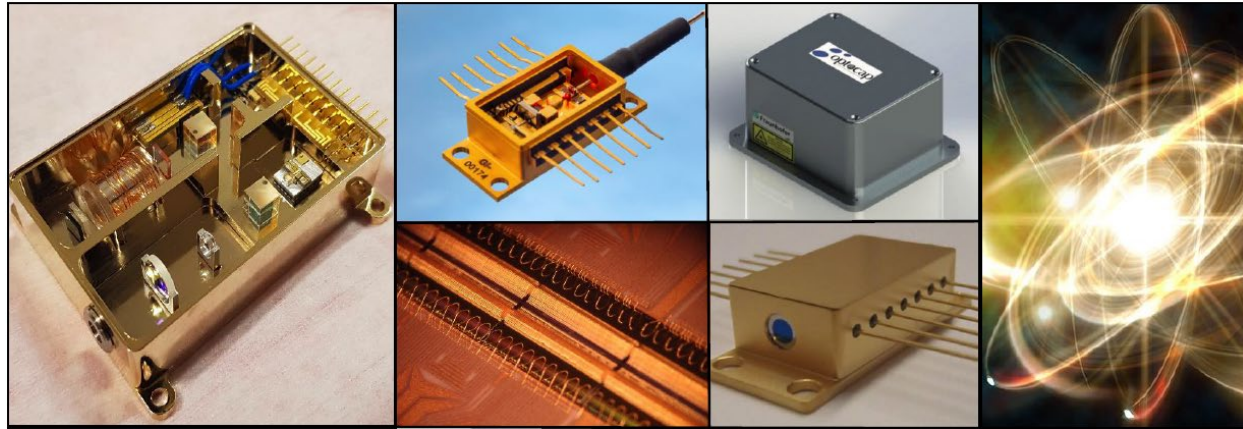




ALTER TECHNOLOGY TÜV NORD

Laser Modules for Quantum Applications
8 May 2019

Agenda



- Quantum applications
- Laser Modules for quantum applications
 - FLAME
 - REMOTE
- Other ATG Quantum related projects
- Summary

Quantum Applications

- **Laser-cooled atoms**
- **Atom Interferometers**
- **Atomic Clocks**
 - Timestamping: The “Flash Crash”, GPS & Telecommunications
- **Gravitometers**
 - Geological surveying, Defence
- **Quantum Computers**
 - Drug discovery
- **Photon-enhanced imaging / ranging / sensing**
 - High-value autonomy



