Optics for Einstein Telescope

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www.einsteintelescope.nl / www.etpathfinder.eu

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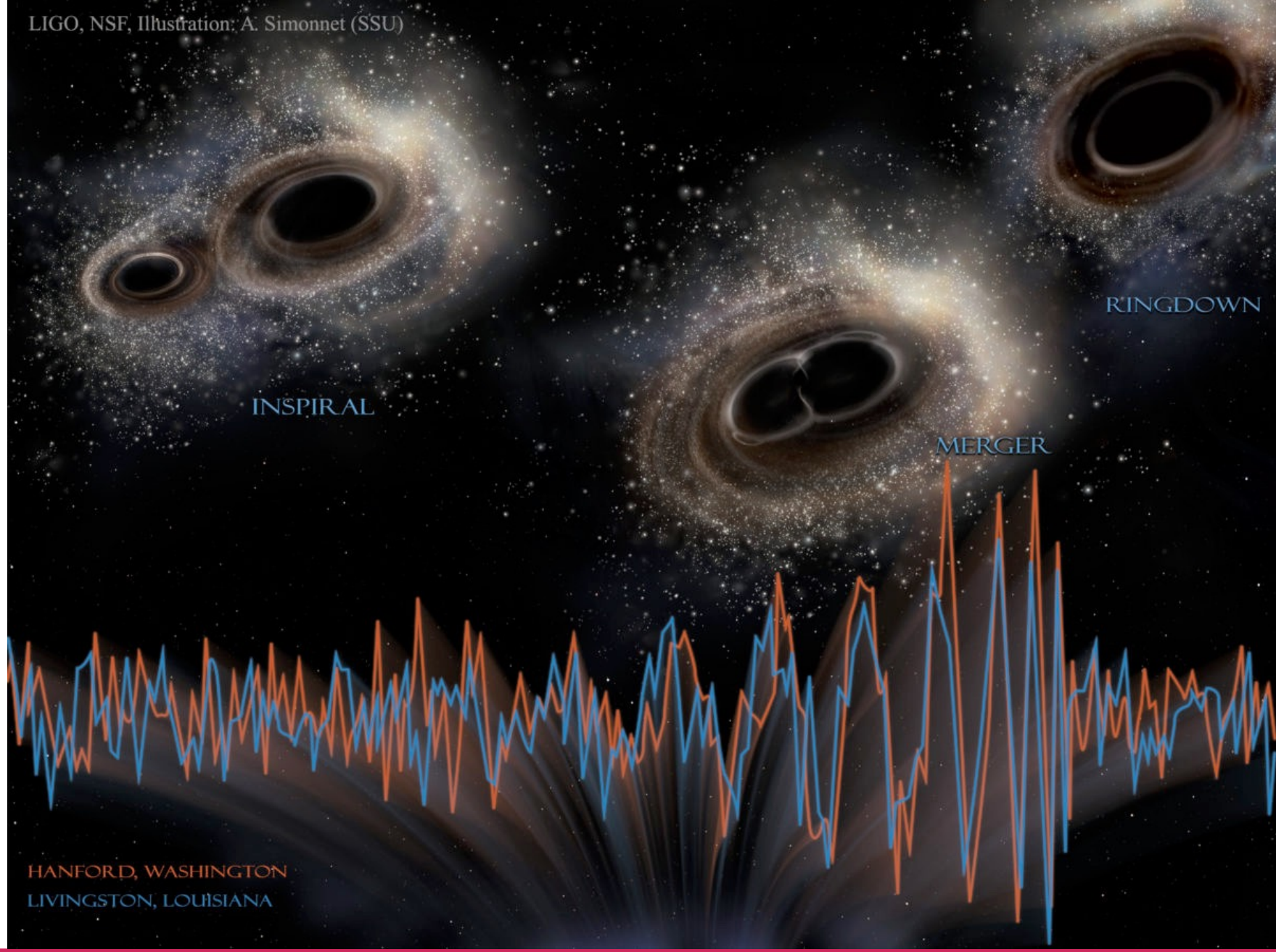
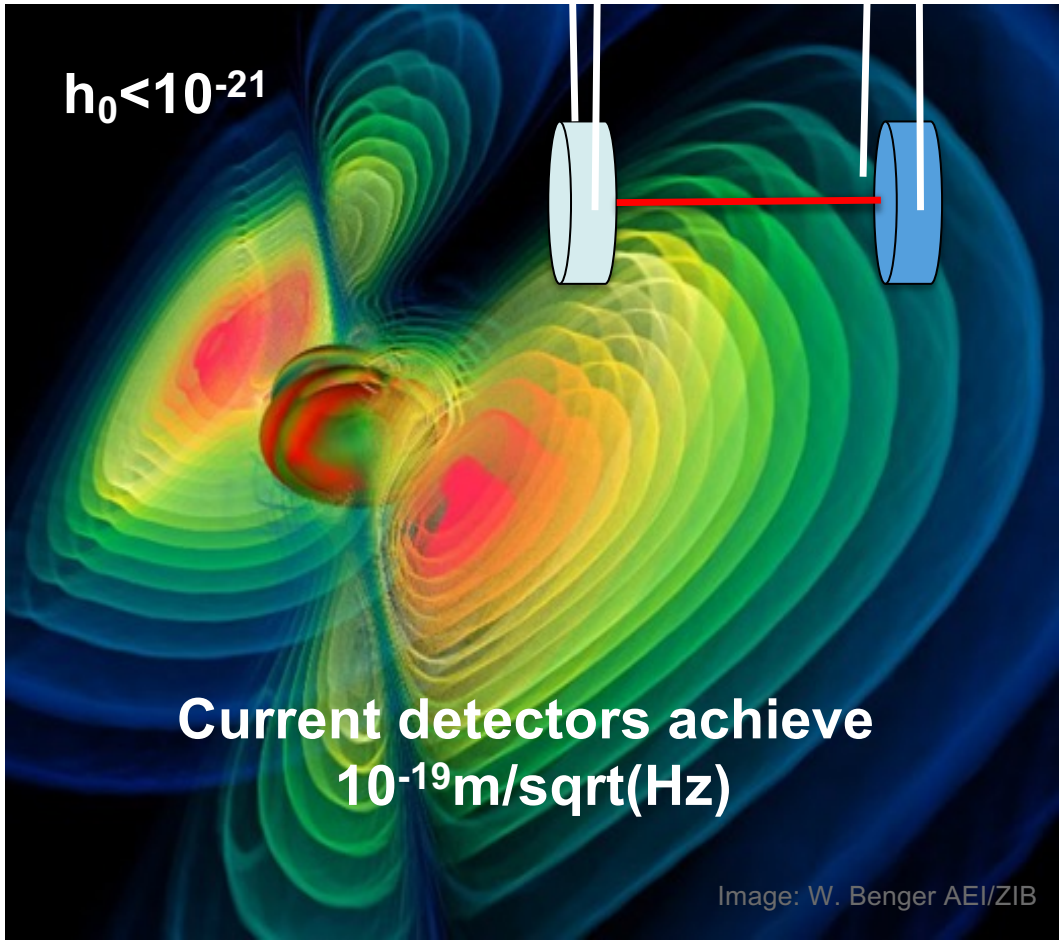
A new window to the Universe

