Optical Technologies

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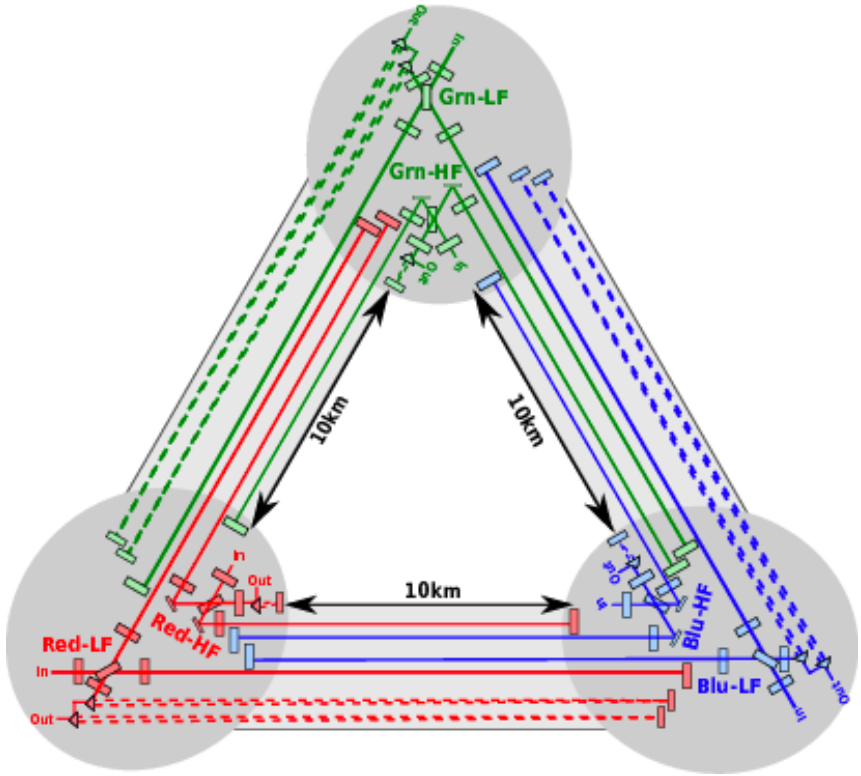
ET Technologies webinar, 15th July 2020