Examples of Quantum Technologies

Enhanced Imaging

- Single-photon detectors
- Time-of-flight imaging
- High-sensitivity imaging

Secure Communication

- Quantum key distribution
- Handheld/portable
- Optical networks

Atom/ion-based Sensing

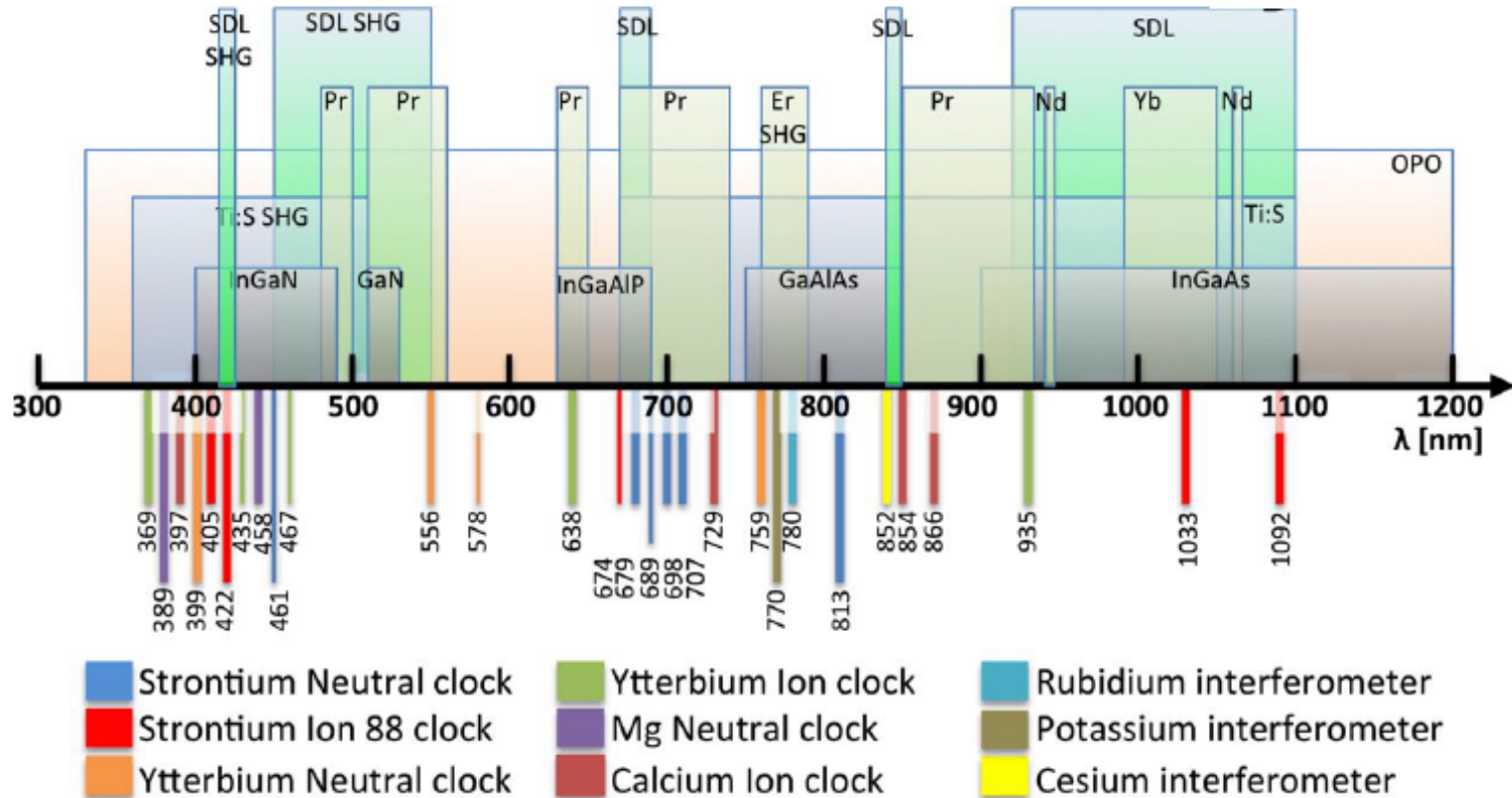
- Gravity sensors
- Rotation sensors
- magnetic field sensors
- Optical clocks

Quantum Computing

- Entanglement-based processing
- Single photon networking
- Random number generation

Laser Sources Required

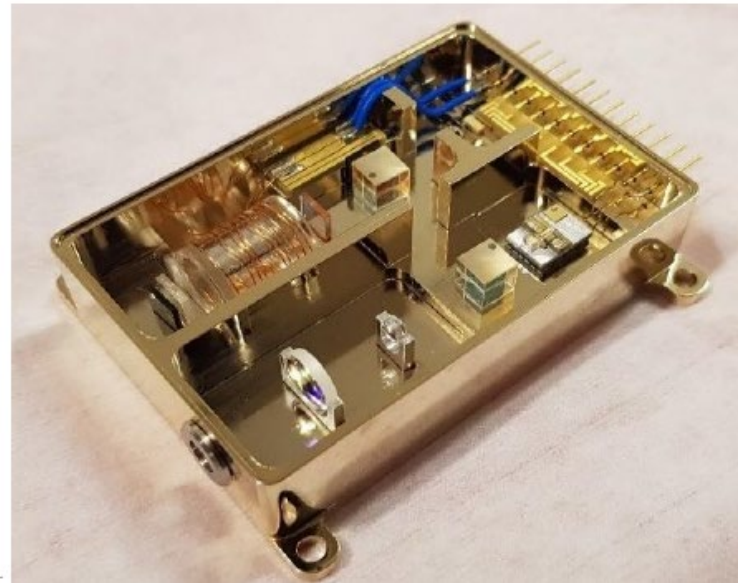
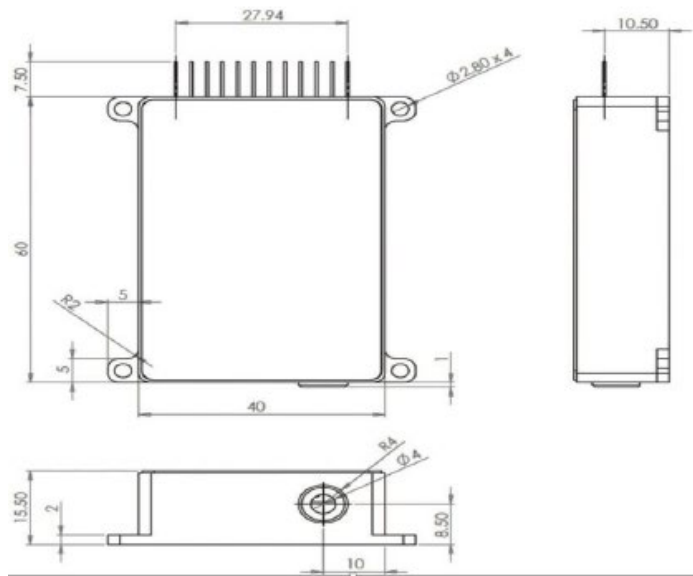
- Power
- Wavelength
- Delivery
- Optical Isolation
- Linewidth
- Tunability
- Stabilisation
- Drift



