Laser Fabrication, Sensors and Instrumentation for Earth Observation

Capabilities of the Fraunhofer Centre for Applied Photonics

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Outline

- What is Fraunhofer UK and Fraunhofer Centre for Applied Photonics?
- Introduction to Fraunhofer CAP laser fabrication facilities
- Example optical systems for EO and what can laser fabrication offer?
- Cold atom sensors and why they can impact EO
- Conclusions

What is Fraunhofer UK and Fraunhofer Centre for Applied Photonics?

- A legally independent affiliate in the Fraunhofer network
- A UK, not for profit, research and technology organisation, RTO. Based in Glasgow.
- Providing professional applied R&D services in photonics
- Active in many application sectors
- Working collaboratively with industry (incl. ESA) to translate technology into products

Quantum Technology - palm sized stabilized laser developed for Optocap LTD. **Renewable Energy** - Fh-CAP develops wind speed instrumentation for the renewables industry. **Condition monitoring** - oil monitoring system developed with SensorWorks LTD. **Healthcare** - Fh-CAP is developing a diagnostic instrument to combat anti-microbial resistance.

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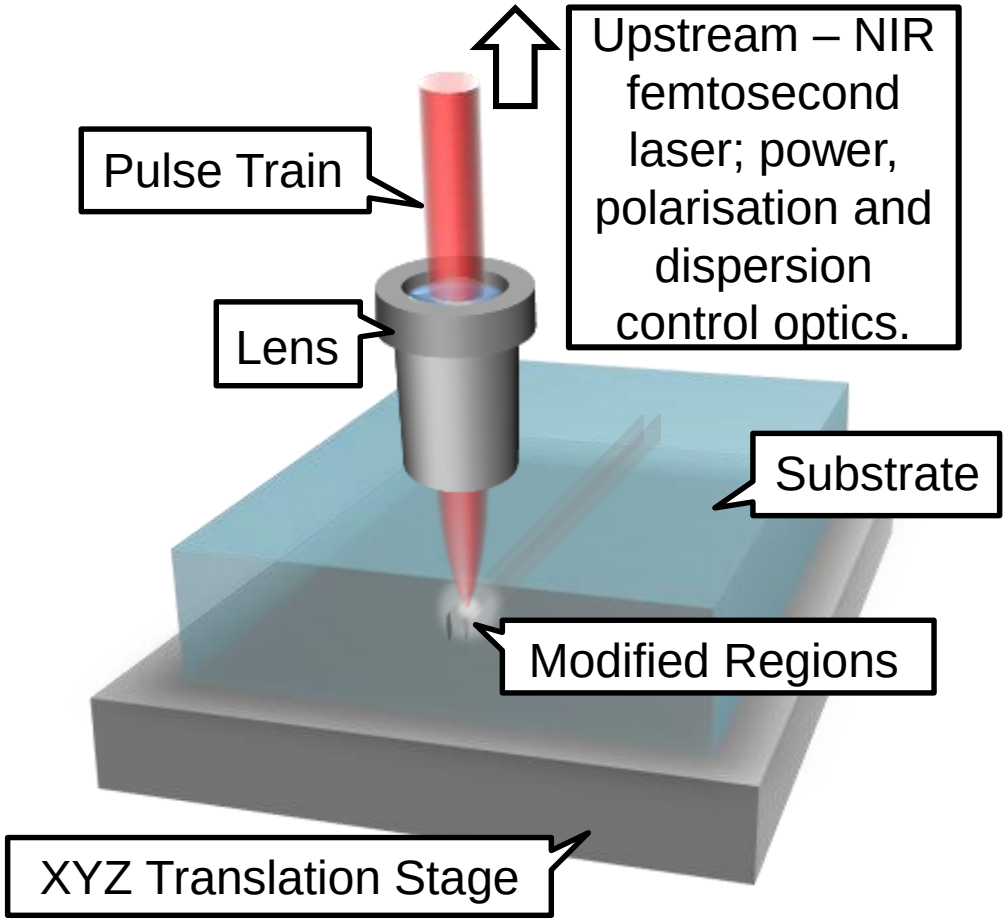
Fraunhofer CAP Laser Fabrication Facilities

