



Science and  
Technology  
Facilities Council

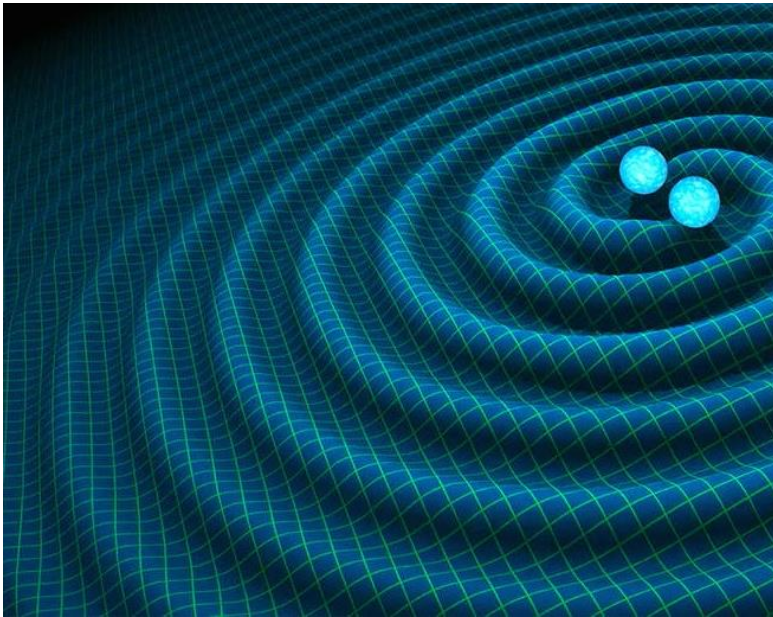
# Atom interferometry observatory and network

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15<sup>th</sup> February 2022

# AION Consortium

## Atom interferometry using strontium atoms

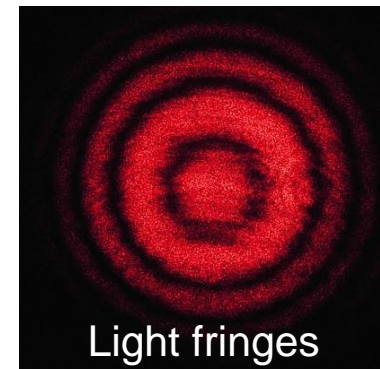
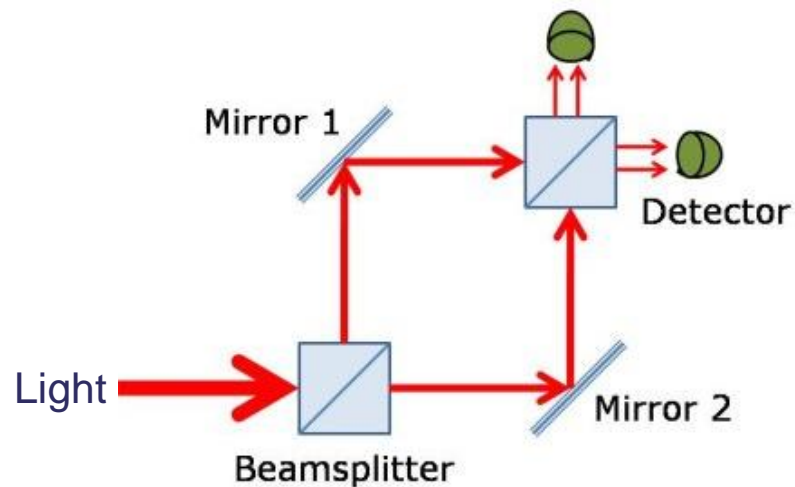


- Ultra-light dark matter
- Mid-frequency gravitational waves (0.01 Hz - few Hz)
- Variations in fundamental constants
- Fundamental physics principles