- Seeing dark objects otherwise not accessible with “normal” astronomy.
- Shedding light on the components of the Universe (dark matter, dark energy).
- Better understanding of Gravity, the least understood force.

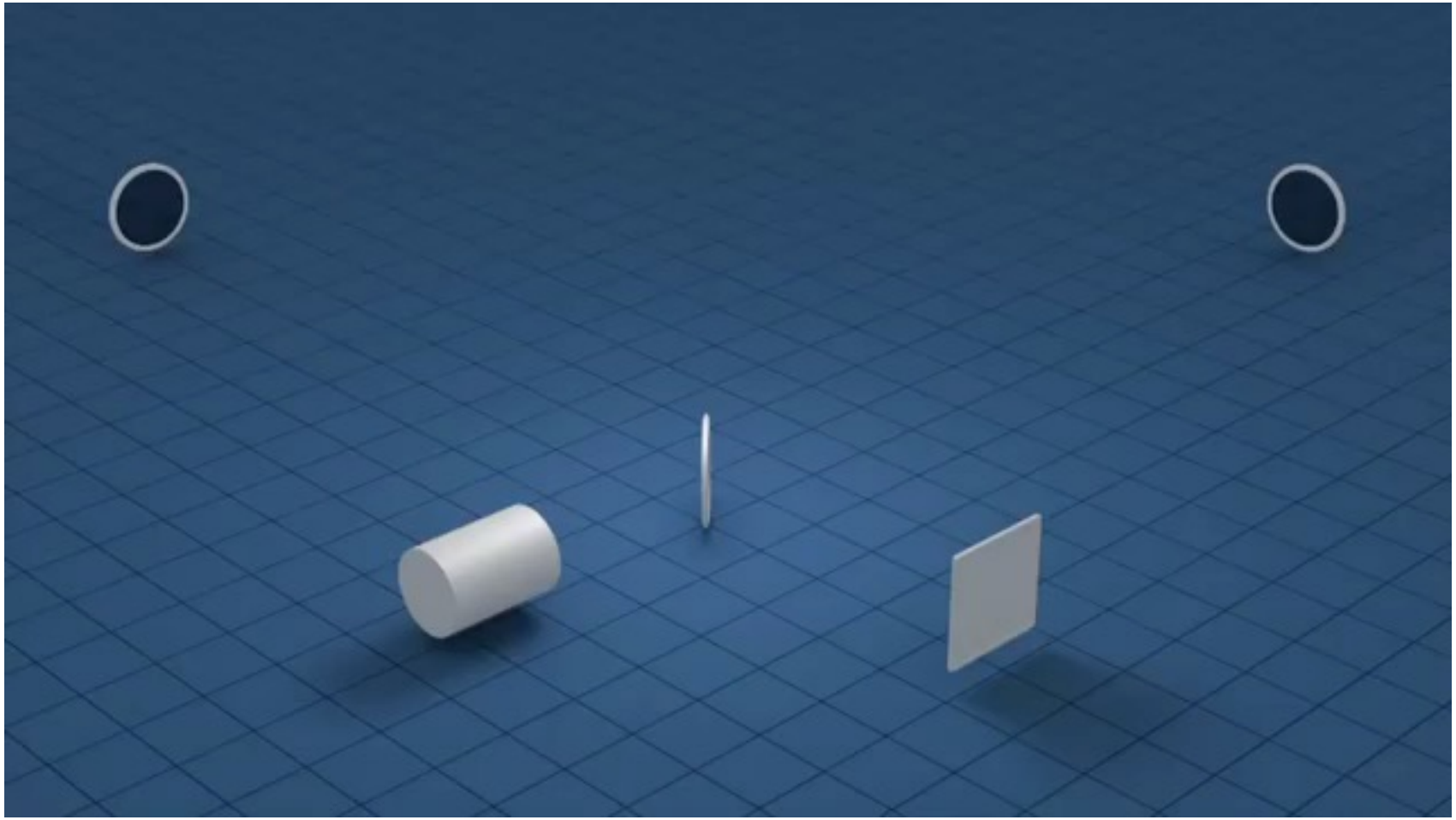


How to build a gravitational wave detector?

- In order to detect GW you need to very accurately measure the position of test masses.