- Multiple sources available, chiefly NIR femtosecond fibre laser – 1030nm, 250 fs to >10 ps, single shot to 40 MHz, up to 20 μJ pulses, up to 10W.
- High precision stages with large working area – 200 by 200 mm with submicron precision.
- Direct Laser writing – surface and subsurface structuring (ULI, Ultrafast laser Inscription)



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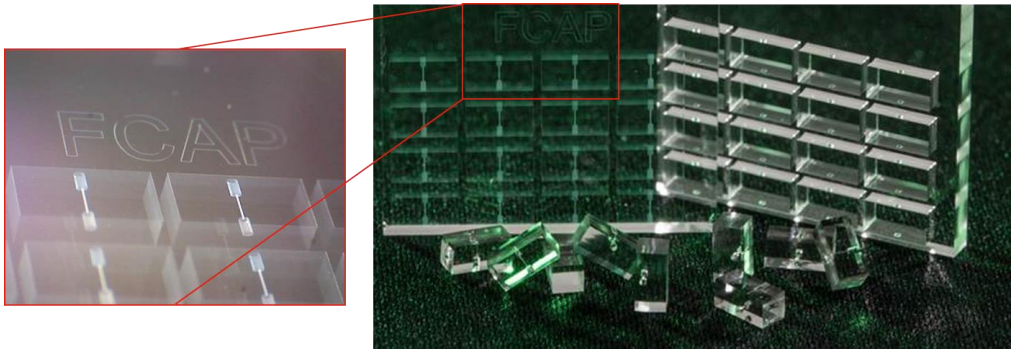
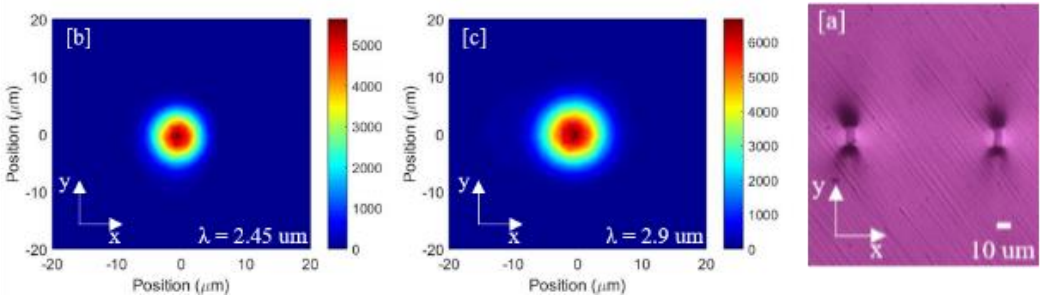
What Can Fraunhofer CAP Laser Fabrication Facilities Offer the EO Community?

- Induce index contrast – waveguide lasers, couplers, splitters, fan-outs, shaping
- Induce differential etching – micro-fluidics, micro-optical components
- Both – opto-fluidics, waveguides coupled to micro-optical components
- Laser welding including dissimilar materials?
- Low HAZ laser processing?





Opto-fluidic Sensor Chips – 2 by 4 mm size opto-fludic chips consisting of central microfluidic channel crossed by directly written waveguides for absorption spectroscopy. **Chalcogenide Glass Waveguides** – Suited for Mid-IR photonic circuits.