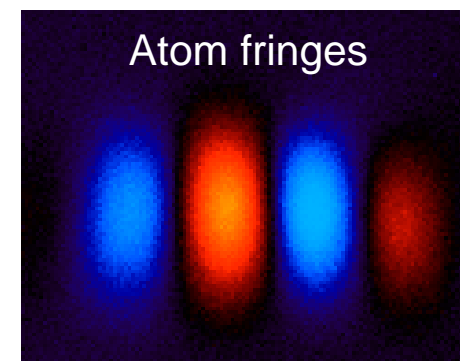
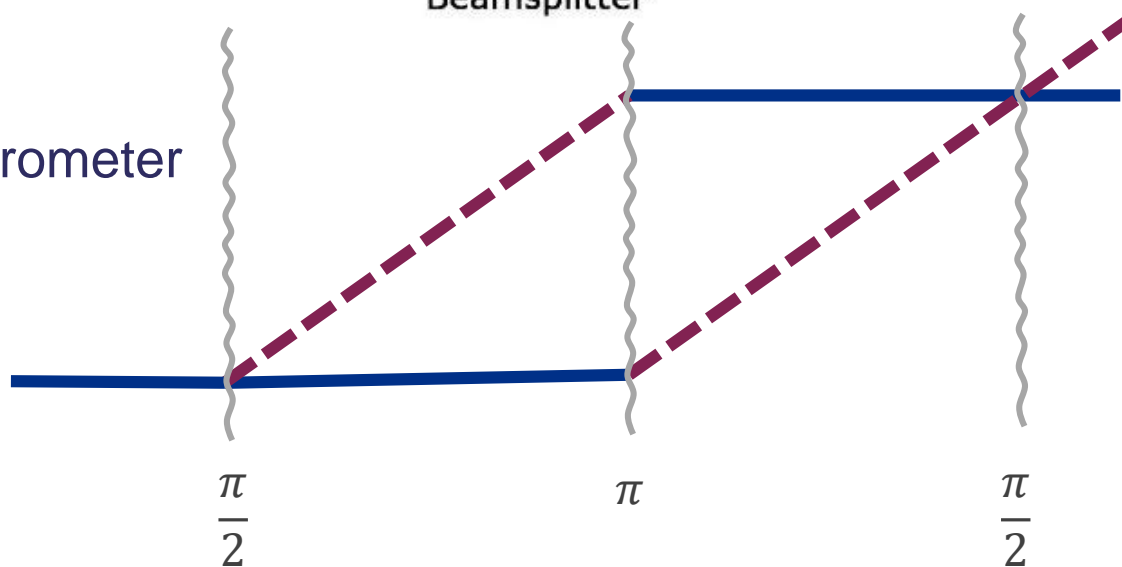


