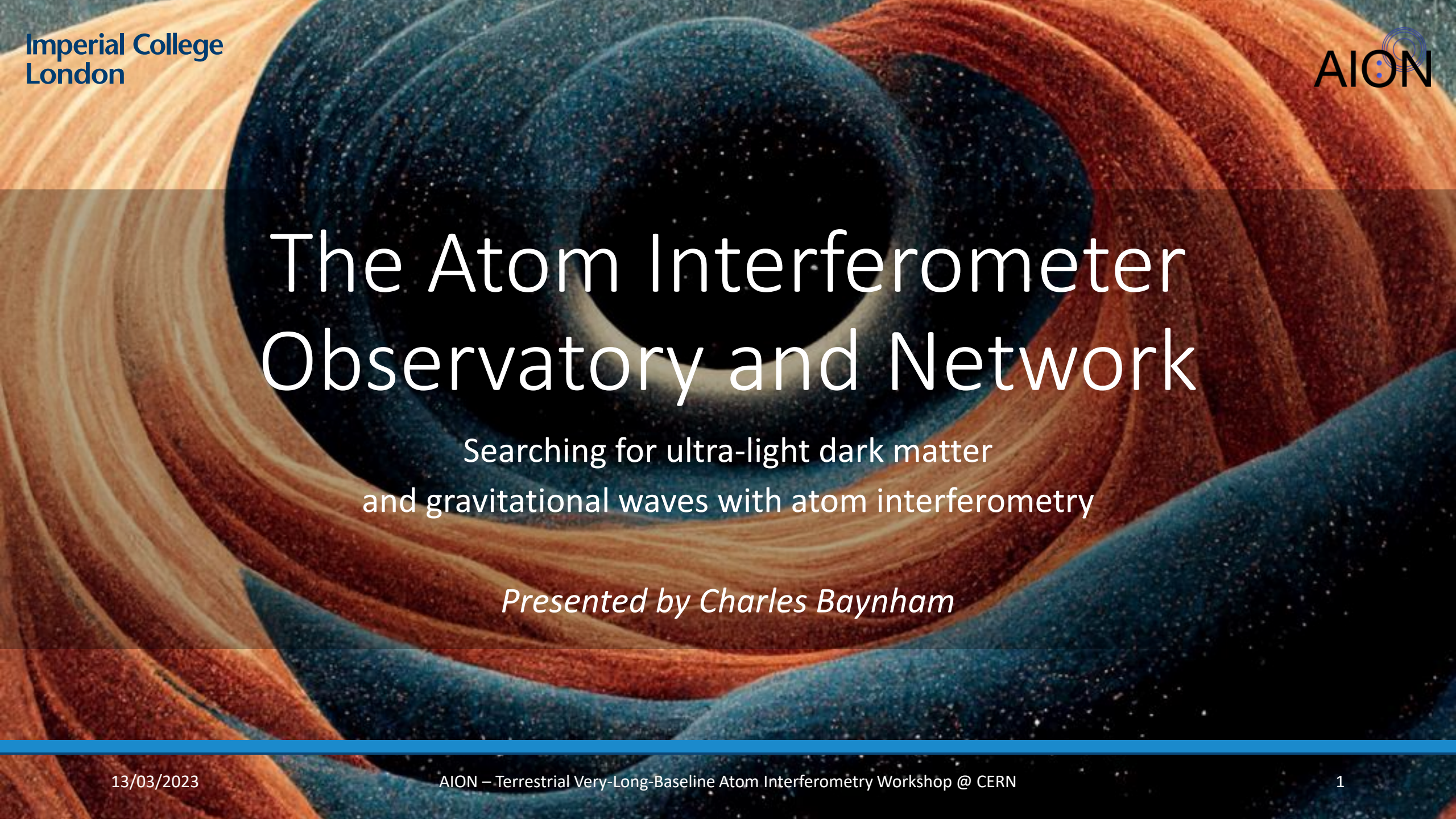


Imperial College London

AION

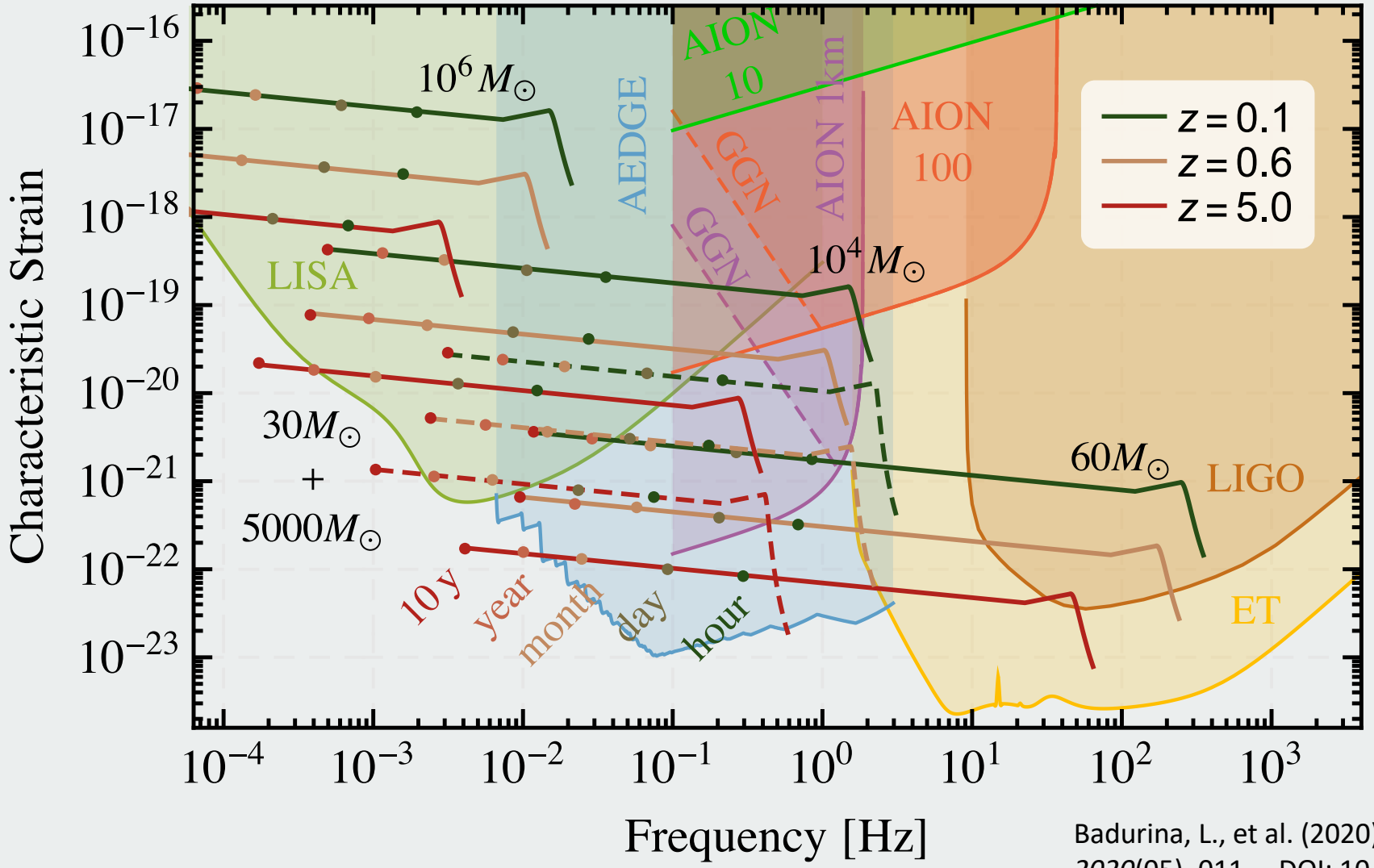
The Atom Interferometer Observatory and Network

Searching for ultra-light dark matter
and gravitational waves with atom interferometry