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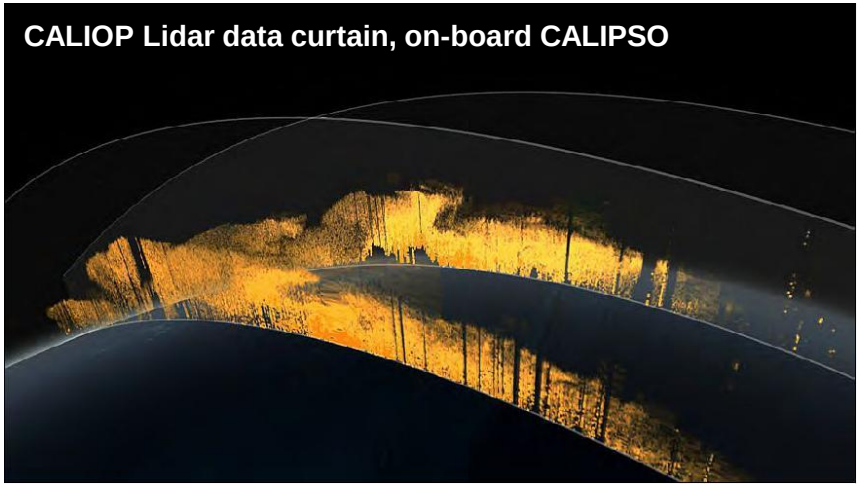
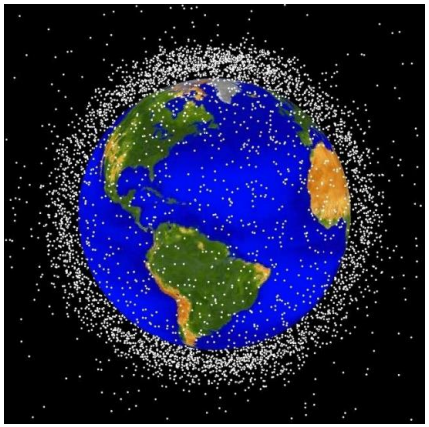
EO optical systems - Lidar

- EO data – climate and atmospheric conditions, vegetation cover, 3D mapping etc…
- Tracking of debris is a critical issue that a laser based lidar system can solve.
- Constellation position tracking and monitoring is critical for earth observation missions where precise knowledge of all satellites is required to generate the data.