LASER MODULES FOR QUANTUM APPLICATIONS

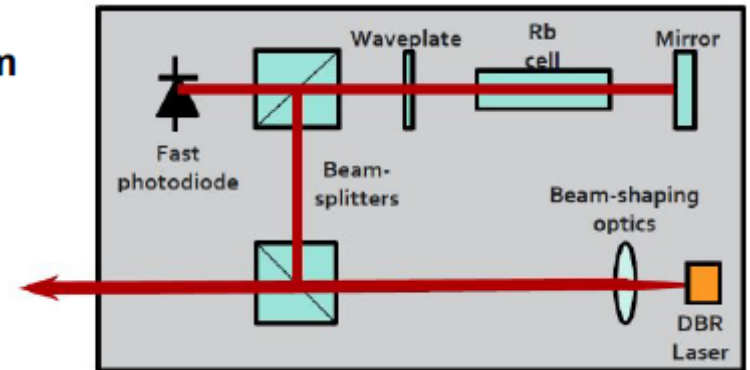
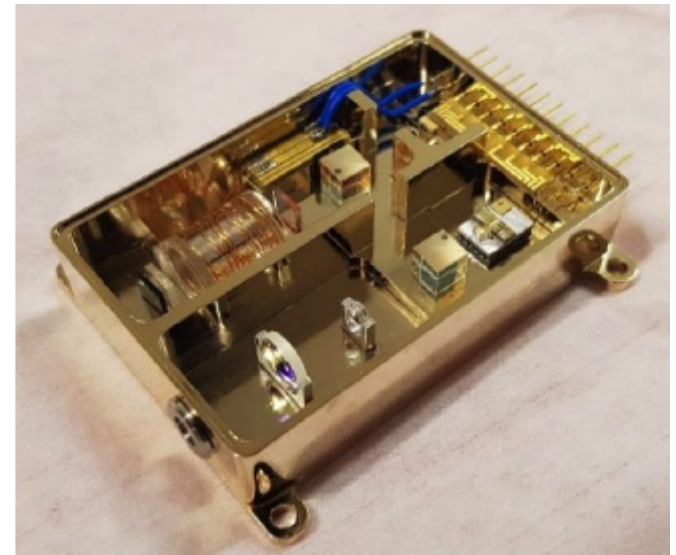
- FLAME: Frequency-Stabilised-Laser-Modules-with-Integrated-Reference.
 - In collaboration with Fraunhofer UK
 - 780nm Laser (Rubidium Transitions)
 - Integrated gas cell for frequency stabilization

FLAME



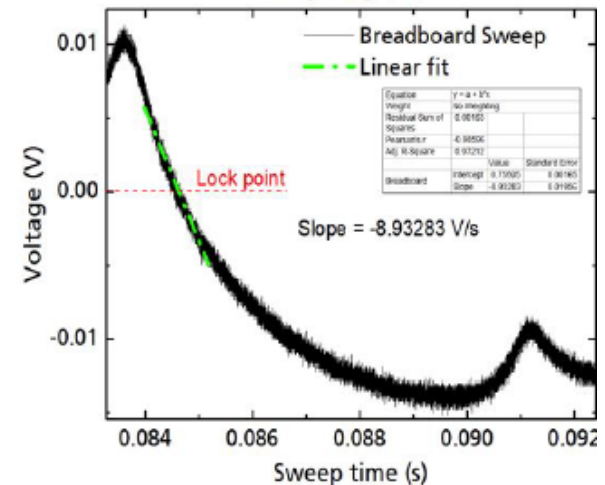
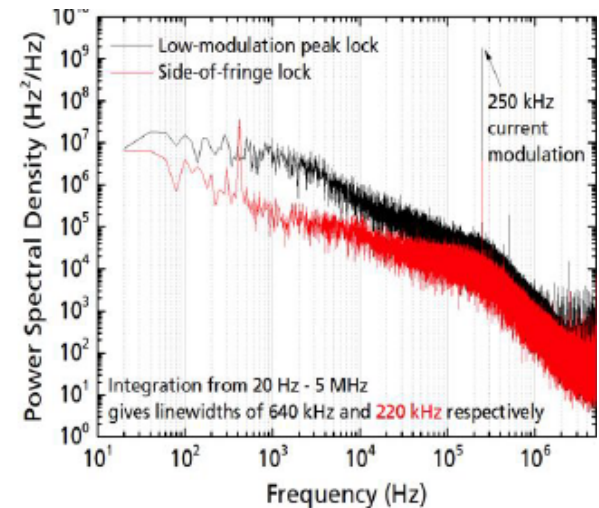
Optocap Package Stabilised 780.24nm Source