Maastricht University

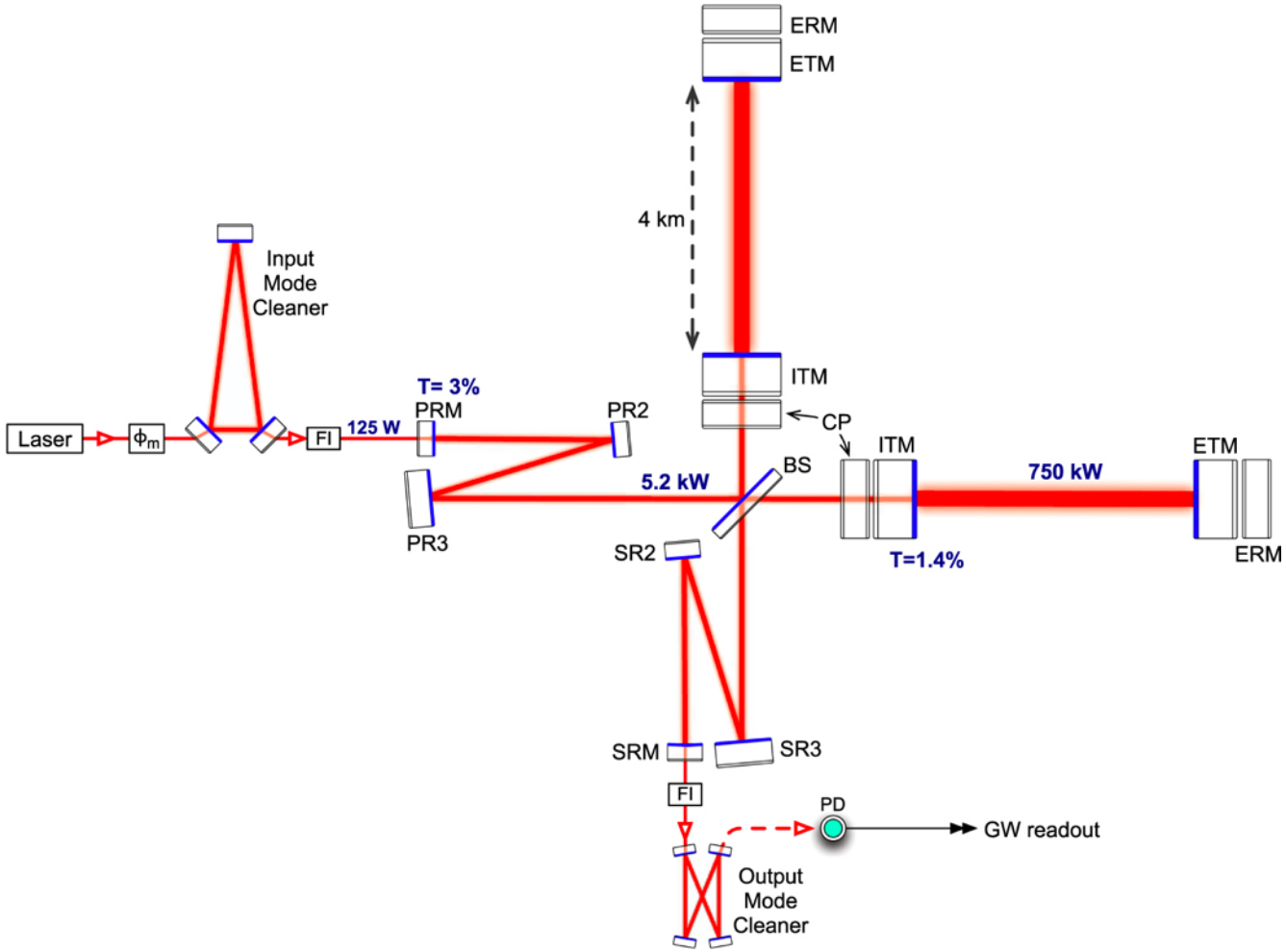
Nikhef

ET Optics Overview

- ET Optical Layout…



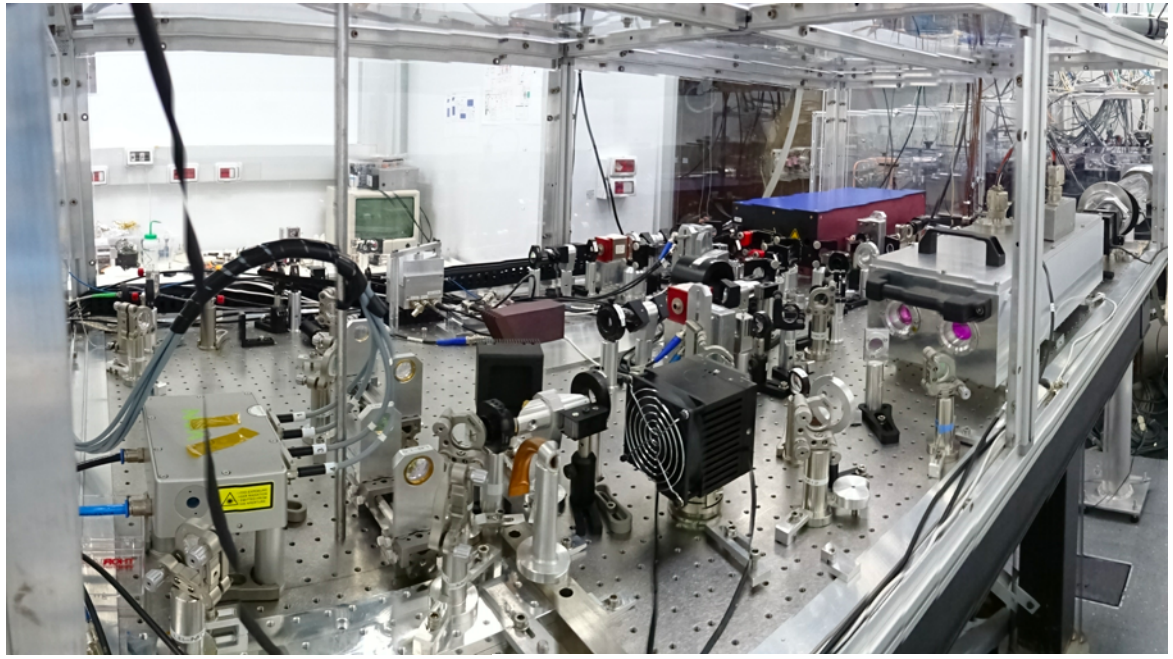
- … where each triangle is two of these:



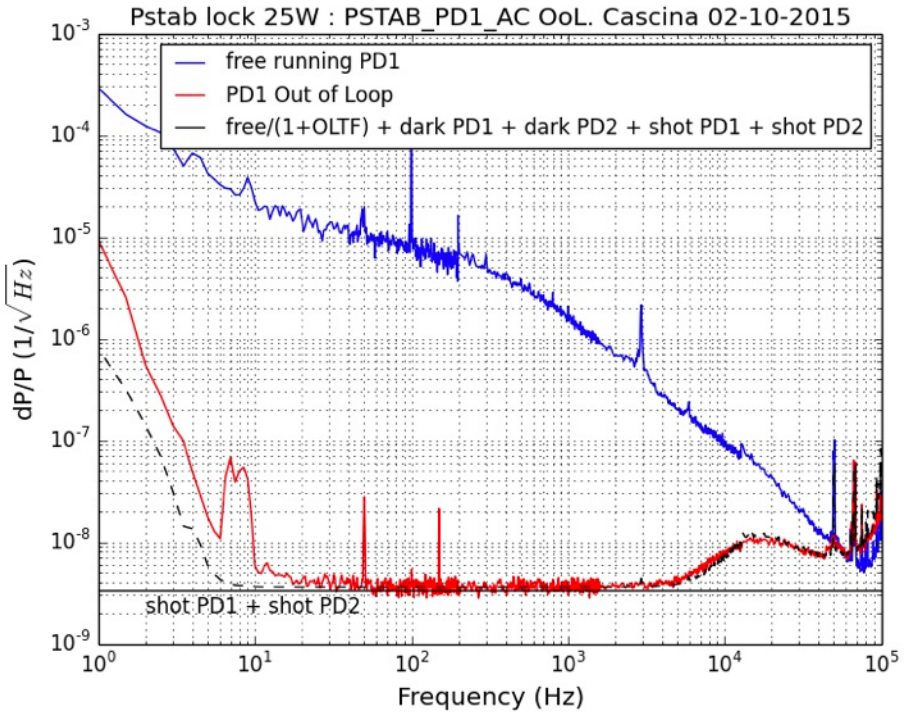
Laser Sources

- Current interferometers
  - 1064nm
  - NPRO solid state seed
  - Amplified to around 200W

- Challenge for ET:
  - 1064nm, 1550nm
  - Similar powers
- Requirements
  - CW, single frequency
  - Low RIN
  - Low phase noise
  - >95% TEM_{00} mode content
- Stabilized to 10km arm cavities
  - Needs fast actuators that are linear over a wide range
  - Absolute frequency stability less important



Photos: Artemis



Main Mirrors

- Current detectors (& ET high frequency)
  - Fused silica with extremely low absorption (ppm level) at 1064nm
  - Radii of curvature several km, deviation a few meters
  - Deviation from perfect sphere < 2nm
  - Super polishing <0.2nm RMS

- Challenge for ET: silicon mirrors
  - ca. 45cm diameter, 55cm thickness
  - High purity, >10kΩcm, for ppm-scale optical absorption
  - Similar polishing requirements
- 4 per detector, i.e. 12 for ET, plus spares
- Upgrades roughly every 5 years
- Smaller scale *now* for ETpathfinder