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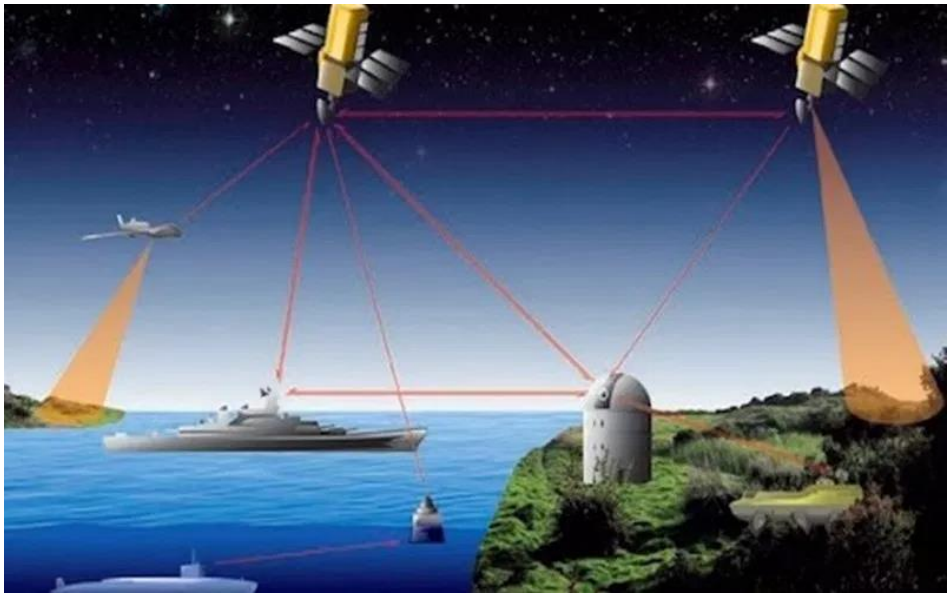
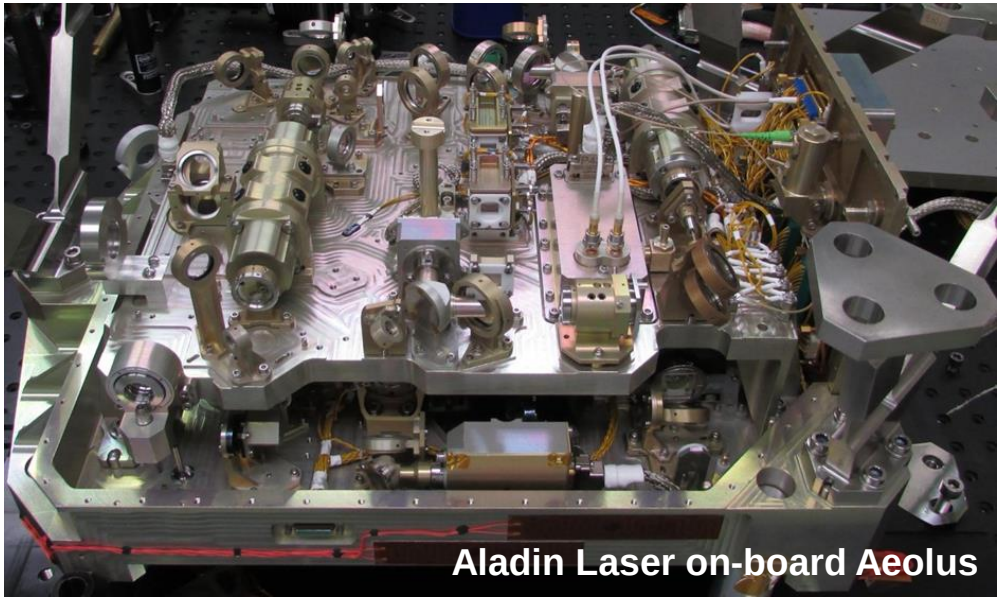
EO optical systems - Optical Communication

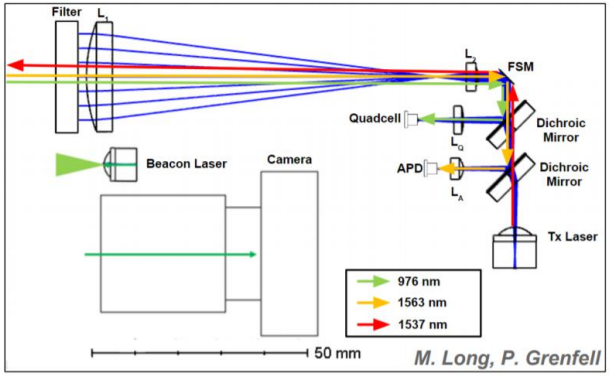
- Optical communications offers a route to high capacity data transfer with security.
- Critical for a range of Earth observations missions where bandwidth and storage limit the collection of high resolution images/large datasets.
- Satellite-satellite and satellite-HAPS links are practical methods for small satellites to offload information where communications can be completed by standard methods.

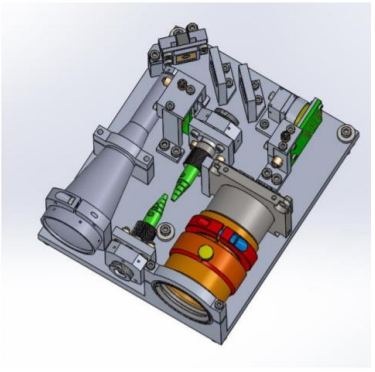


Areas For Innovation

- Optical communication systems are reliant on a range of free-space optics components in order to deliver performance.
- There is the prospect to replace these components with compact and robust monolithic modules.
- Reduce system complexity and SWaP leading to reduced costs and increased uptake.