Presented by Charles Baynham

1. Our goals
2. Our quantum technology
3. The AION philosophy
4. The 10m detector

AION's goals

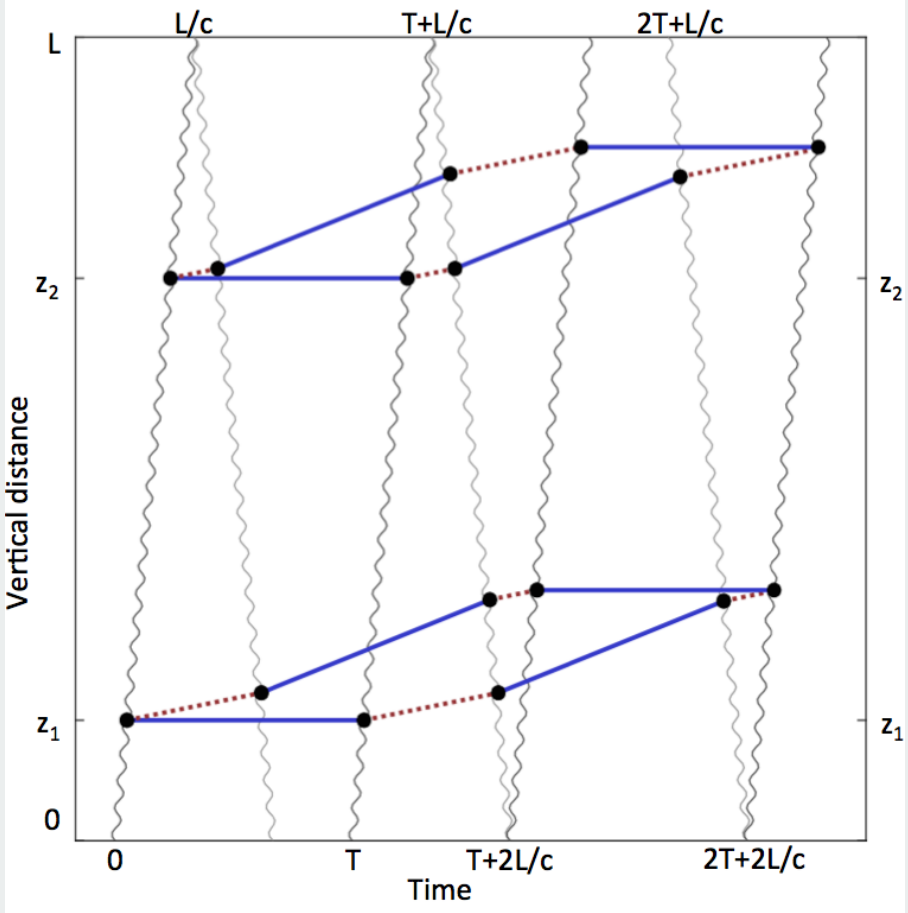


Detectable black hole mergers by mass and redshift

We plan a 100m, km-scale and, ultimately, space-based detector (AEDGE) to fill the gap

Badurina, L., et al. (2020). *Journal of Cosmology and Astroparticle Physics*, *2020*(05), 011. DOI: 10.1088/1475-7516/2020/05/011

What do we need?