- First you need to make your test masses quieter than what you want to measure.
- Secondly, you need to readout out the strain to the required precision without (!) introducing ‘too much’ additional noise.



Using Light as our yardstick



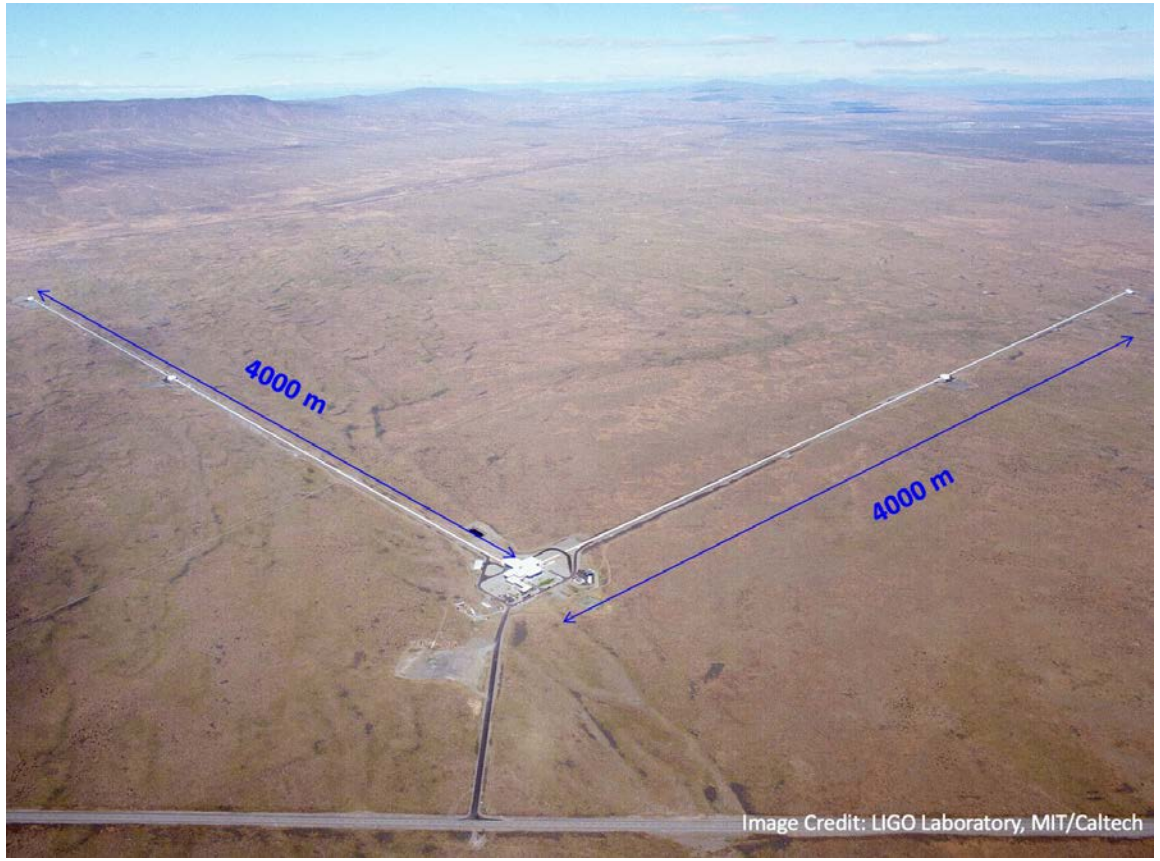
Large laser interferometers for measuring tiny changes