Aladin Laser on-board Aeolus





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Solutions by Laser Fabrication

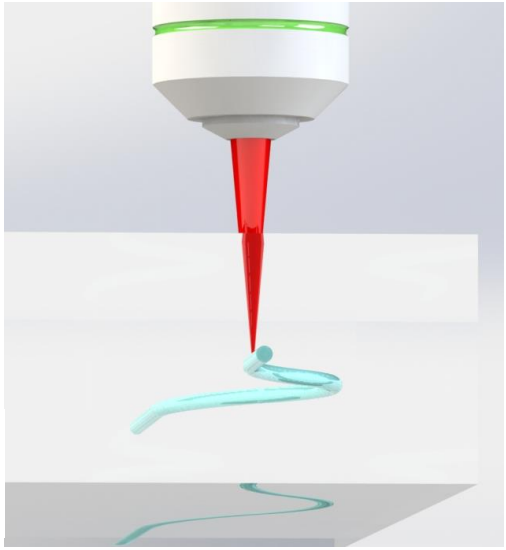
- Novel approach for Photonic Integrated Circuits (PIC) for EO – common substrates and prospects for hybrid integration.
- Disruptive to the existing approaches used in space – predominantly free-space optics.
- Provides same functionality with increase robustness & reliability and reduced SWaP.

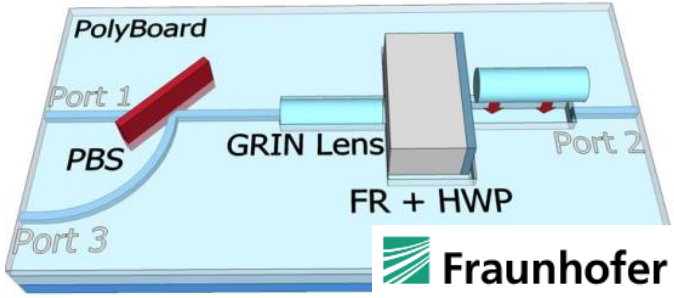
PowerPhotonic

OPTOSCRIBE

optocap

Innovate UK





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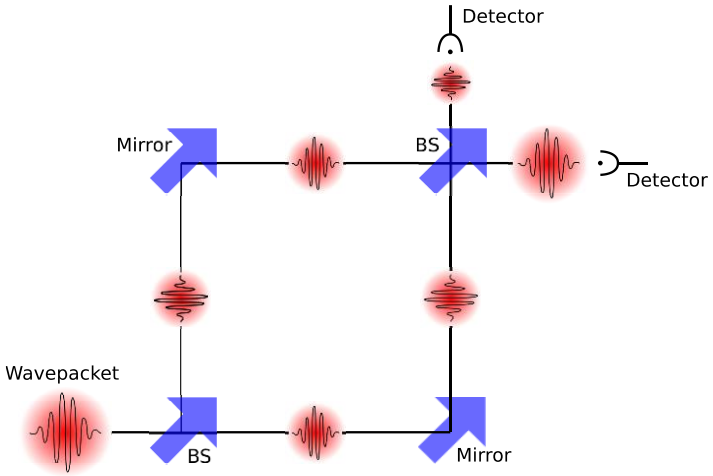
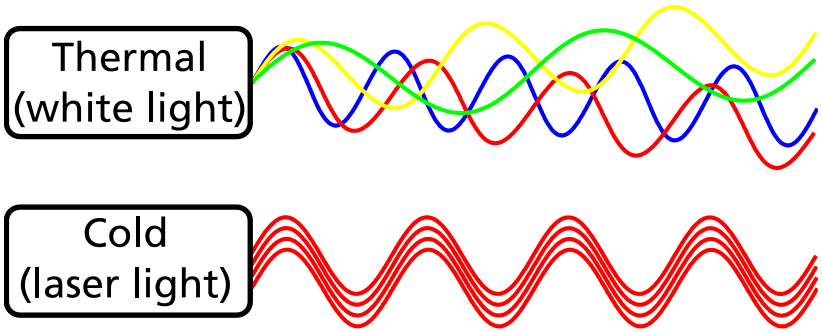
Why cold atoms/ what are cold atoms

