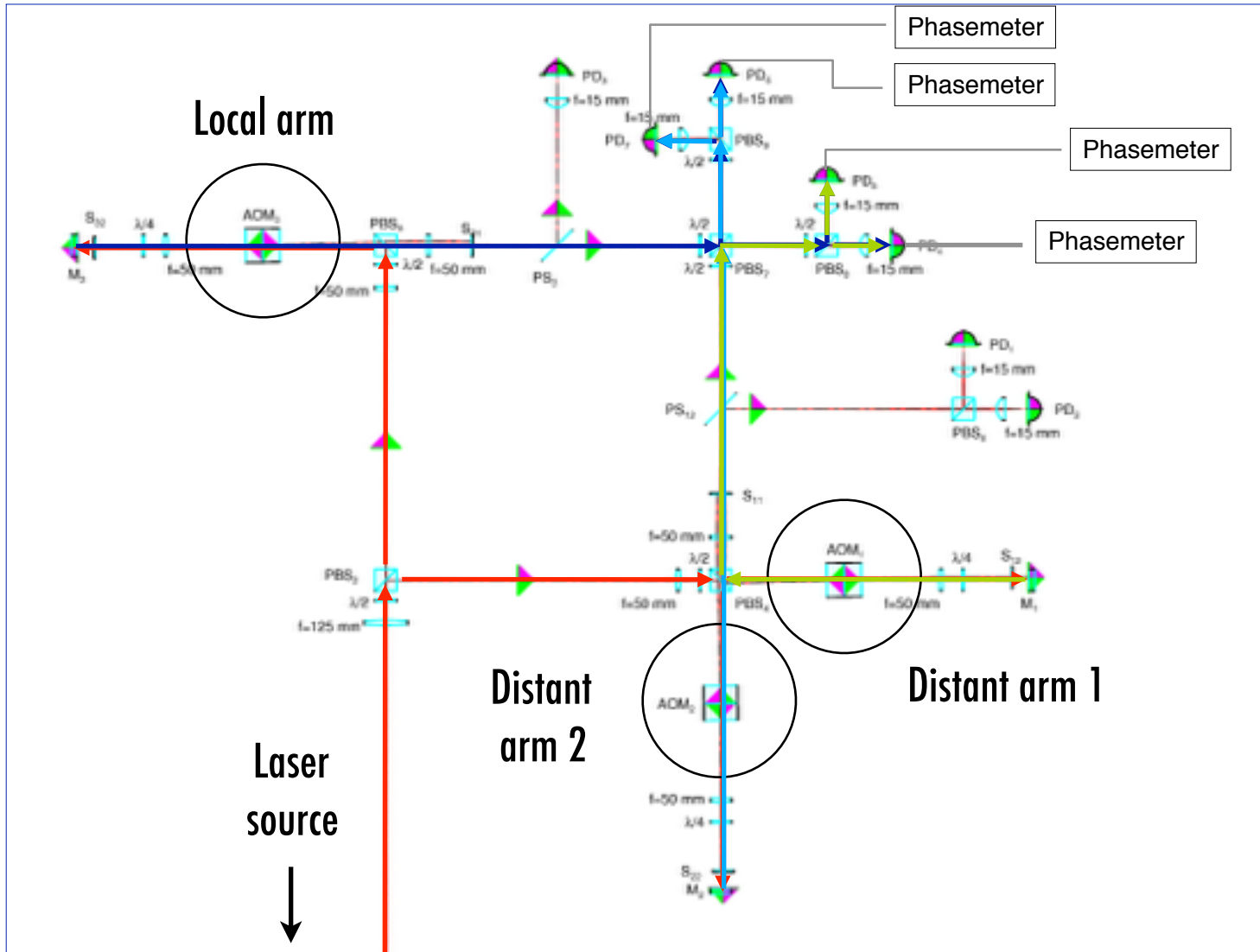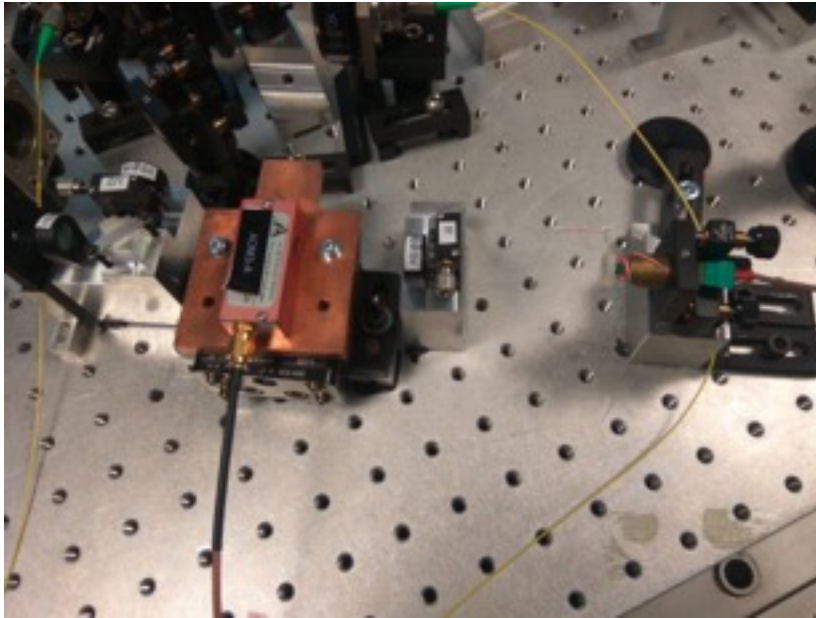
eLISA on Table: principle