Optimal Arm length:

$$L = \frac{\lambda_g}{4}$$

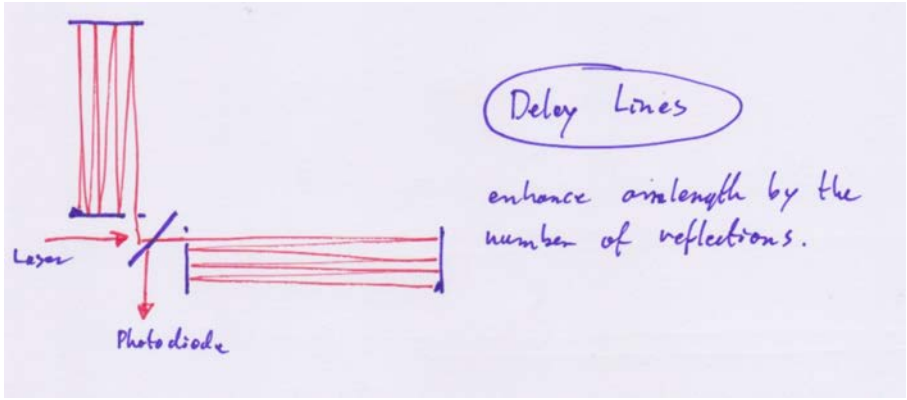
GW wavelength

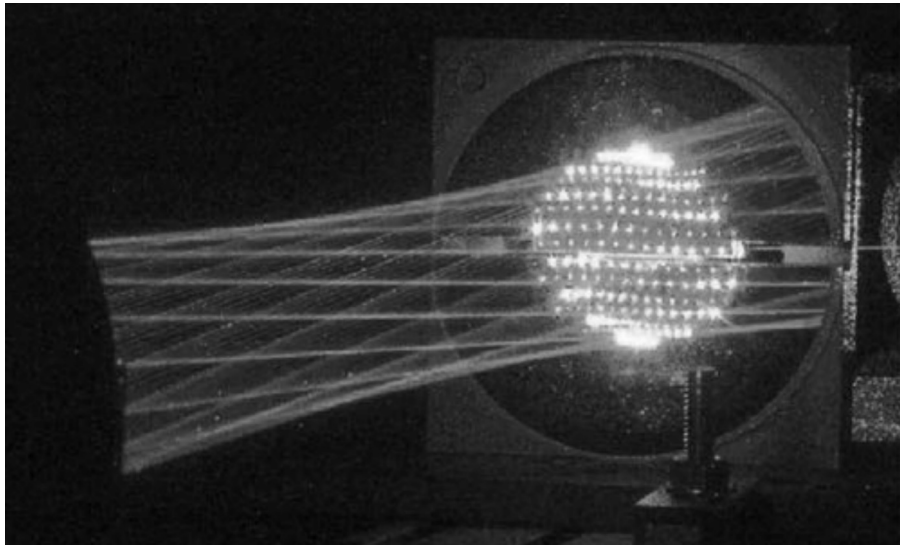
Example: GW signal at 100 Hz => optimal arm length of 750 km



How to make your interferometer arms long?