Cold atom interferometry

- Increase in sensitivity offered by interference of matter rather than optical waves.
- Atom propagates & interferes while light acts as the beamsplitter & mirror.
- Cool atoms to just above absolute zero by reducing atom's kinetic energy.
- Allows atoms to be trapped and precisely manipulated.





Cold atoms v thermal atoms

Advantages

- All atoms in phase (coherent)
- Long coherence time
- Ease of manipulation & control

Disadvantages

- Reduced atom number

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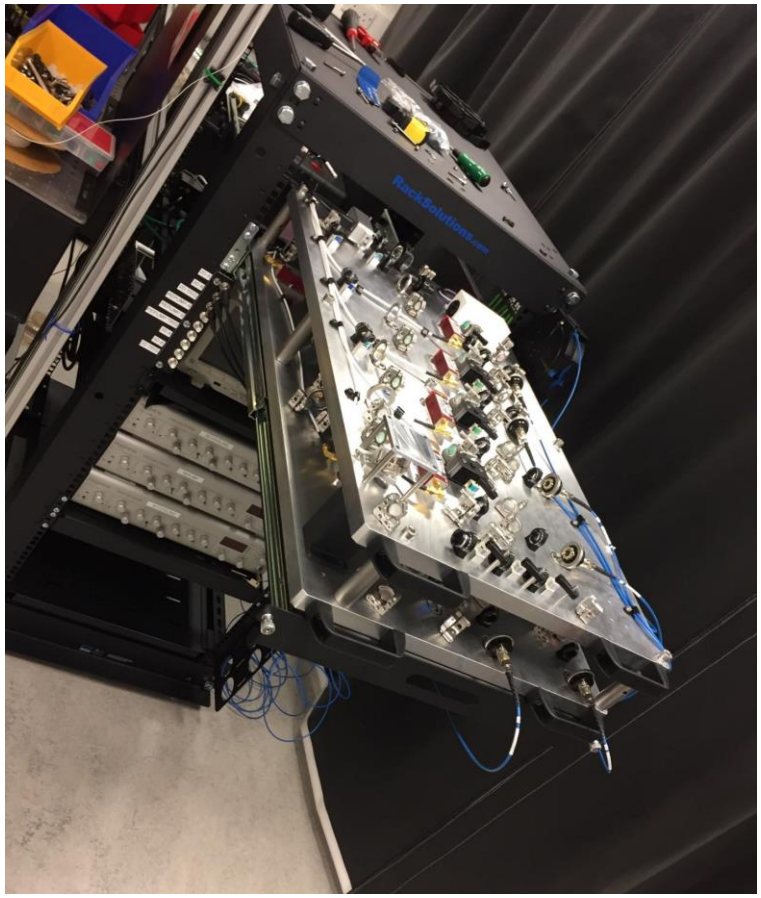
Fraunhofer CAP Cold Atom Projects – inertial sensing

Innovate UK funded project to develop high-flux source of cold atoms for inertial sensing

- Full rubidium cooling system
  - Beam delivery optics
  - Fibre delivery system
  - Sequencing and timing electronics
  - Low overall system SWaP
- Further development being explored