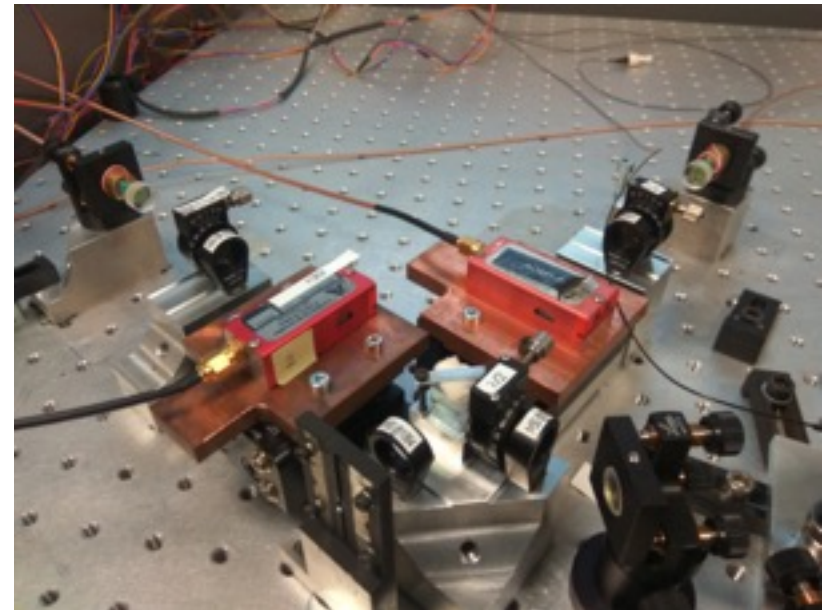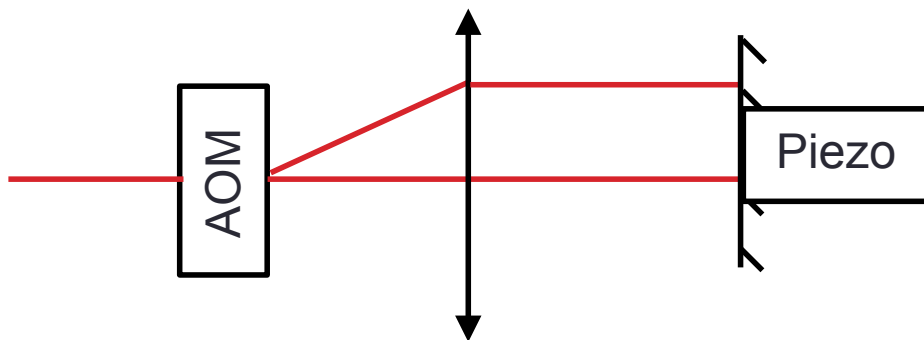# eLISA on Table: optical layout