- **Cleanliness & low-outgassing: Gold-coated components, flux-free soldering, low-outgassing space-qualified adhesives, proven cleaning techniques**
- **Automated wirebonding and pick & place alignment of many components minimise production time and maximise repeatability**
- **Beam-expander telescope to reduce output beam divergence**
- **Heating of the integrated Rubidium cell for improved wavelength locking.**



Cold atom interferometry:

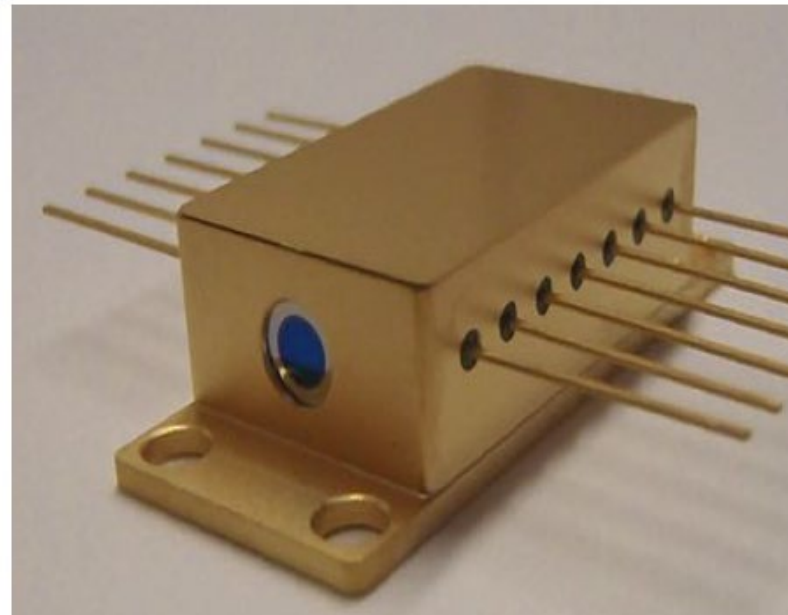
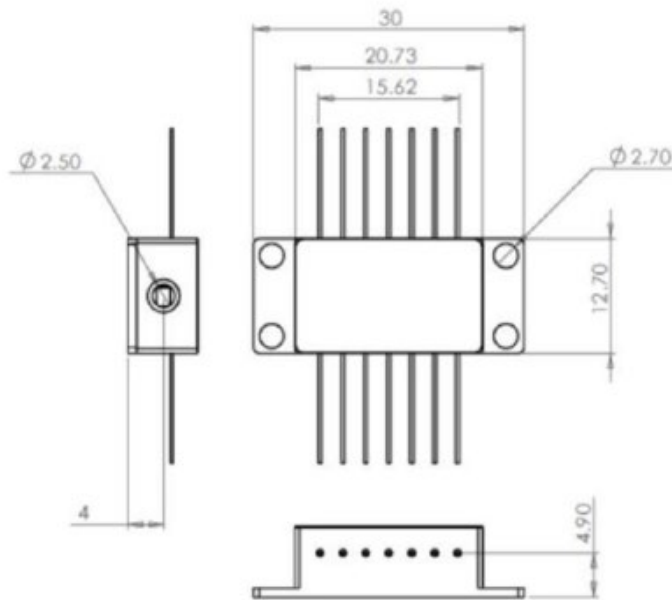
- Interference of atoms rather than photons for gravity and inertial sensors
- Significant increase in sensitivity for cold atom-based sensors vs optical-based
- Markets across aerospace, Earth observation, navigation, space, defence and research
- Requires stabilised single frequency lasers to interact with the atoms
- For Rubidium atoms, the key transition is at 780 nm.
- Narrow Linewidth laser with integrated Rubidium reference cell
- >150mW
- 780.24nm
- <500kHz linewidth