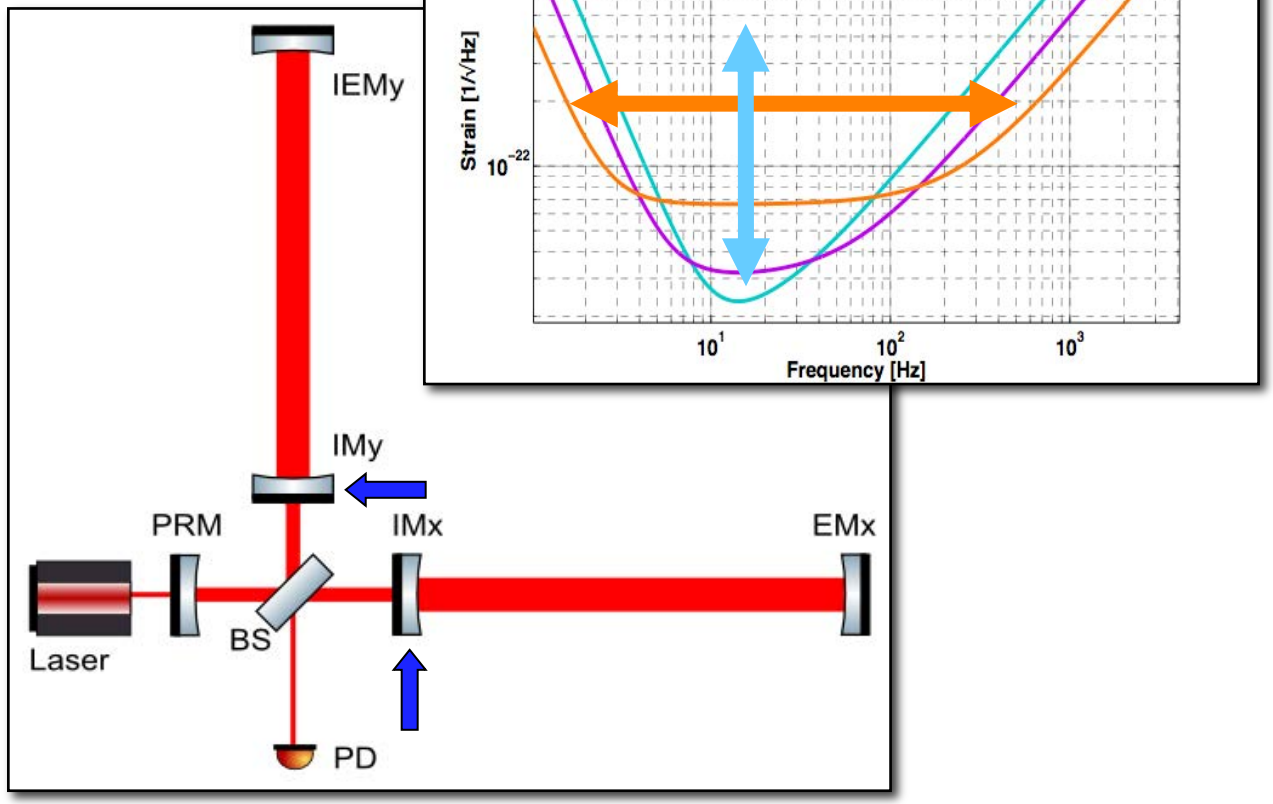
Heriott Delay Line