# Light vs. Cold Atoms: Interferometry

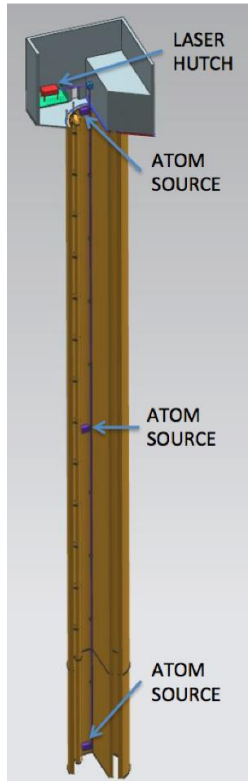
Light interferometer



Atom interferometer

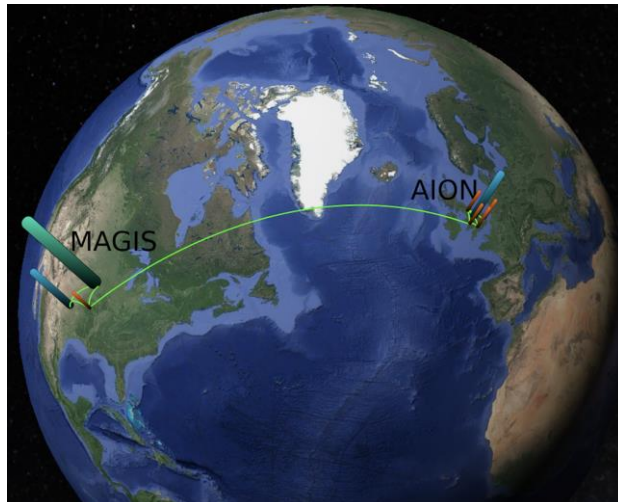


# Ground Based Large Scale AIs

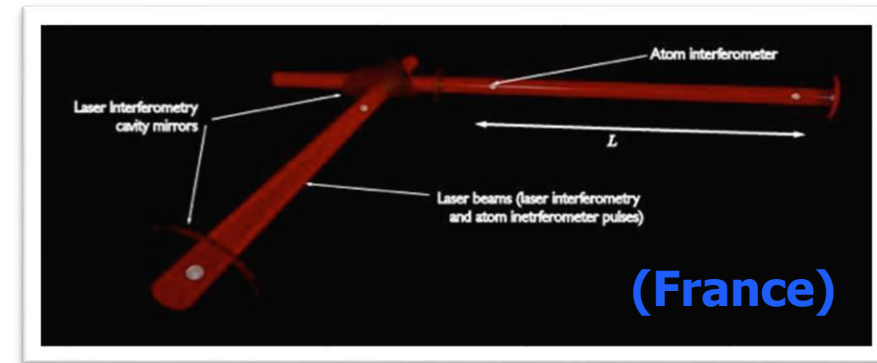


**MAGIS:** Terrestrial shaft detector using atom interferometer at  $O(100\text{m})$   
(US)

**AION:** Terrestrial shaft detector using atom interferometer at 10m –  $O(100\text{m})$  planned  
(UK)

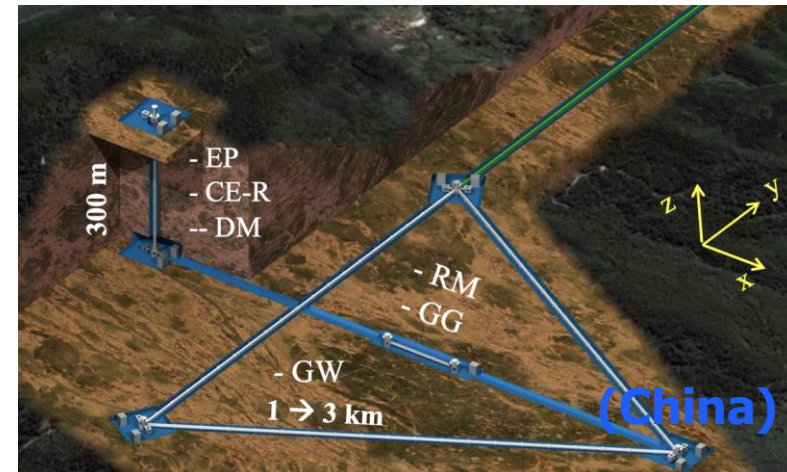


**MIGA:** Terrestrial detector using atom interferometer at  $O(100\text{m})$



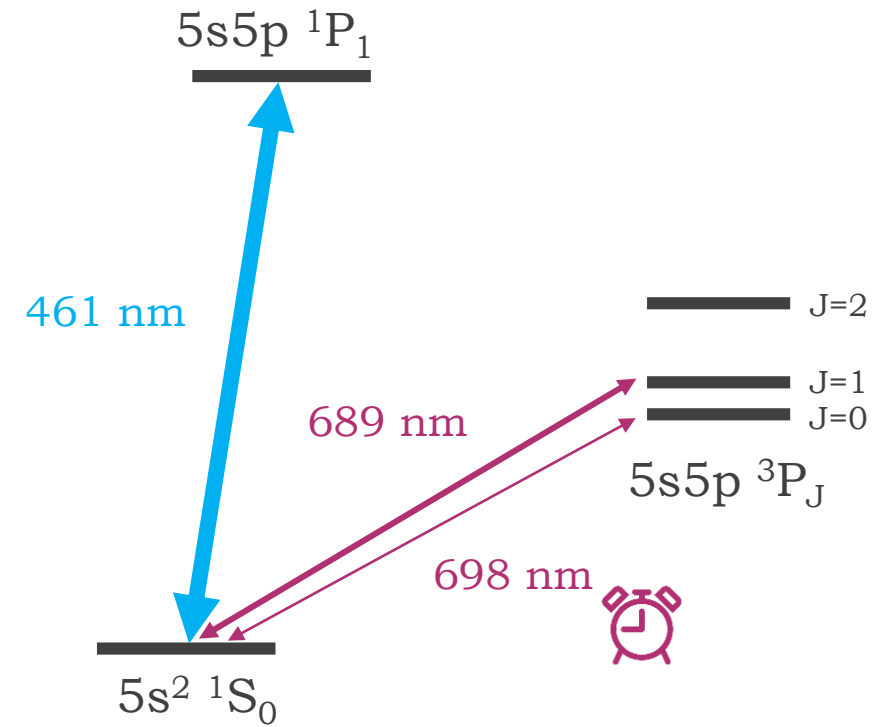
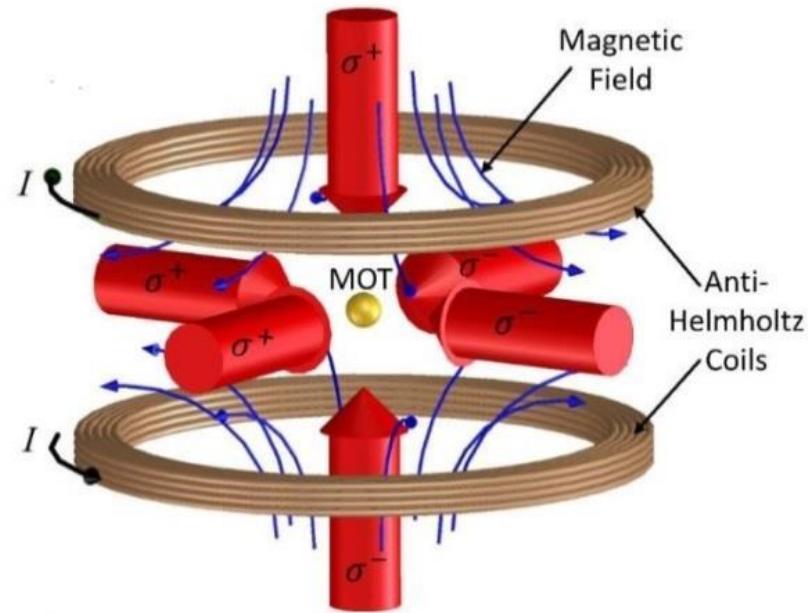
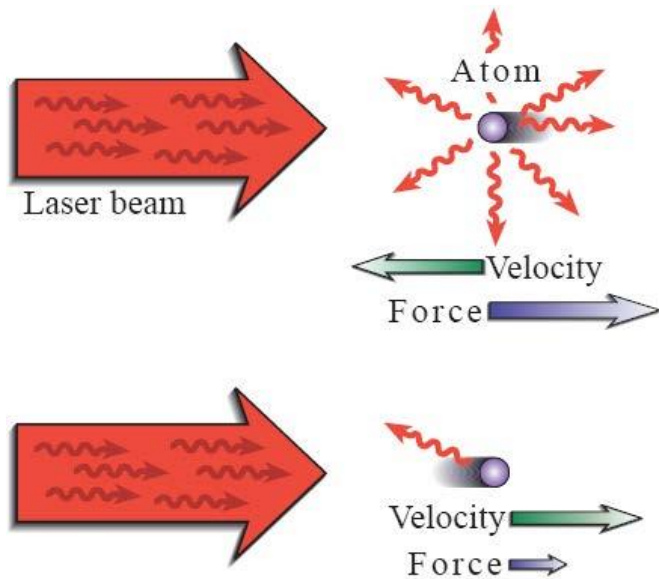
(France)