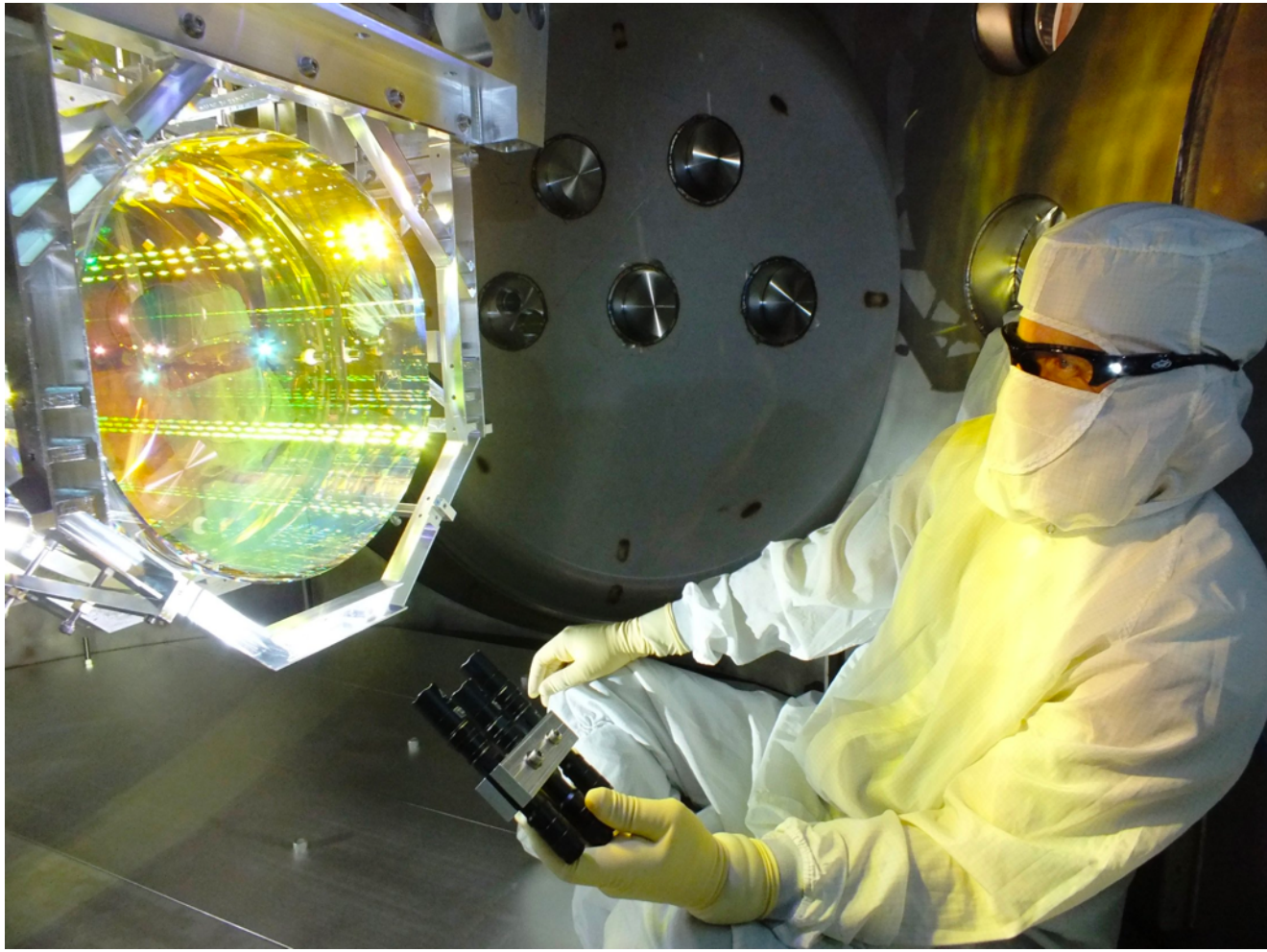
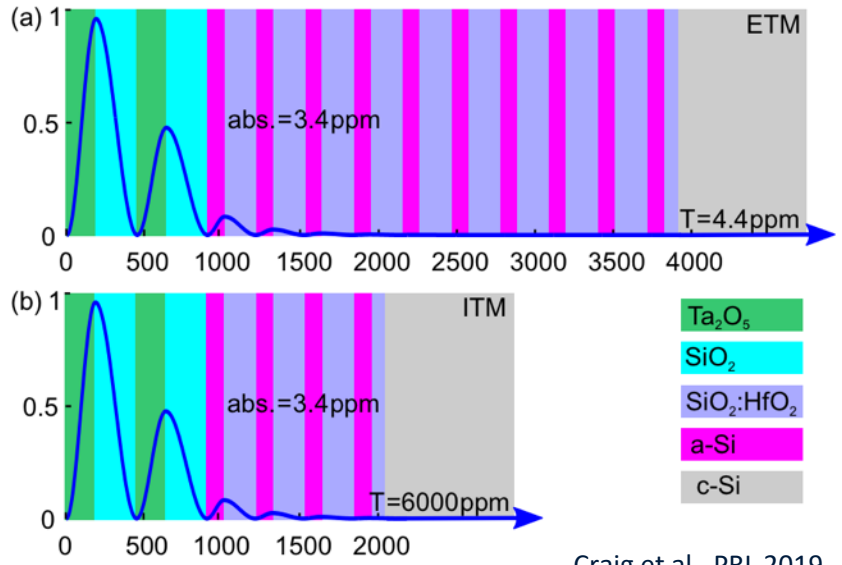