eLISA on Table

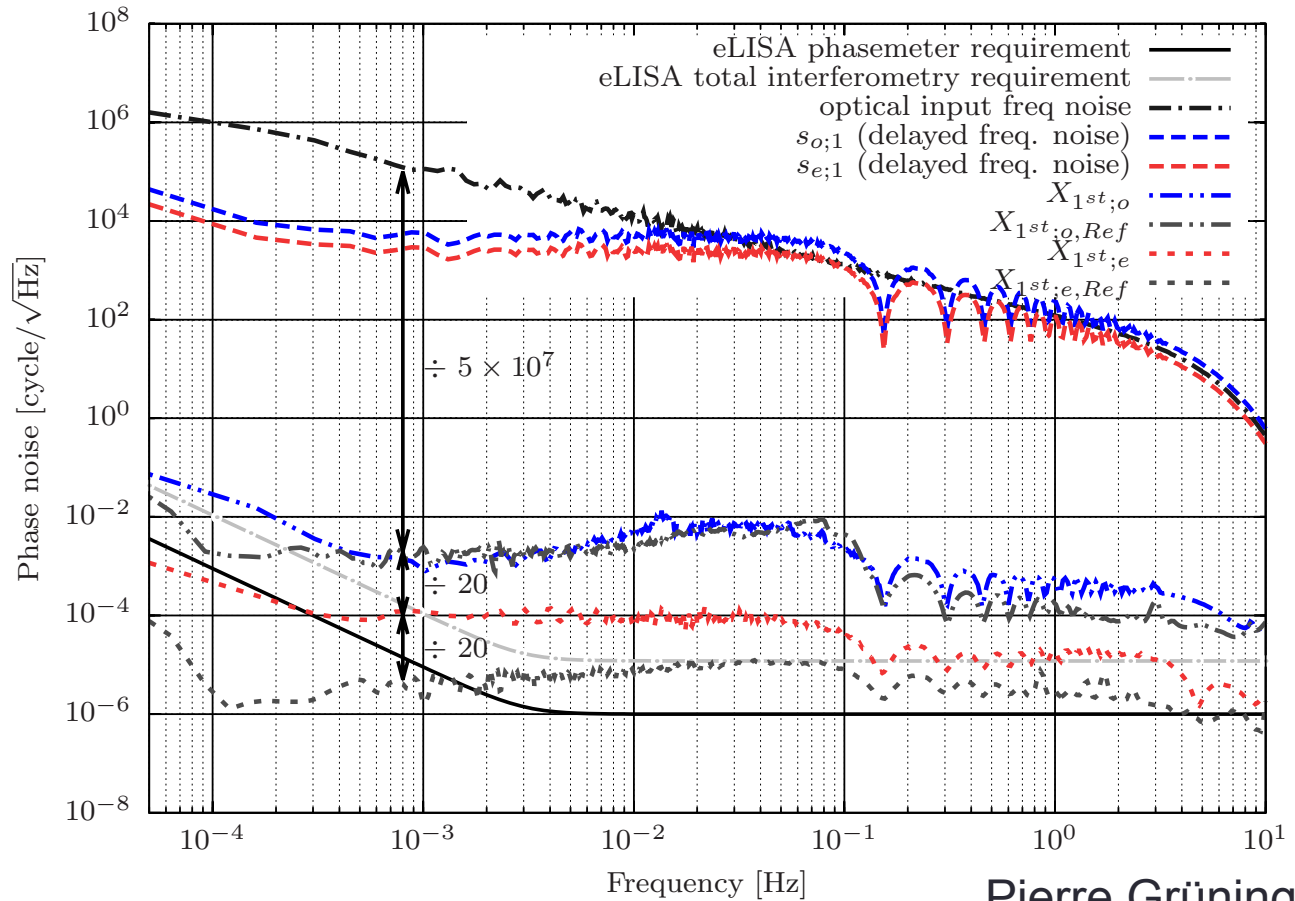Bragg's cell in cat's eye configuration:

The diffracted beam is modulated in frequency

eLISA on Table

results for both
interferometers in the
following configuration:

- TDI 1st generation,
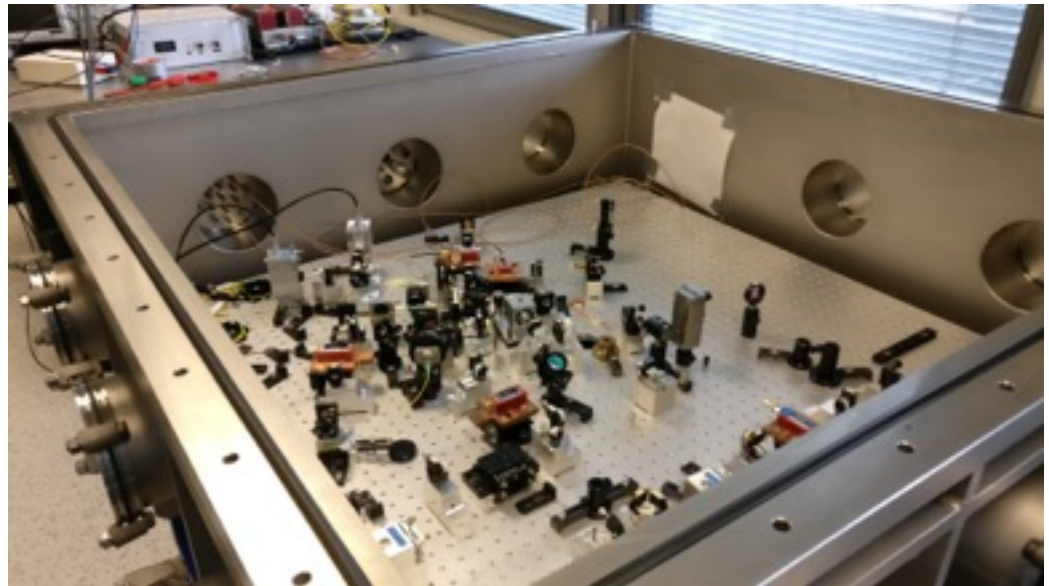- static, uneven arms,
- white noise.

Pierre Grüning

LISA on Table

Optical interferometer:

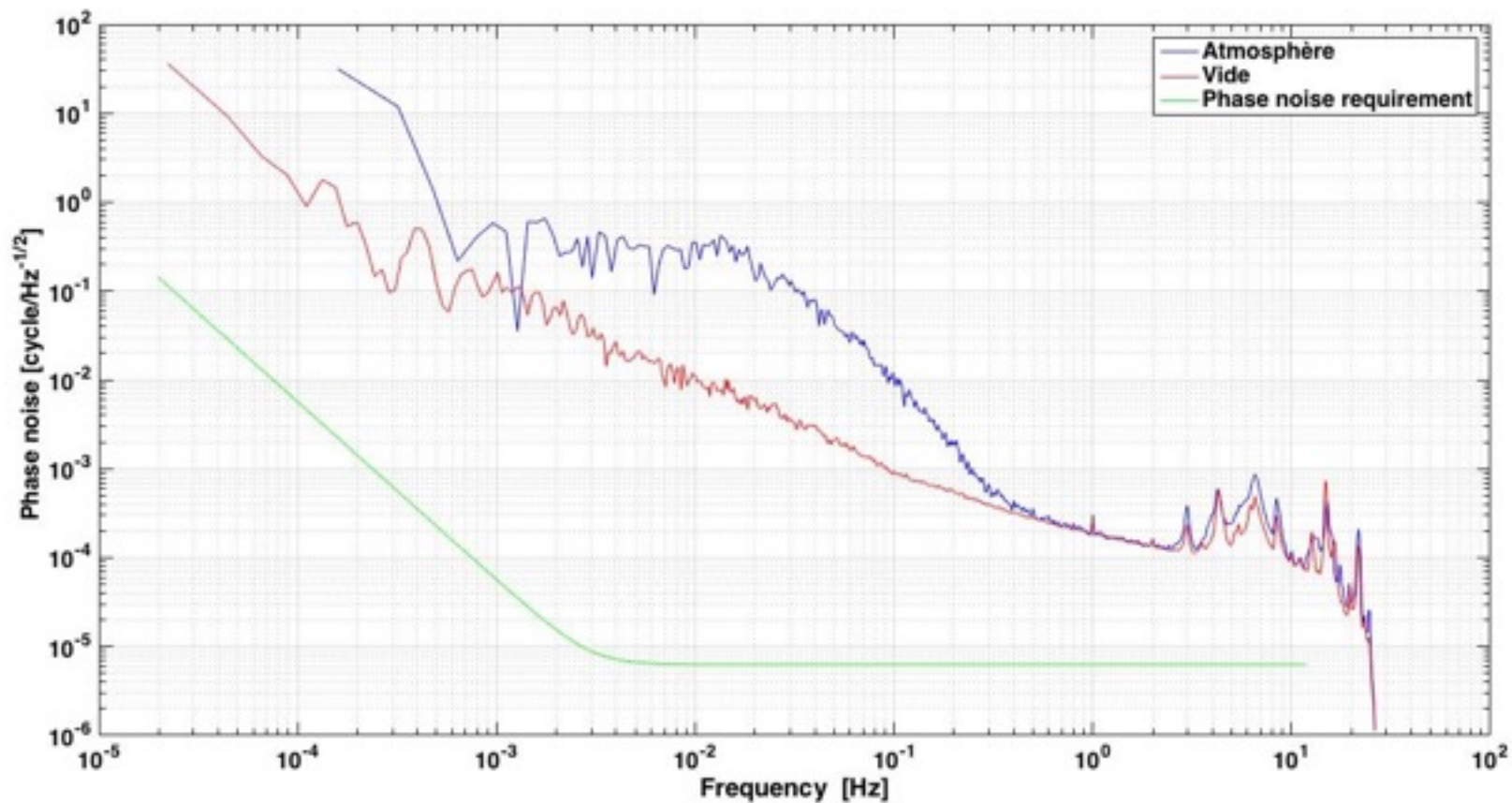Only limited by the system, which means TDI 1st generation works