**ZIGA:** Terrestrial detector for large scale atomic interferometers, gyros and clocks at  $O(100\text{M})$

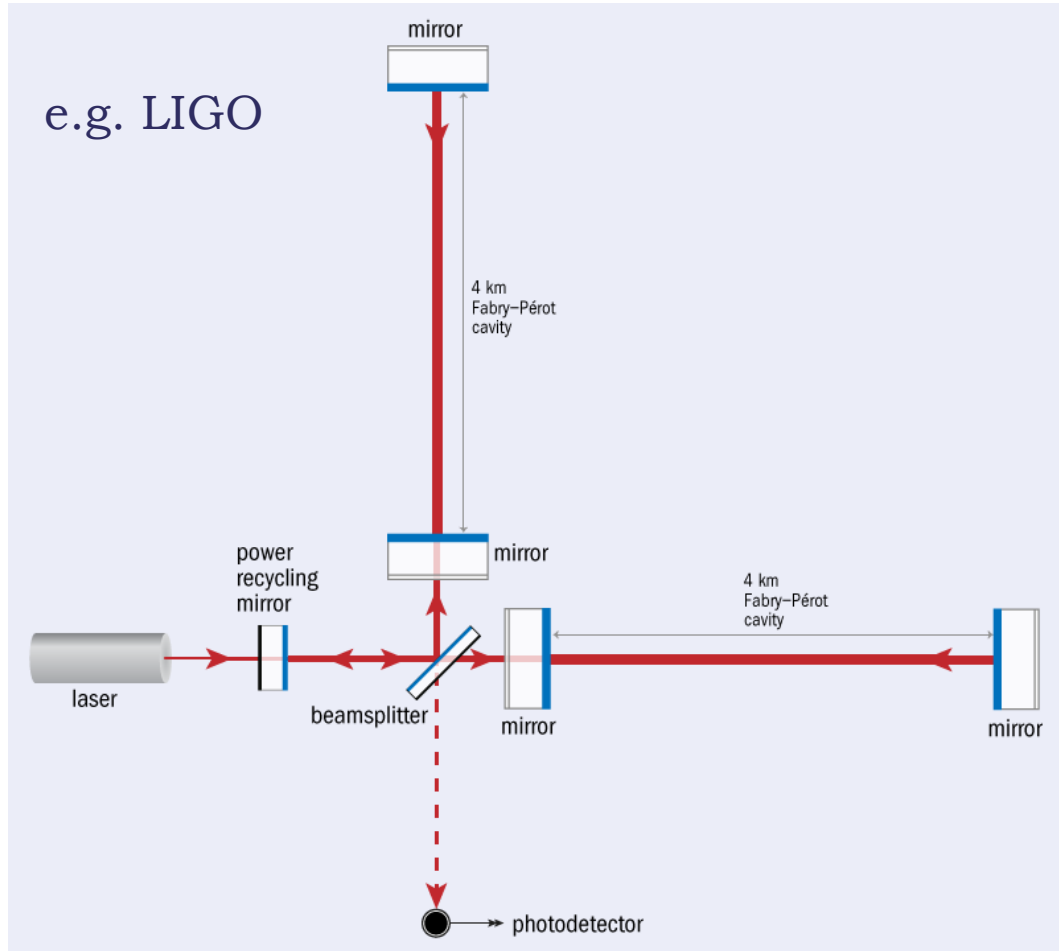


(China)