A differential atom interferometer with $N_{LMT} = 1$

The atoms spend significant time in the metastable state

Sensitivity $\propto N_{LMT} \times T^{\frac{5}{4}}$

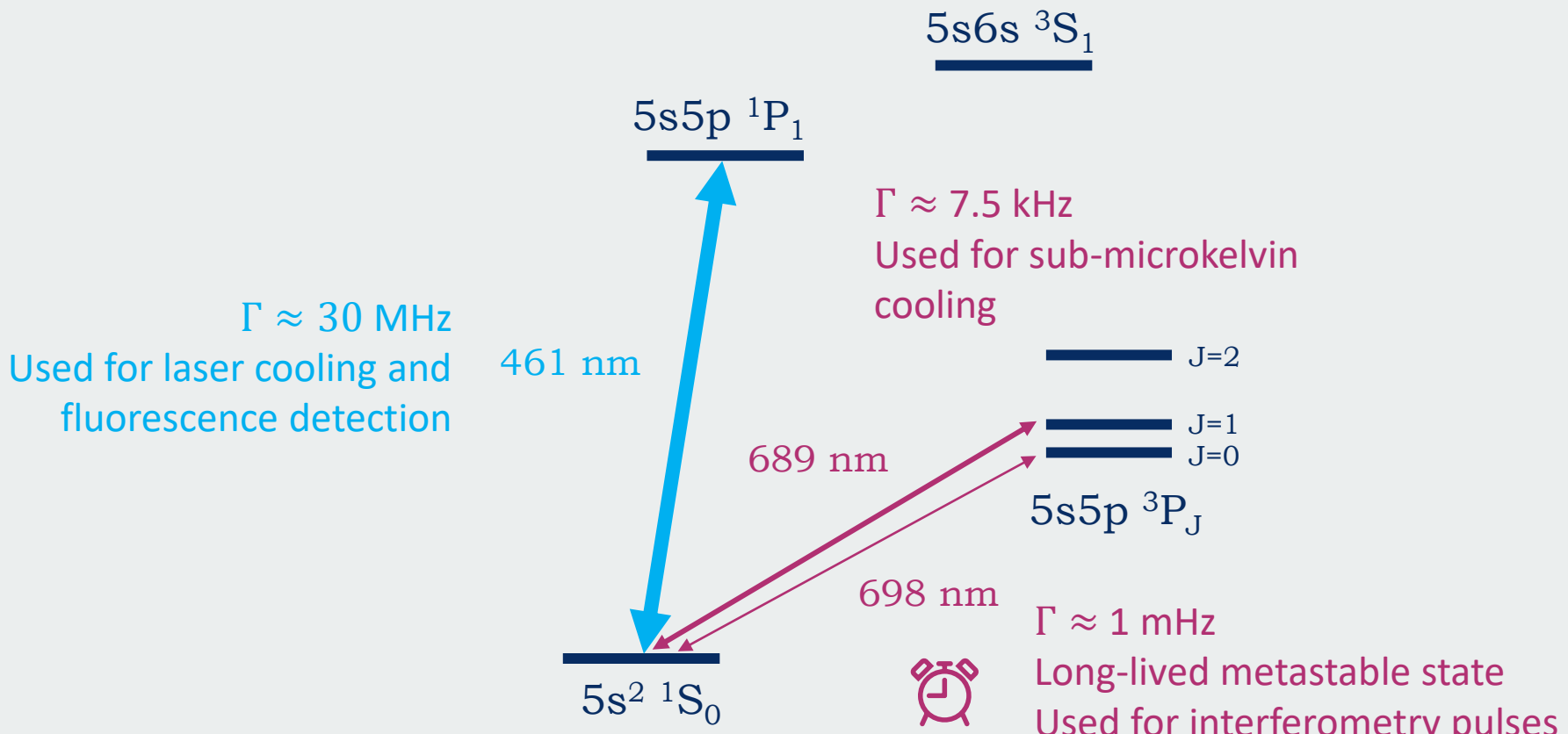
Blue = atoms in ground state

Red = atoms in metastable state

Grey = π or $\frac{\pi}{2}$ light pulses

Badurina, L., et al. (2020). *Journal of Cosmology and Astroparticle Physics*, *2020*(05), 011. DOI: 10.1088/1475-7516/2020/05/011
Graham, Peter W., et al. *Physical review letters* 110.17 (2013): 171102. DOI: 10.1103/PhysRevLett.110.171102
Rudolph, Jan, et al. *Physical review letters* 124.8 (2020): 083604. DOI: 10.1103/PhysRevLett.124.083604

Strontium

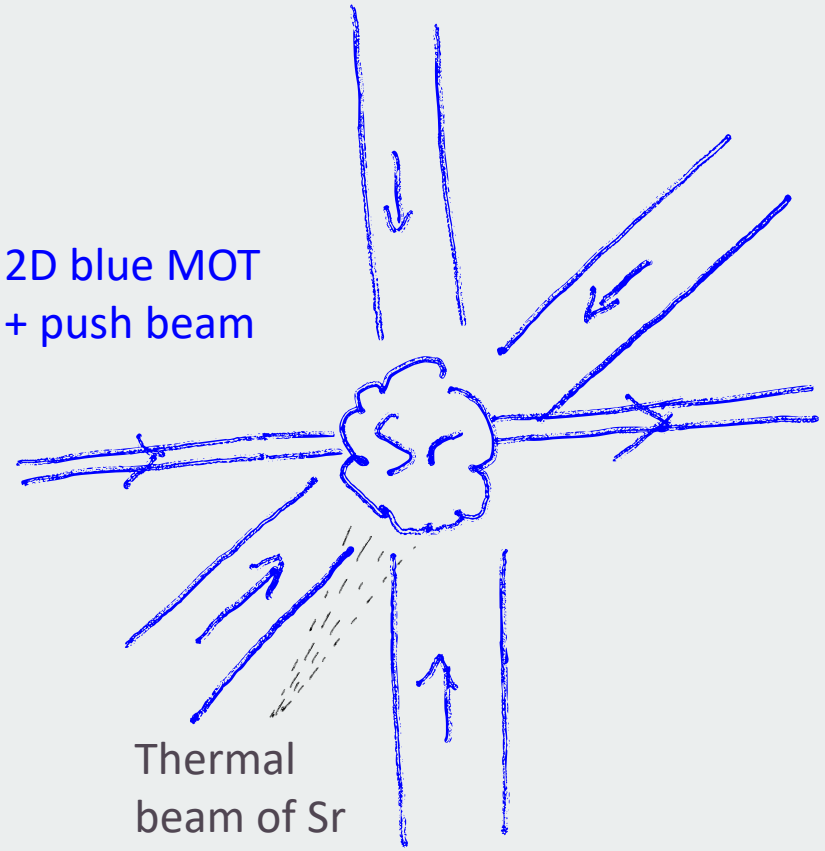

5s6s $^3S_1$
5s5p $^1P_1$
Γ ≈ 7.5 kHz
Used for sub-microkelvin cooling
Γ ≈ 30 MHz
Used for laser cooling and fluorescence detection
461 nm
J=2
J=1
J=0
689 nm
5s5p ^3P_J
698 nm
Γ ≈ 1 mHz
Long-lived metastable state
Used for interferometry pulses
5s^2 $^1S_0$