LOT is now in a vacuum chamber to further reduce optical noise

This requires a lot of experimental work
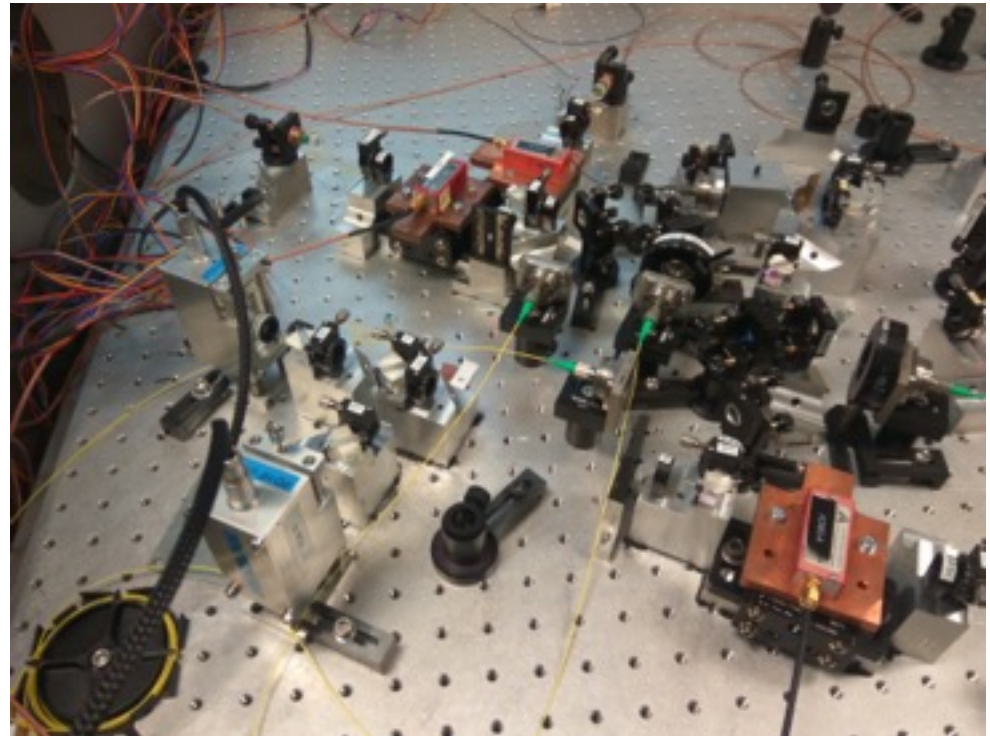
LISA on Table

Vacuum operation validation

LISA on Table

On-going work:

- Active compensation optimisation

- Optical system noise investigation

- Doppler effect simulations

Thank you!