AIRBUS ColdQuanta PA Innovate UK

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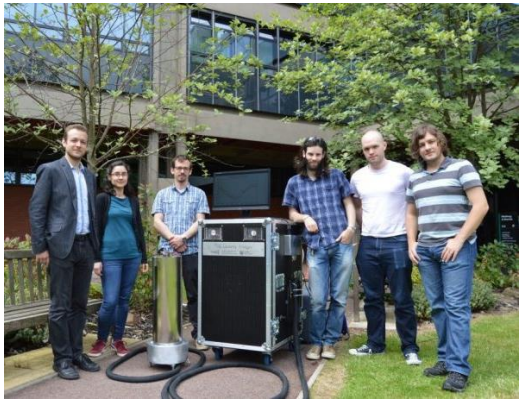
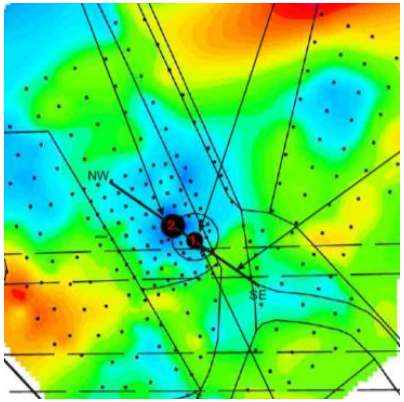
Fraunhofer CAP Cold Atom Projects – gravity sensing

Involved in an Innovate UK funded project to develop a quantum gravity sensor

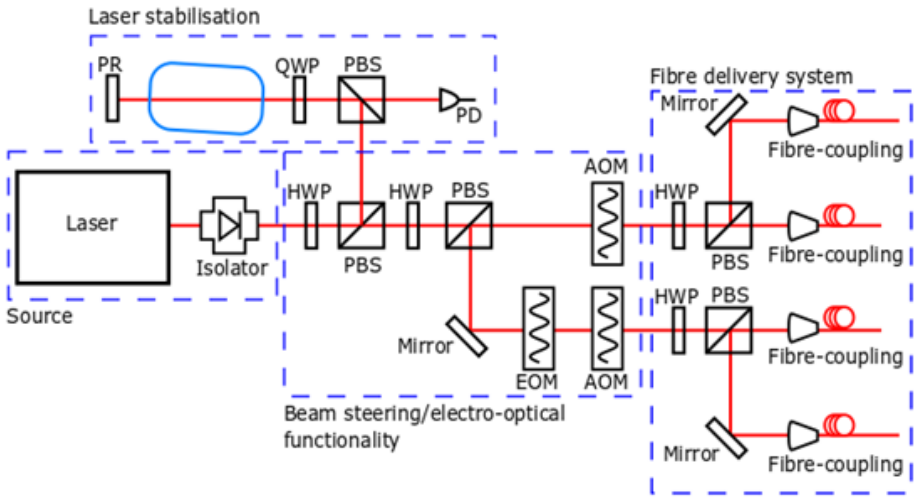
- Lead for all laser development (>50% of project)
  - Full rubidium laser system
  - Multiple architectures developed including full supply chain
- Field testing of instruments requiring environmental testing