Photo: LIGO lab

Optical Coatings

- Current status
  - Silica/Tantala dichroic coatings
  - Optimized for very low absorption & scattering (ppm level)
  - Optimized for low mechanical loss (becomes high at low temperatures)
  - Two optics coated at once, for minimal spread in reflectivity

- Challenge for ET:
  - Low-loss (optical & mechanical) coatings for cryogenic silicon test-masses
  - Virtually free from scattering/absorbing points
  - Large diameter (45cm), homogeneous
  - Able to handle larger masses and diameters



Craig et al., PRL 2019

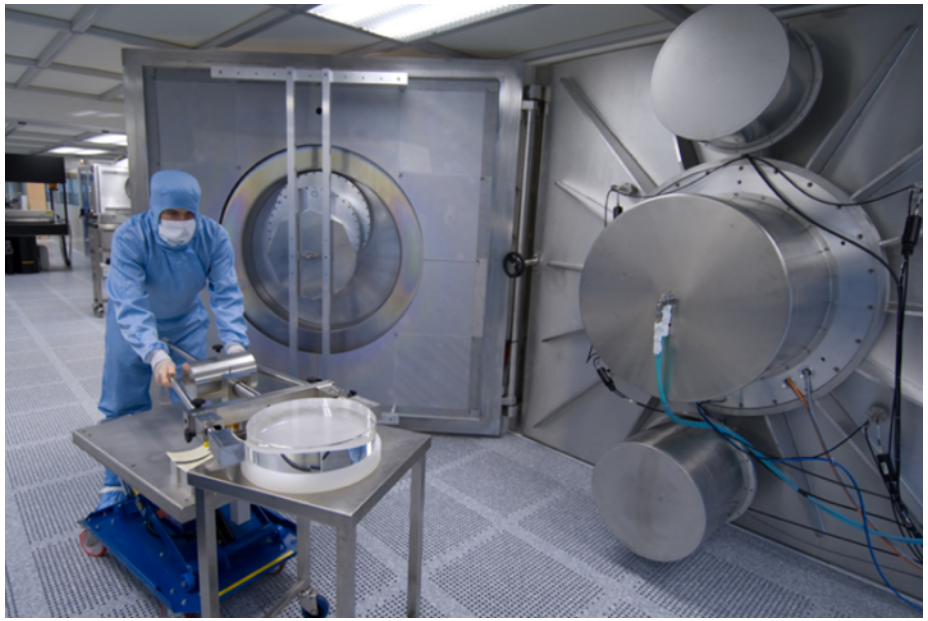


Photo: LMA

Optical Sensing and Metrology

- Several types of optical sensors and metrology used during production and during operation

- Measuring reflected and transmitted waveform during polishing and coating, as well as surface roughness
- Beam profile monitoring and analysis
- In-situ monitoring of mirror curvature (wavefront sensors)
- Position alignment of test-masses with wide-range optical sensors