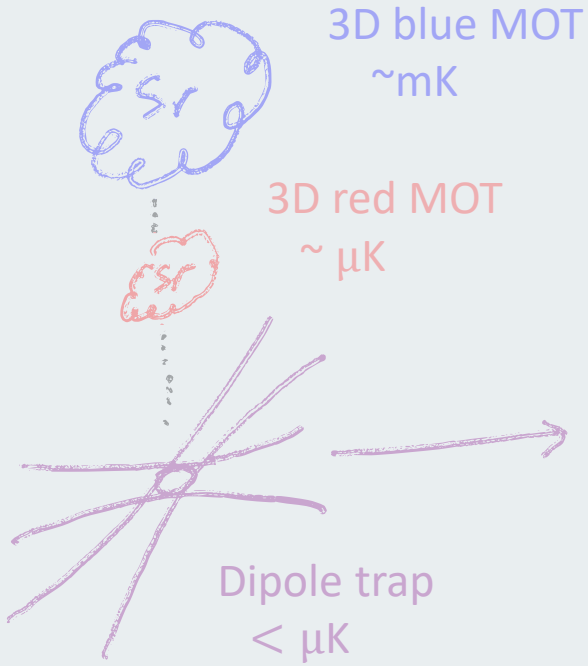
The AION sidearm

Chamber 1

Chamber 2

Beamline





Launch and
LMTs

PSR Image: Sugarbaker, Alex, et al. *Physical Review Letters* 111.11 (2013): 113002. DOI: 10.1103/PhysRevLett.111.113002
Simulations: Chen, X., et al. "AtomECS" *arXiv preprint arXiv:2105.06447* (2021).

How do we increase our sensitivity?

More atoms

High flux
Efficient cooling
Continuous loading

Longer flight

Low temperatures
Atom optics

Larger momentum split

Low temperatures
Laser frequency stability
Pulse wavefront quality

More resolution

Squeezed states
Interleaved interferometers

More reliability

Scalable engineering
Centralized infrastructure

The AION philosophy

Centralized infrastructure

- UHV systems
- Stable lasers
- Experimental control
- Optical systems

Distributed development

- Atom transport / launch
- Prototype 10m differential interferometry
- MAGIS networking
- State squeezing
- Instrument engineering
- Large momentum transfer
- Sensitivity / phenomenology studies

