2um laser R&D plans at Cardiff University

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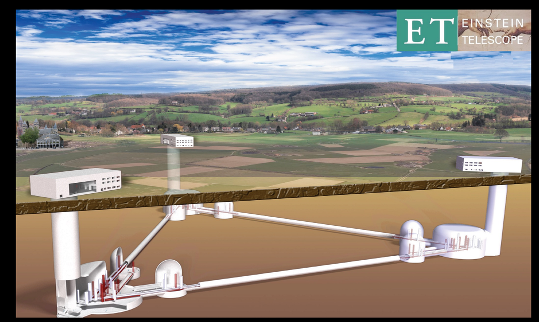
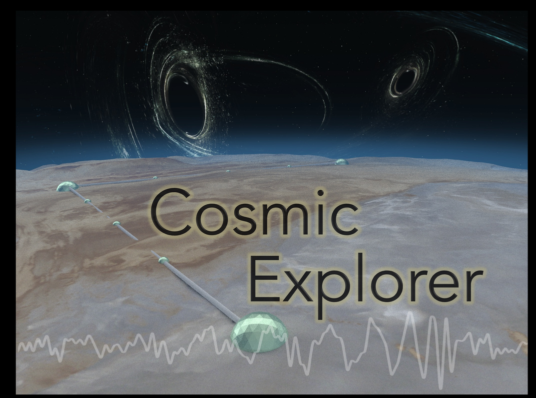
Laser Wavelength will be Changed in Next Generation

	LIGO Voyager	Einstein Telescope	Cosmic Explorer
	2030s	2030s	2040s
Facility	Current LIGO	Underground	Overground
Arm length	4km	10 km	40 km
Temperature	120 K	10 K	120 K
Material	Silicon	Silicon	Silicon
wavelength	2 um	1.55 or 2 um	2 um





In the next-generation detectors, lowering the thermal noise requires a cryogenic temperature with silicon test masses. To use silicon as test masses, a longer wavelength is required because silicon is opaque for the light at the conventional wavelength of 1064 nm. However, we do not have much experience on different wavelengths in our GW detector context. 2um wavelength is a strong candidate and is expected to be advantageous for absorptions in mirror coating than other wavelengths (e.g., 1550 nm). The key is the readiness of the technologies.

Technologies to be Developed for 2um Laser

Compatibility of Optics
- Faraday Isolator
- Efficient Photodiodes (~80% today)
- Modulators
- High power operation

Characteristics with Room Temperature Fused Silica
- Scattering loss (should ∝ $1/\lambda^2$)
- Absorption (CP, BS)
- Coating loss