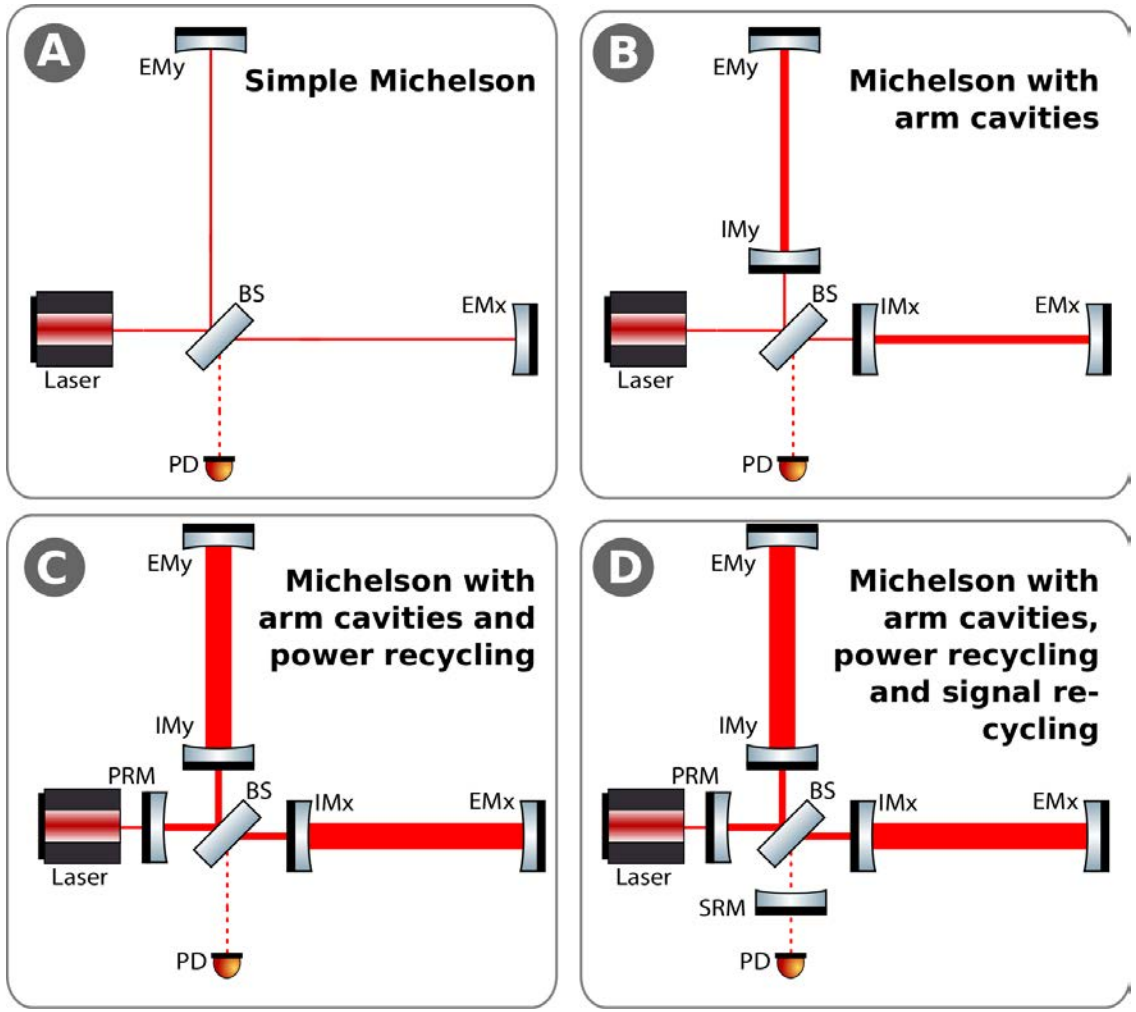


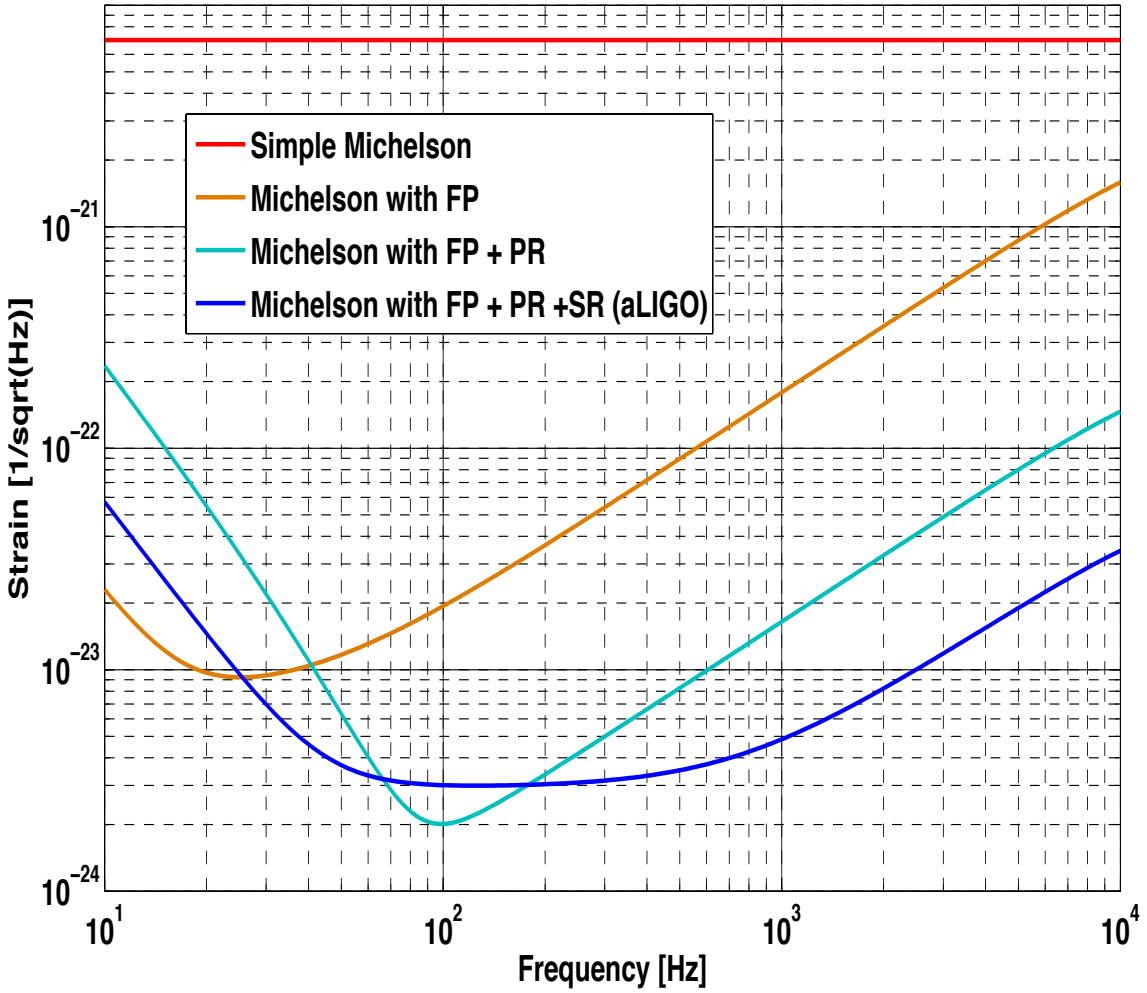
vs.