→ Integration to detector

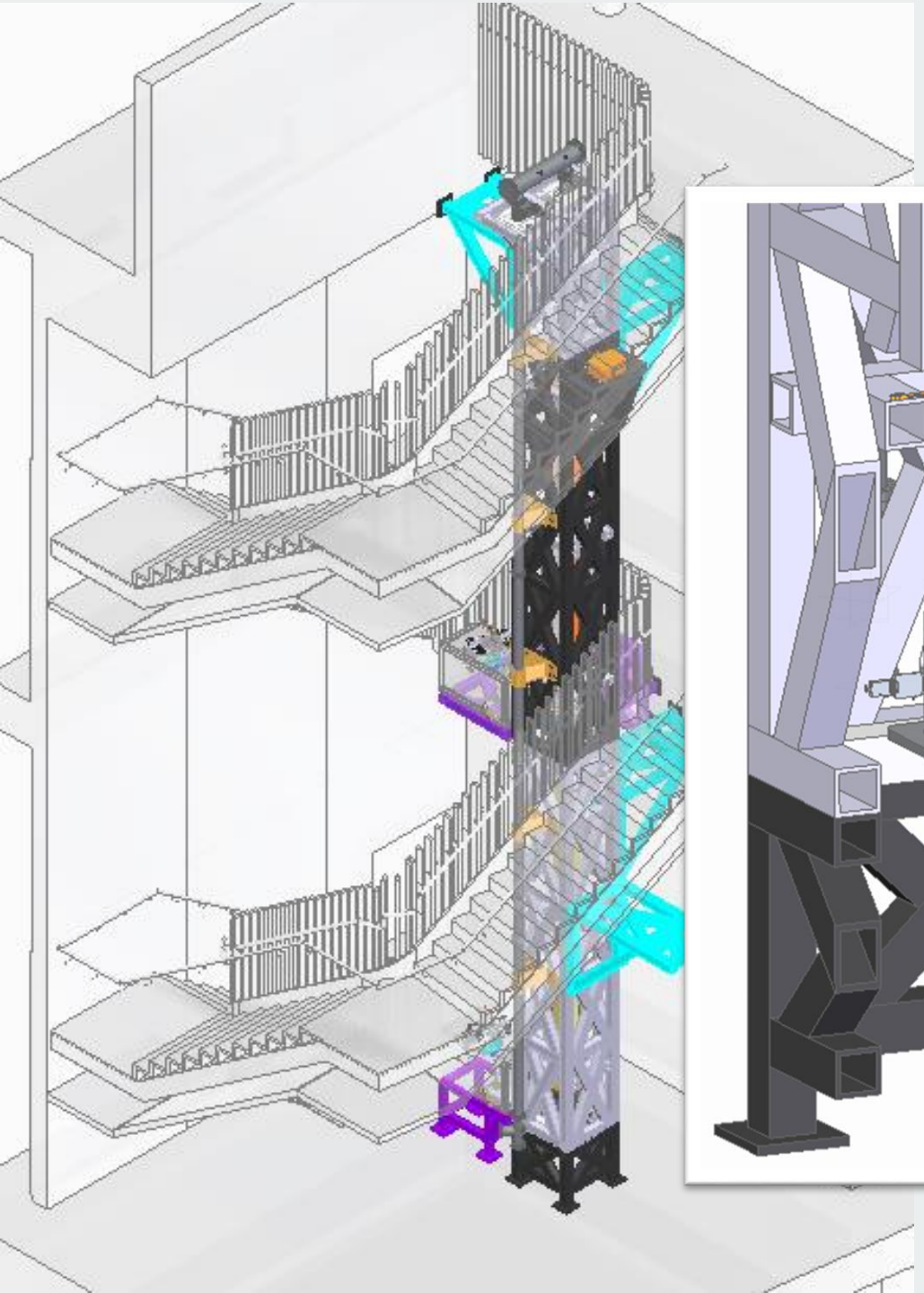
Cambridge July 2022

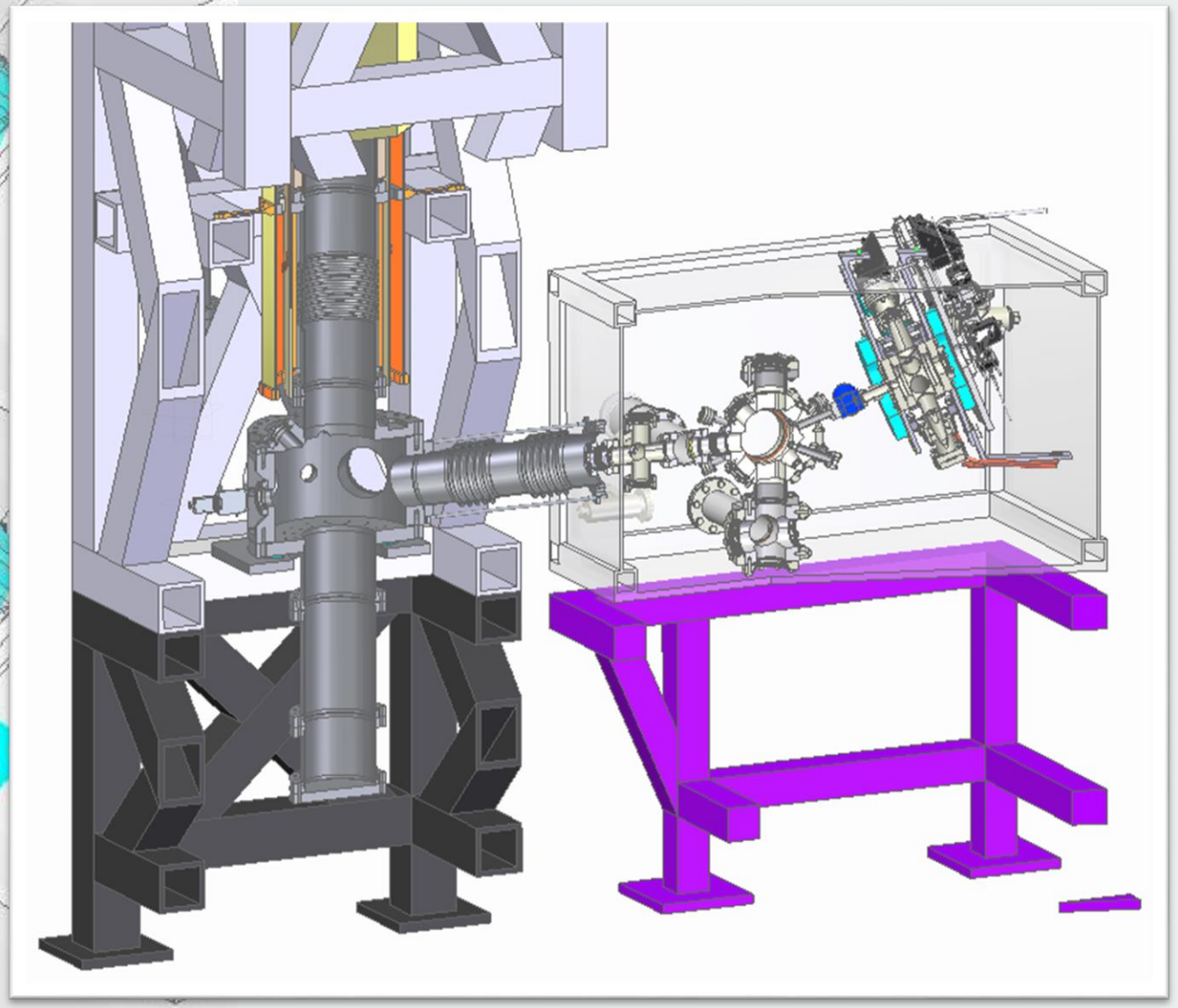
Oxford September 2022

Birmingham July 20

AL October 2022

AION-10





Two interferometers

Lasers supplied from adjacent low-noise laser lab

Interferometry beam first runs the length of the instrument for beam clean-up