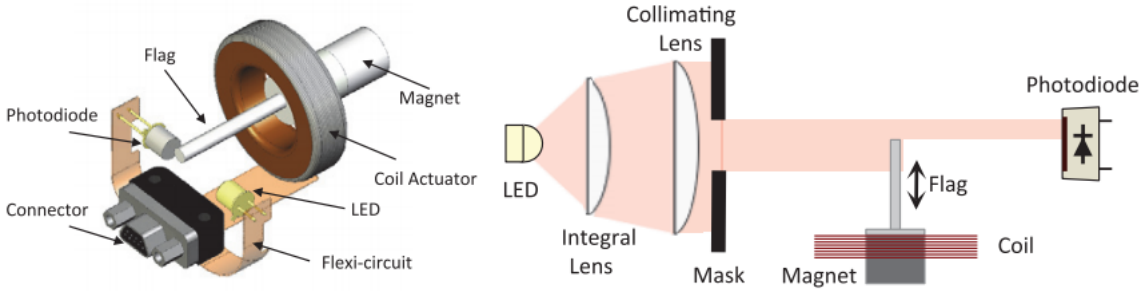
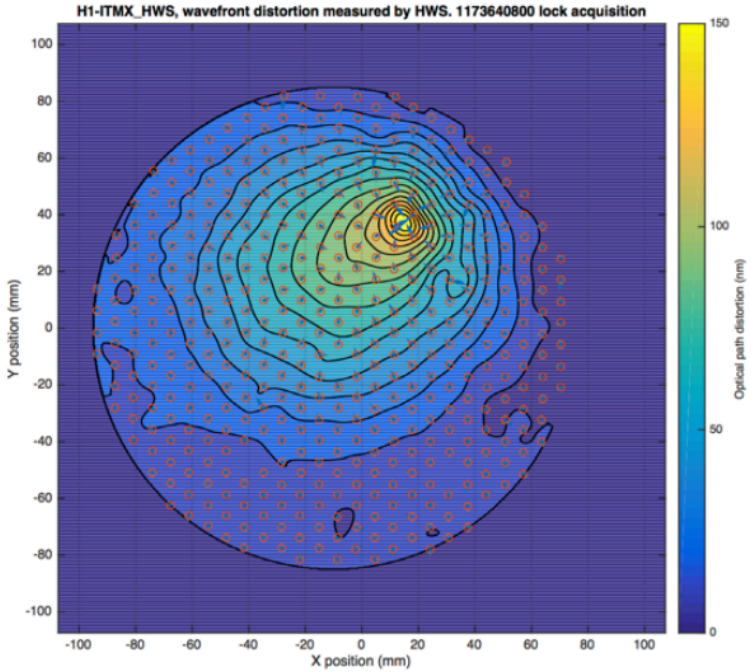


Photo: ZYGO/LIGO lab



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Quantum Technologies

- Squeezed Light was introduced in GW detectors over the past few years
- Successfully reduced shot noise by 6dB, planned to reach 10dB in ET
- High squeezing factors (> 10dB) at low frequencies (1Hz – 10kHz) required