Fabry Perot Resonantors

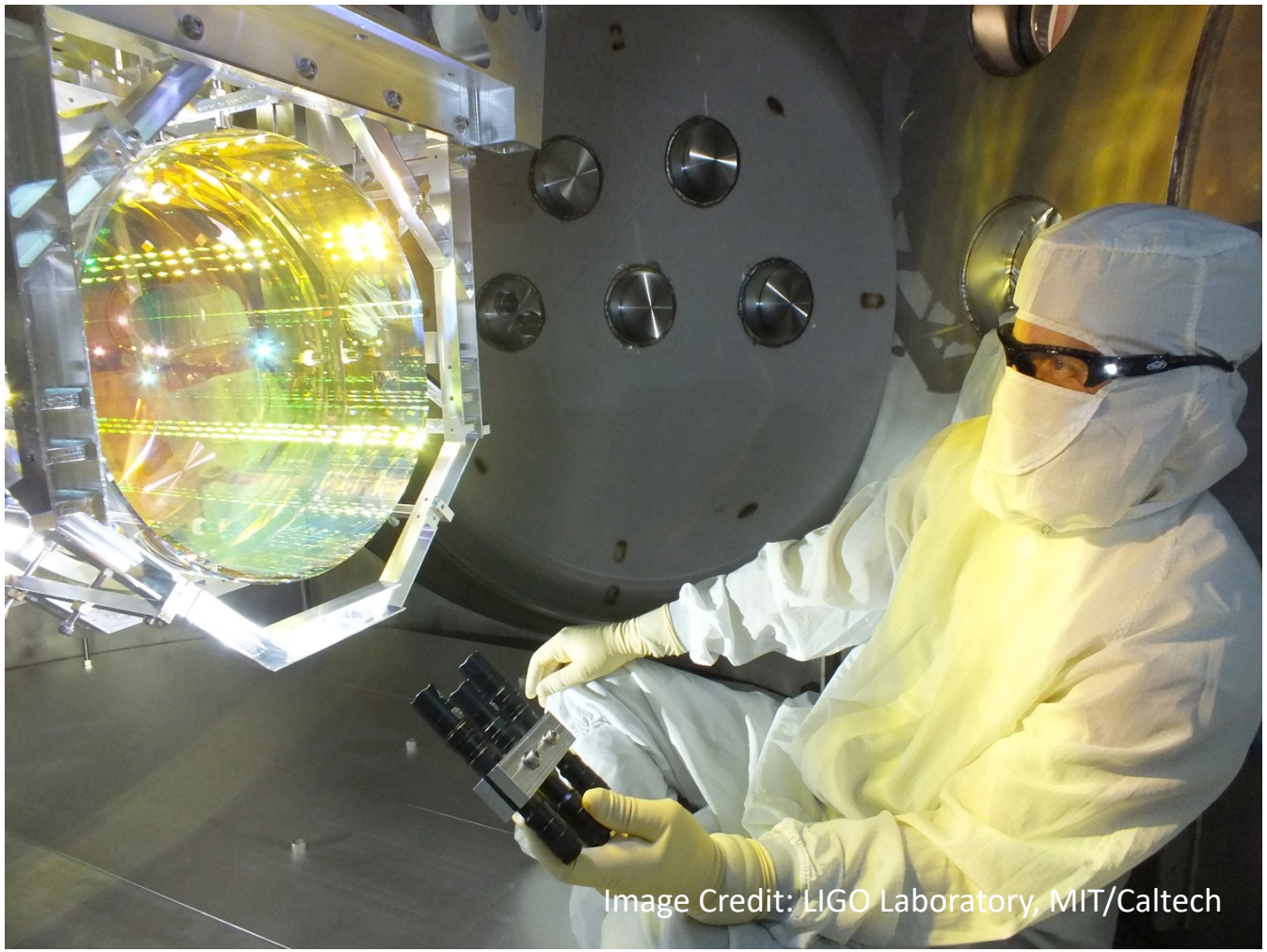


ALIGO Example





State of the Art



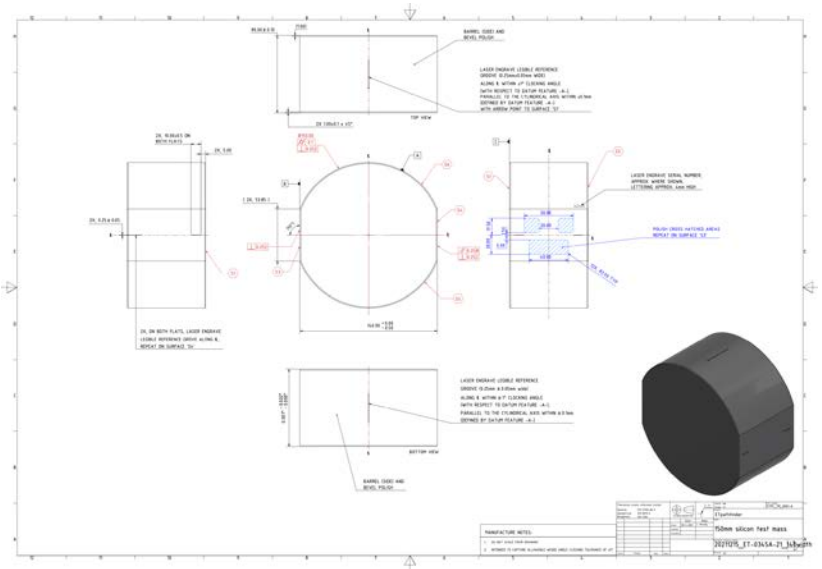
- Ultra-stable laser (**1064nm**, Linewidth <1Hz)
- High power optics: ~400kW CW
- Optical resonantors (km length, high finesse)
- Fused silica substrates, available in ET size (200kg), Largest optic used by LIGO/Virgo: Virgo BS with 55cm diameter.
- **Mirrors polished to nm flatness and 100pm microroughness**
- **Special low Brownian noise coatings**
- **Low absorption (<0.5ppm per coating; <0.25ppm/cm in substrates)**
- **Controlling positions of mirrors to pm accuracy**

Needs for Einstein Telescope

- While High Frequcency are based on mostly available technology, the ET low frequency interferometers pose a variety of challenges.
- Want to operate cryogenic interferometers, i.e. 4 main test masses are cryogenic, rest of the optics can be standard room temeprature.
- Fused silica shows increased noise at cryogenic temperatures and is therefore ruled out.