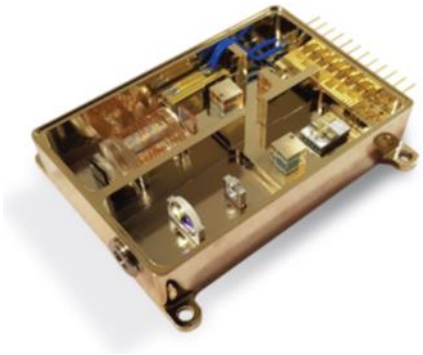


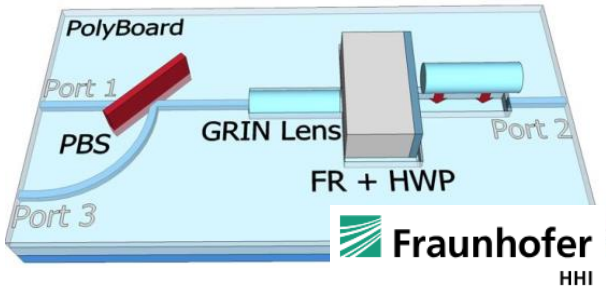


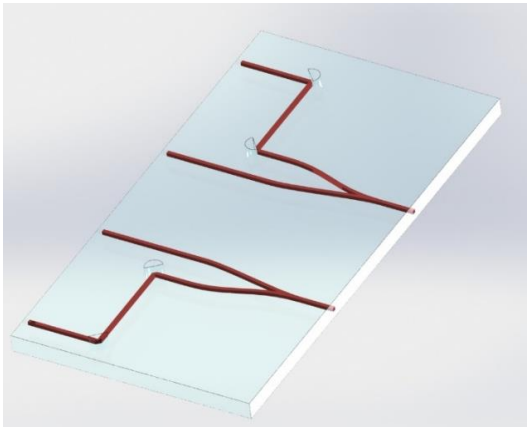
A Long Term View - Laser fabricated cold atom sensors?

- Take existing expertise and solve challenge in a modular manner.
- Take advantage of enabling nature of PIC development – applications in many sectors outwith EO.









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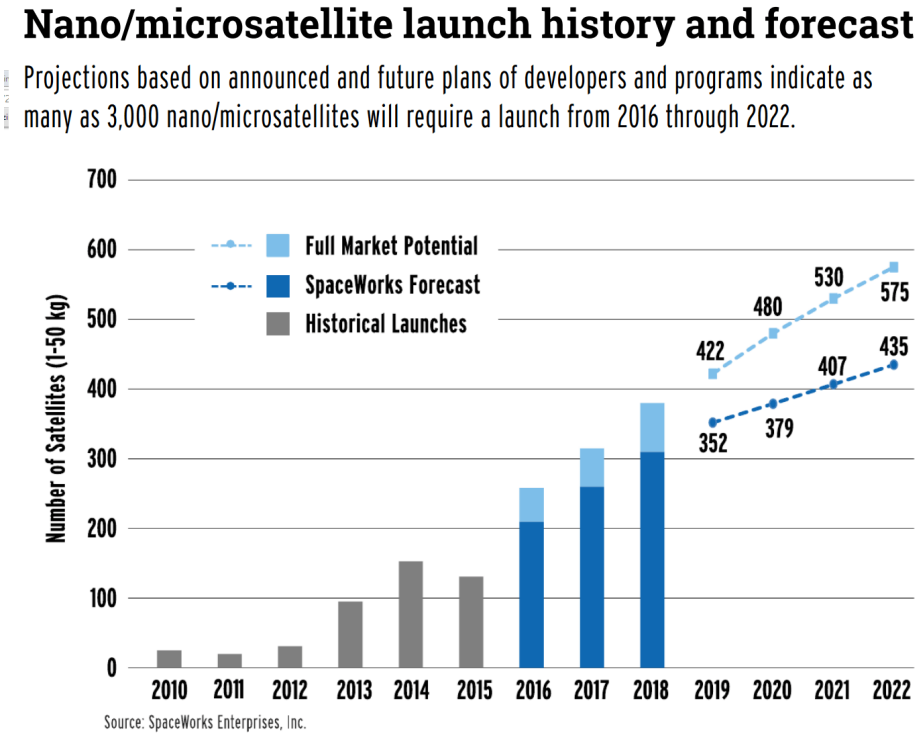
So What?

- Reducing the SWaP of optical systems is required for many functions/instruments on-board EO platforms
- Aim to reduce costs and increase uptake of these systems
- True miniaturisation – i.e. chip scale components to become standard parts. Useful for constellations. Miniaturisation of scientific instrumentation for new science and “ride-sharing”



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Conclusions

- Fraunhofer UK and Fraunhofer Centre for Applied Photonics are here to assist with your R&D efforts
- Vast array of in-house expertise, access to the network of partners we have developed across the UK, and the wider Fraunhofer network
- Ongoing projects in free space and PIC systems that have applications in EO – in particular stabilised laser sources and minitarisation of optical systems

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