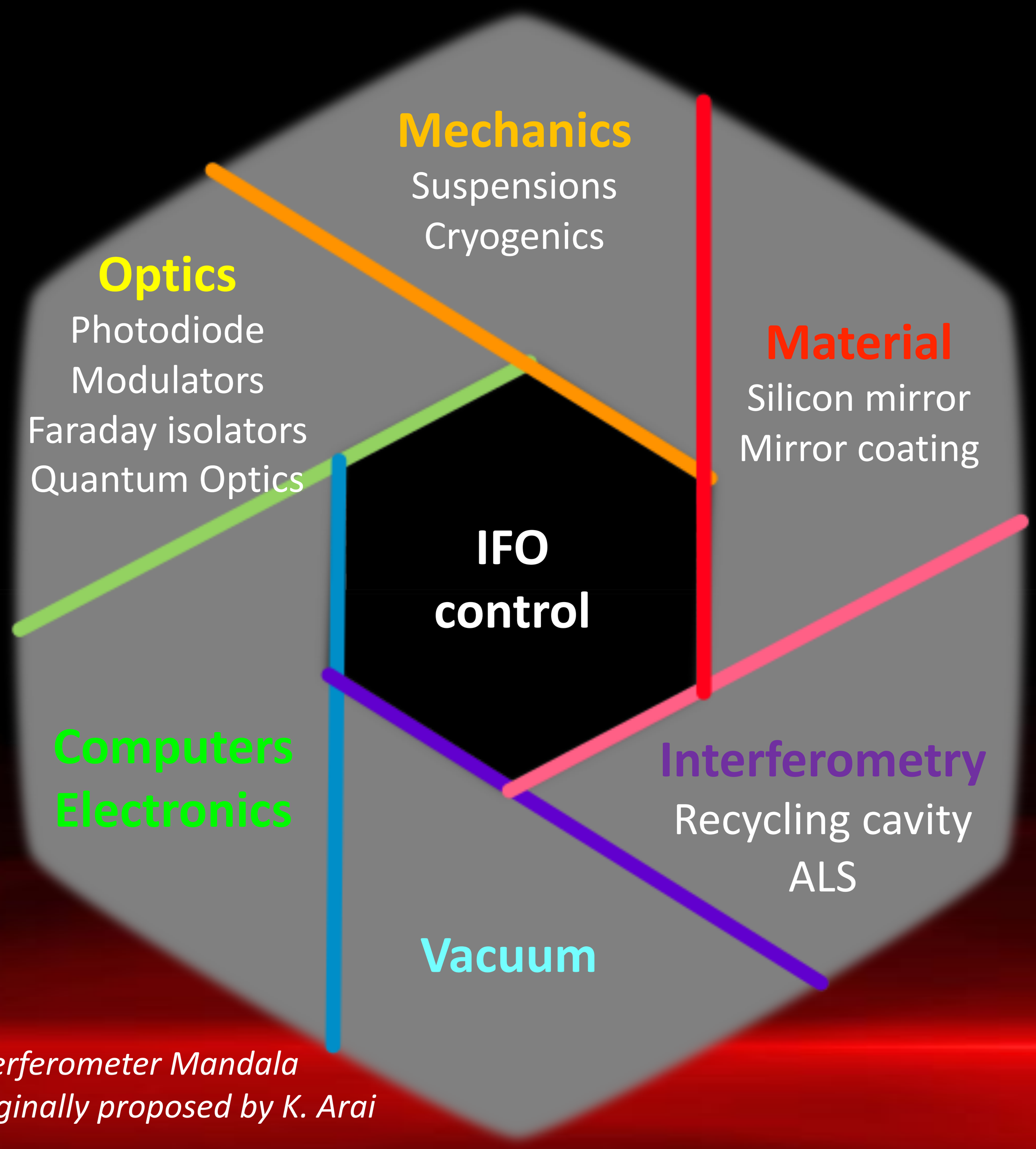
Interferometer technology
- How to do ALS?
- Squeezing?
- Parametric instability?

Workability
- Good sensor card, etc?

Relevant present and previous works
- Narrow linewidth 2um laser at ANU [1]
- Caltech prototype [2]
- There are more relevant researches for 1550 nm, for example,
  - Laser researches at AEI [e.g., 2, 3, 4] and Glasgow [5]
  - Squeezing experiments in AEI and Hamburg [5]
  - ET pathfinder (Maastricht) plan to use 1550 um
- We don't know enough to downselect the wavelengths

[1] D. P. Kapasi, Opt. Express Vol. 28, No.3 (2020) 3280
[2] R X Adhikari et al 2020 Class. Quantum Grav. 37 165003
[3] F. Meylahn et al., LIGO DCC-2001493 (2020)
[4] J. Steinlechner et al 2014 Class. Quantum Grav. **31** 105005
[5] M Mehmet, Opt. Express 19 (2011) 5763
[6] A. Spencer et al., LIGO DCC-G2001453 (2020)

Impacts on the GW Detectors are Significant



Interferometer Mandala
Originally proposed by K. Arai

The GW detectors are extremely complex instruments. Changing the laser wavelength impacts on most of the interferometer, especially Material, Mechanics, and Optics fields in the *interferometer mandala* (left figure).

To plan and design the next-generation detectors, interface between each mandala element must be understood as well as the technologies themselves.

R&D and prototyping must be undertaken in 2020s for this new technology to be ready for the next-generation detectors.

Experimental Plans at Cardiff University

We will prototype an Input Optics System to find out the :

- Planned laser generation by the ANU method [1]
- Mode cleaning
- Frequency stabilization
- Intensity stabilization
- Beam jitter characterization
- Investigate the properties with fused silica optics in room temperature

▪ High power operation is out of our scop for now.
▪ Table-top scale
▪ Looking forward to collaborating with other relevant groups!