- Current ET-LF baseline envisages silicon mirrors:
  - 45 cm diameter and 55cm thickness
  - Low optical absorption; electric resistivity >10kOhm*cm

Example towards ET: ETpathfinder mirrors

- Small Optics: 15cm diameter, 8cm thickness.
- Specially produced Float zone silicon ingots made by Institut for Crystal Growth in Berlin
- High precision polishing (1nm flatness for inner 4 cm diameter, 100pm roughn ess) on 4 surfaces per mirror.



11 Wedge

A horizontal wedge of $0.007^{\circ}{}^{+0.002^{\circ}}_{-0.00^{\circ}}$ $(122\text{urad}^{+35\text{urad}}_{-0\text{urad}})$shall be added to the substrates.

12 Radius of curvature

Refer to the sketch in Figure 1 below for an exaggerated visual representation of S1 and S2 ROC.
Surface 1: The ROC of S1 shall be spherical, concave. ROC: 14.5 m ±0.1 m.
Surface 2: The ROC of S2 shall be spherical, convex. ROC: 9 m ± 0.1 m.

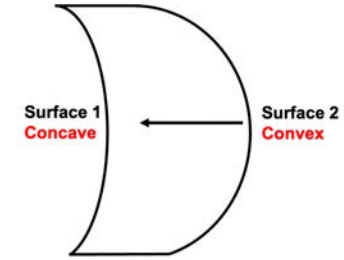
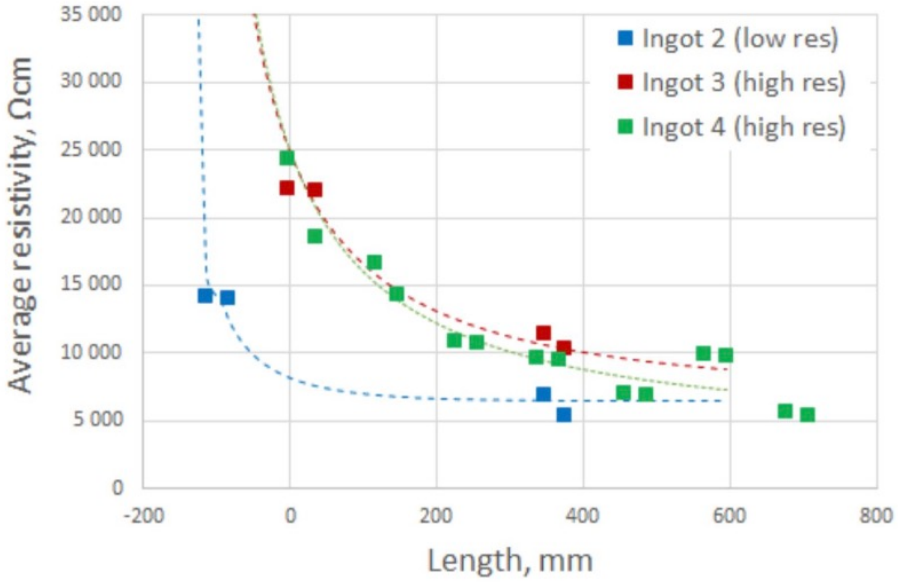


Figure 1: Exaggerated sketch of optic ROC, S1 and S2



Thanks for your attention!
Questions?