# Atom Interferometry

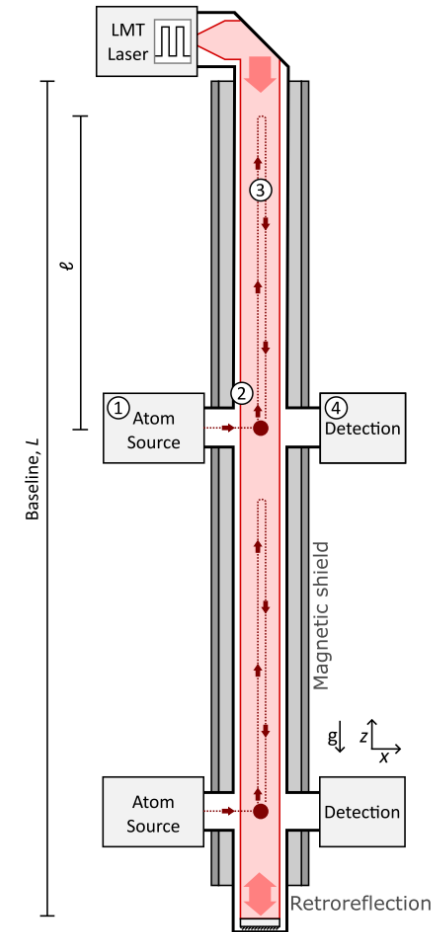
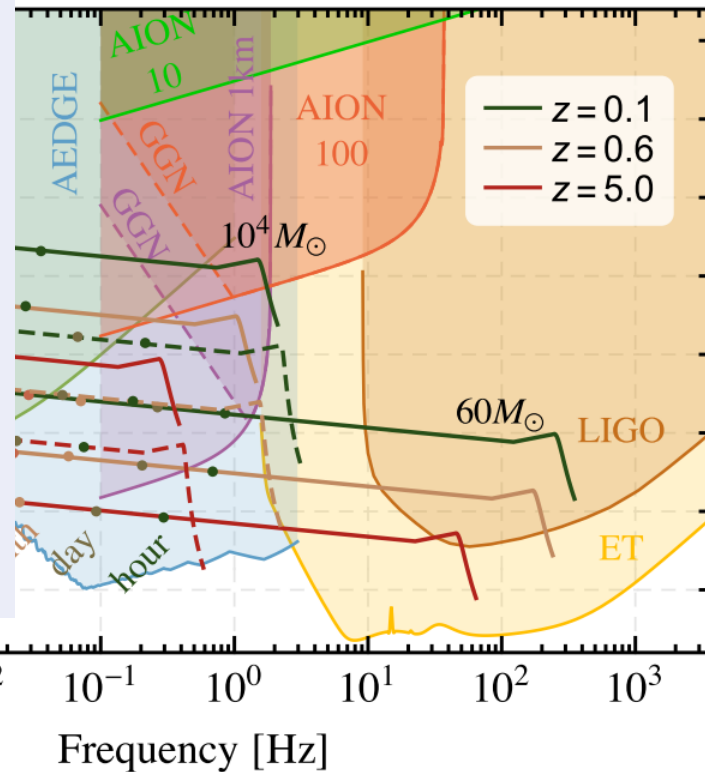