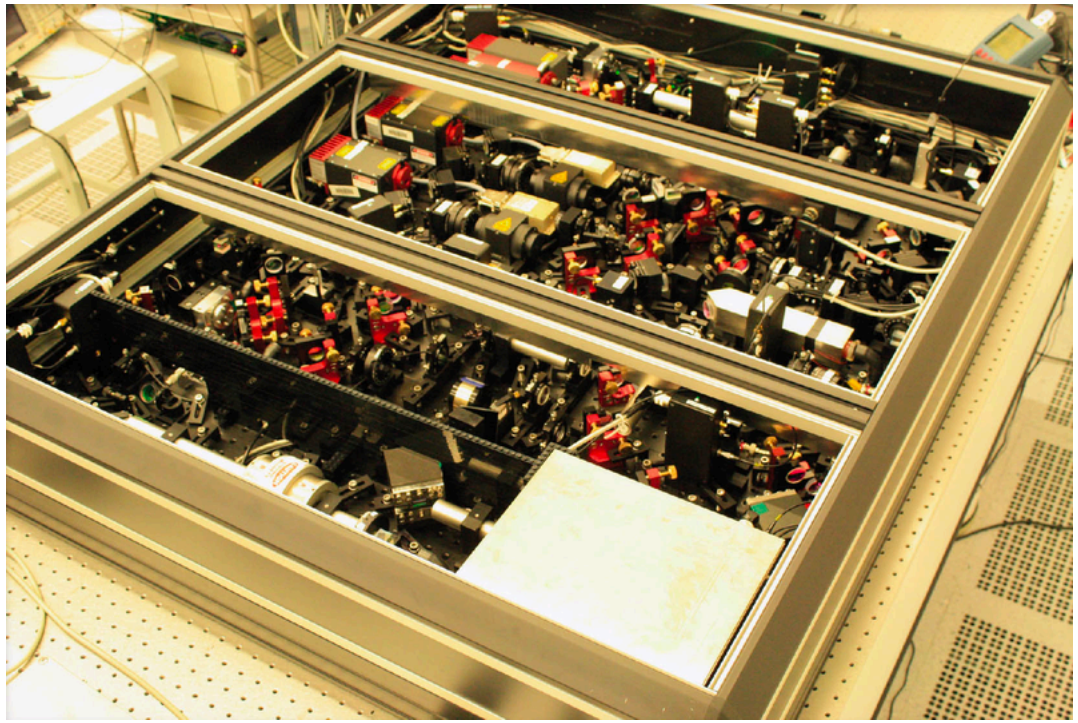
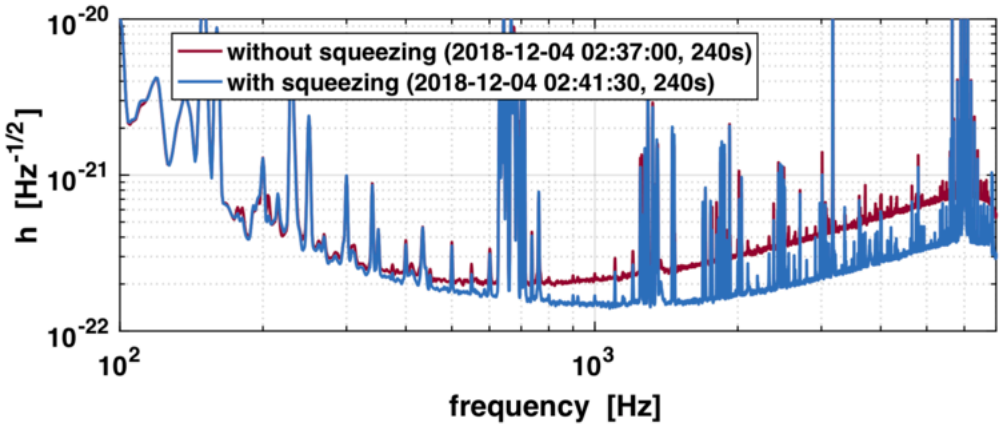
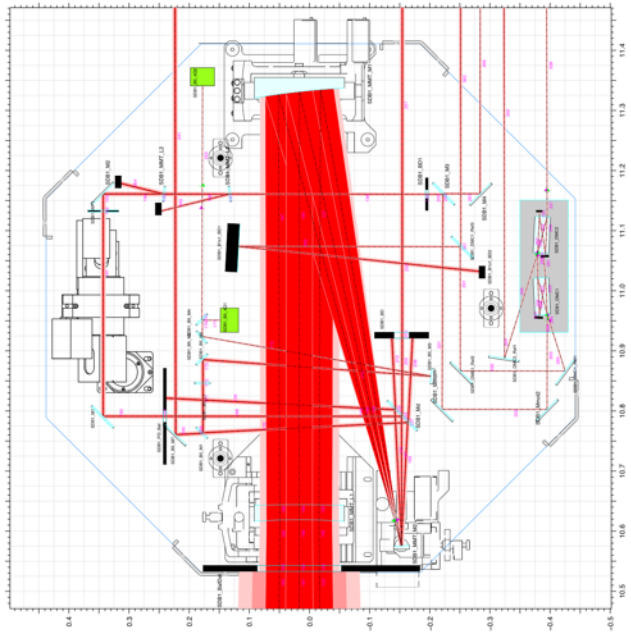


Photo: AEI/GEO600



Auxiliary Optics

- In addition to main test-masses, each interferometer has
  - Around 10 large (20cm scale) optics with very high optical specifications
  - Some telescope optics with off-axis spherical/parabolic mirrors
  - Several hundred small optics, most of them super-polished



- Scope for e.g. free-form optics, adaptive optics, etc.
- In-vacuum and in-air optomechanics

Photo: EGO/Virgo