Delivery optics targeting 1/1000 λ flatness

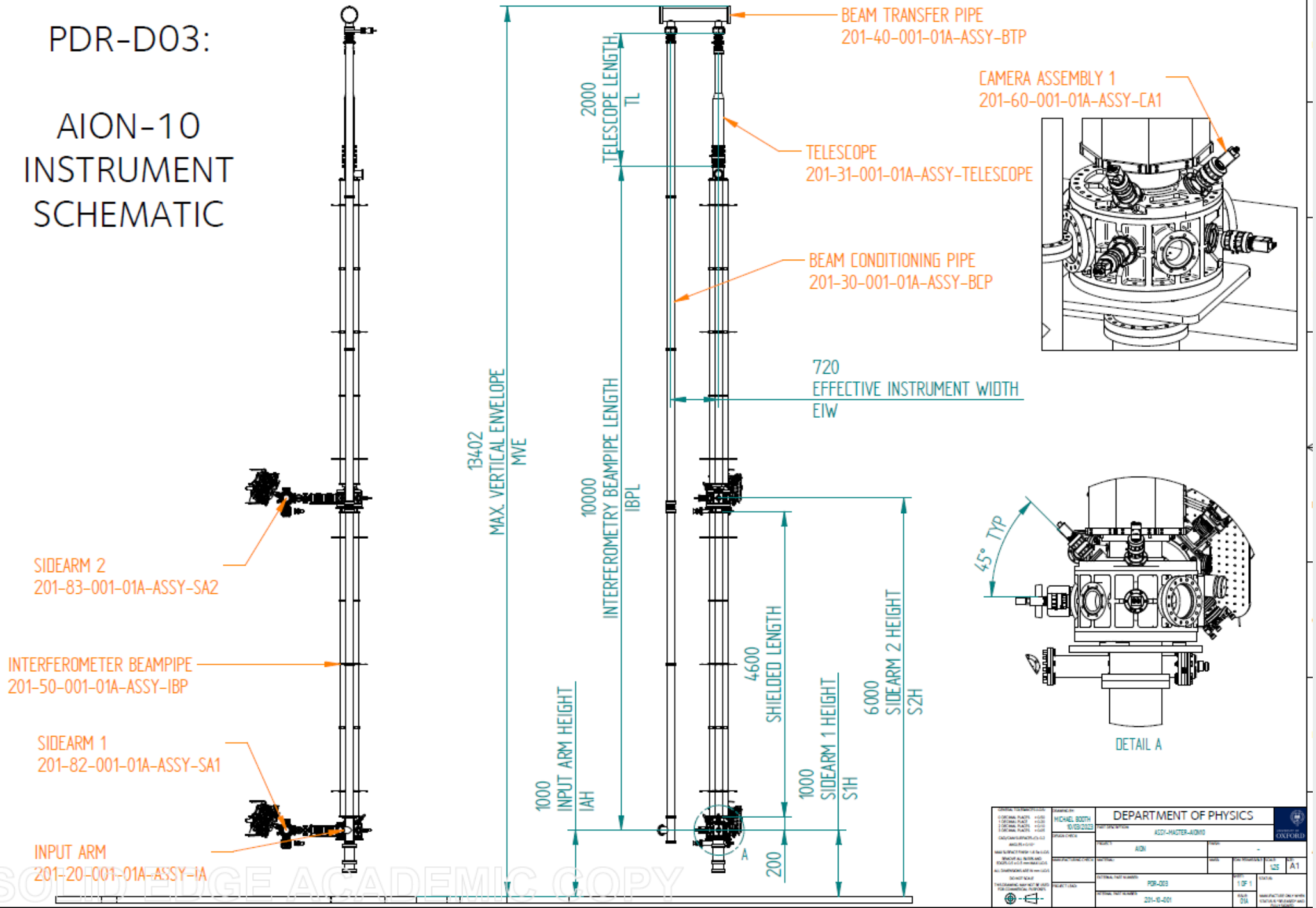
Magnetic shielding and coils:

- Tuneable field from 10mG to 10G
- < 5mG inhomogeneity
- Noise density $< 1\mu G/\sqrt{Hz}$

Retroreflection phase-shear mirror based on MAGIS design

PDR-D03:

AION-10 INSTRUMENT SCHEMATIC



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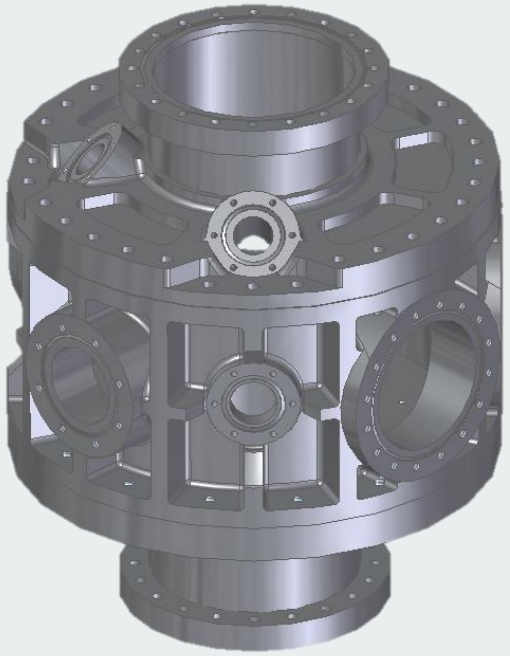
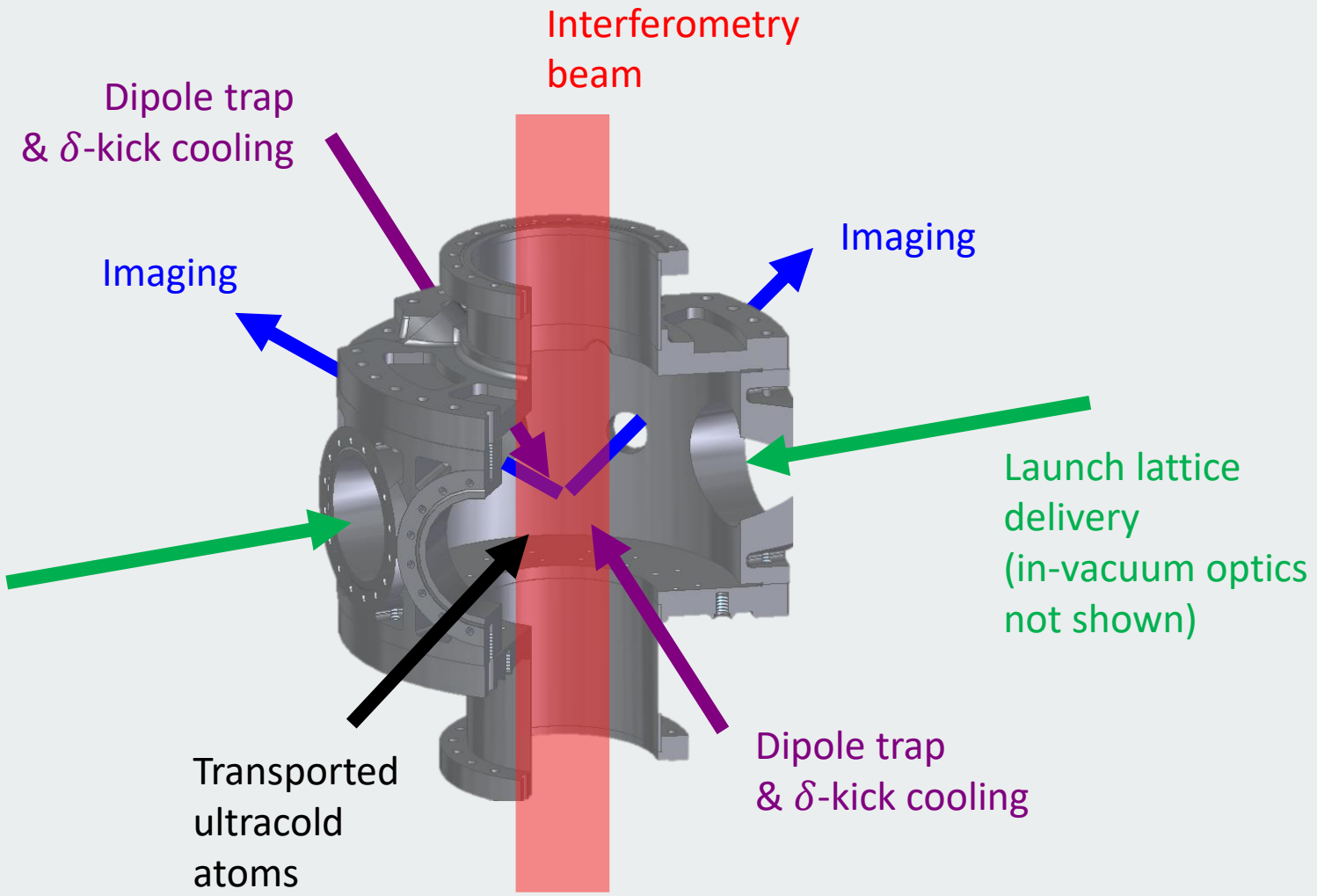
AION-10

AION





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