# Gravitational wave detection

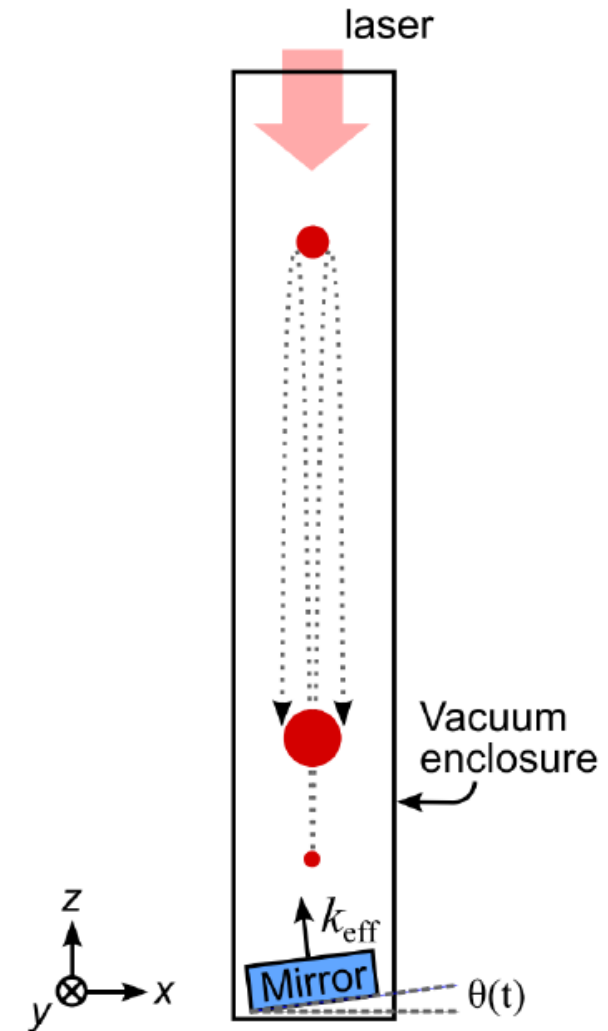
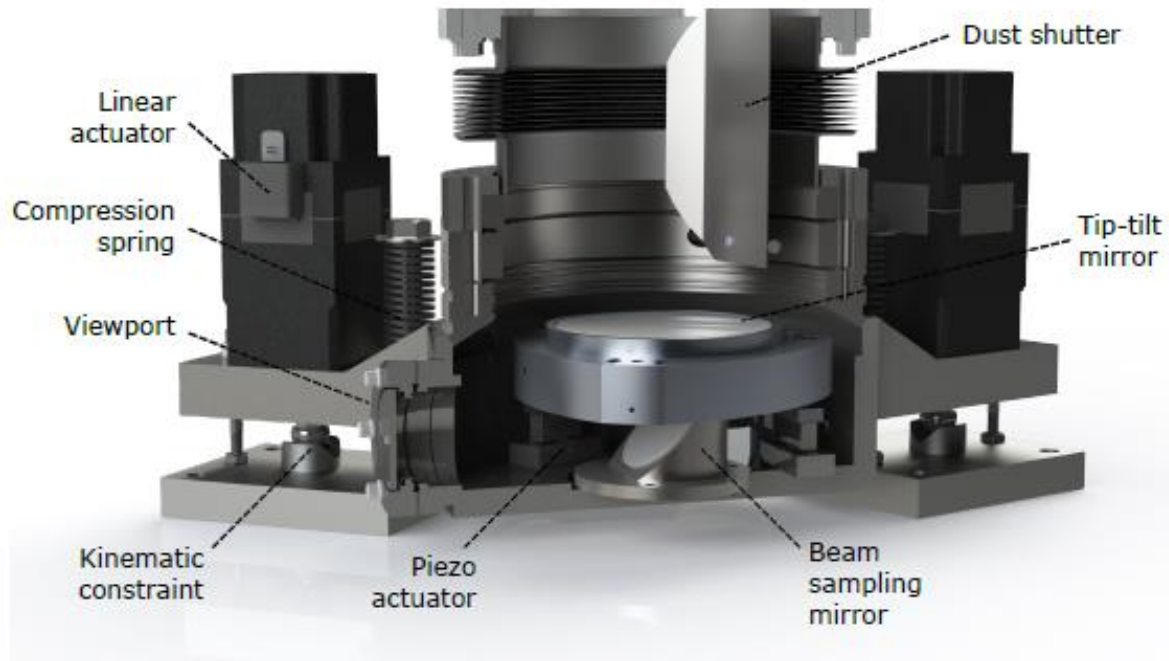


each interferometer

<https://physicsworld.com/a/ligo-detects-first-ever-gravitational-waves-from-two-merging-black-holes/>



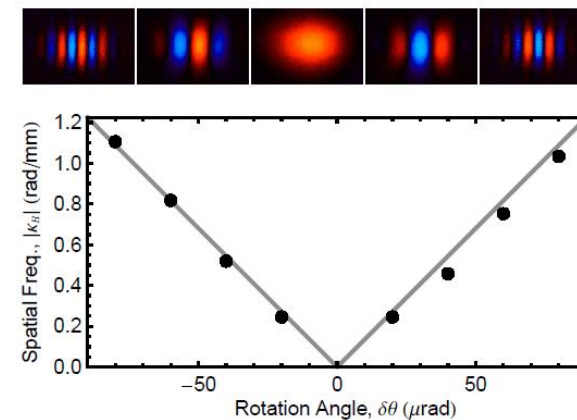
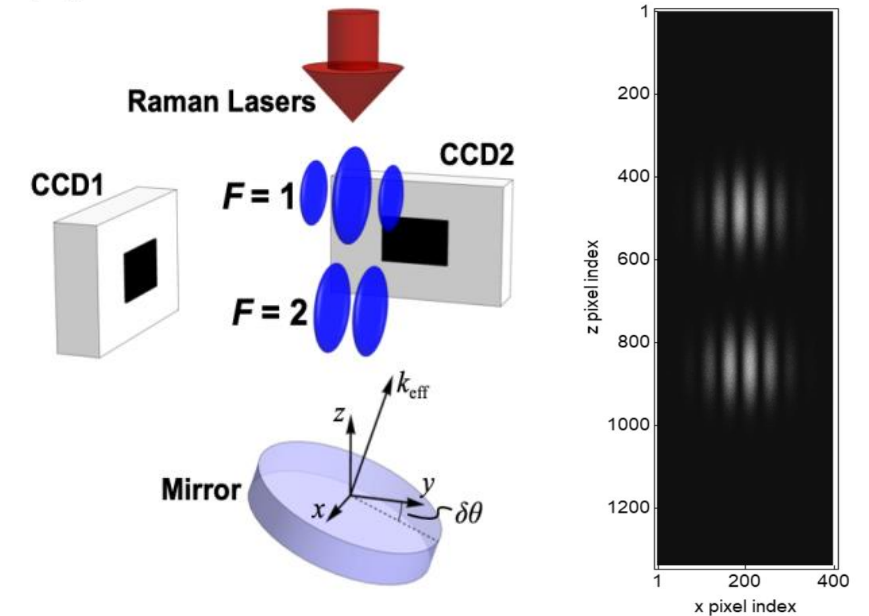
# Detection system



# Phase Shear Readout

- Analogous to optical phase shear plate
- The phase shear in atomic case:
  - Tilting the retro-reflection mirror at the last  $\pi/2$  pulse
  - Spatial fringes on atom cloud of both excited and ground state
- These spatial fringes encodes interferometer phase allowing for single shot phase and contrast readout

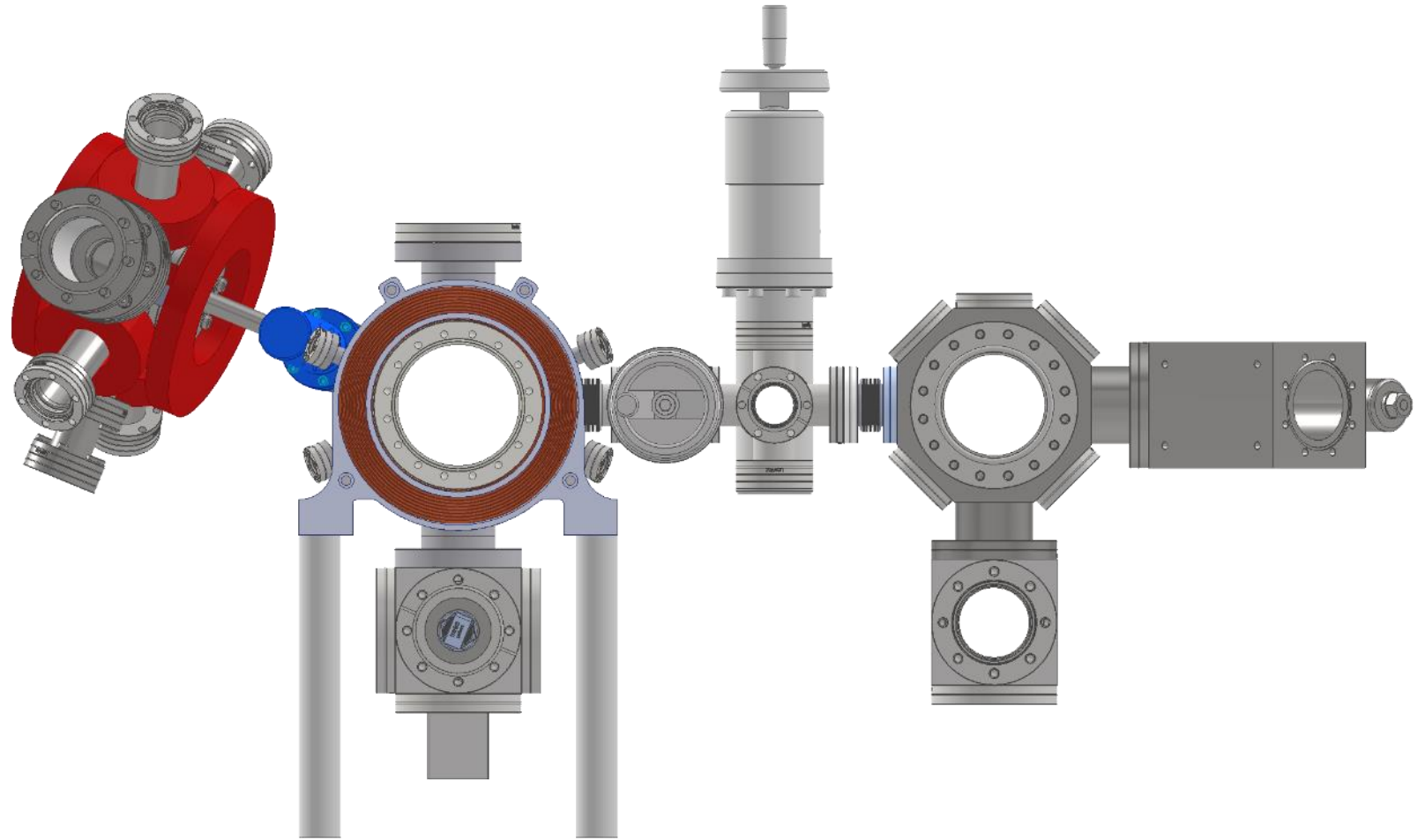
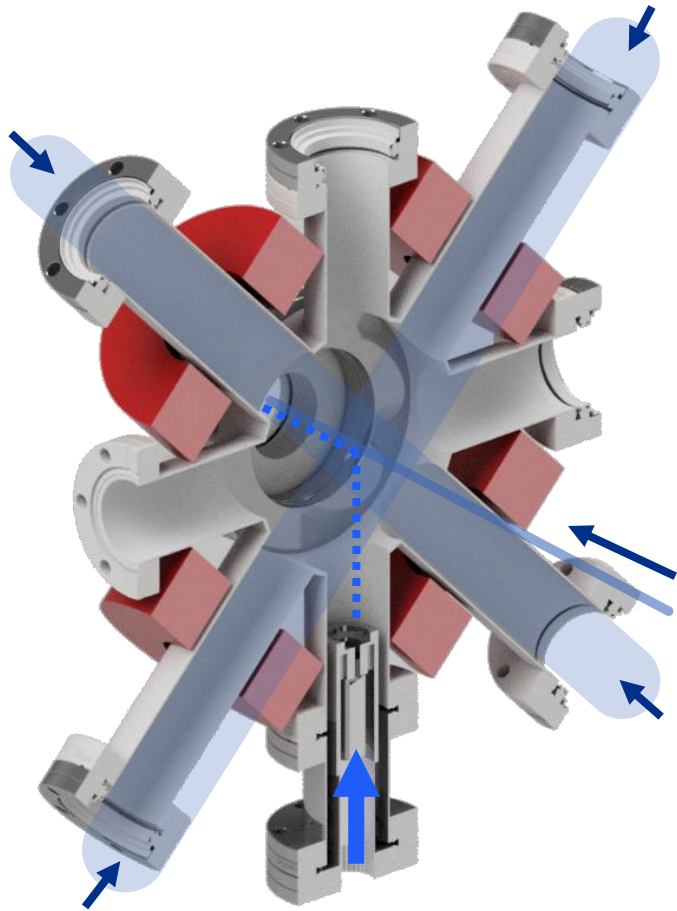
$$P(\mathbf{r}) = \frac{1}{2} + \frac{C}{2} \sin(\boldsymbol{\kappa} \cdot \mathbf{r} + \phi_0)$$



<http://dx.doi.org/10.1103/PhysRevLett.111.113002>



# AION in the lab



~ 1.5 m

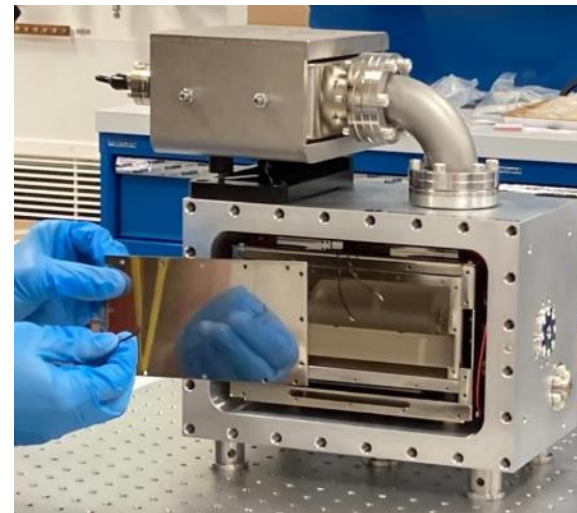
# Sr Lab (R100)

- Significant equipment investment
- 25 m<sup>2</sup> lab space
- Temperature and humidity control
- Neighbouring cold-atoms lab (rubidium)
- Numerous space facilities



# Skills

- Optics
- Ultra-high vacuum
- Computer Aided Design
- Electronics
- Experiment modelling
- Programming
- Troubleshooting
- Communication
- Collaboration



# Team



+ AION & MAGIC collaborators





# Ultra-light dark matter couplings

## Linear coupling