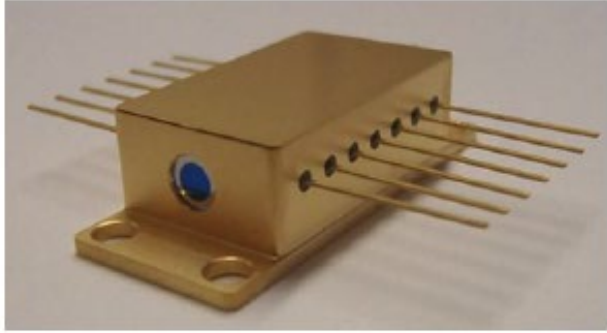
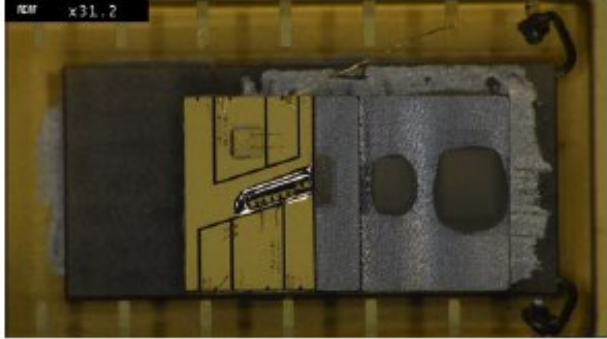
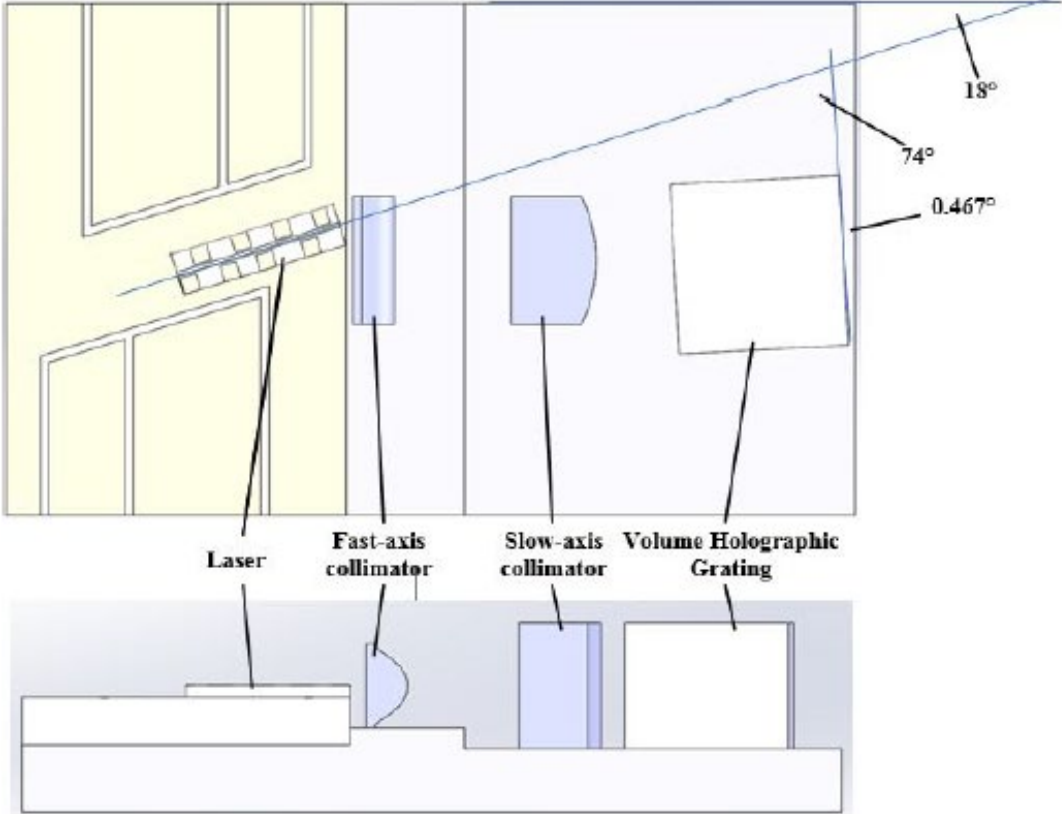
LASER MODULES FOR QUANTUM APPLICATIONS

- REMOTE : RuggEd Mirco-ECDL technology for cOld aTom applications in space
 - GaN based
 - External Cavity Laser at 461nm
 - 422nm also available for Strontium ion atomic clocks

REMOTE



Optocap REMOTE-780: Butterfly-Packaged ECDL



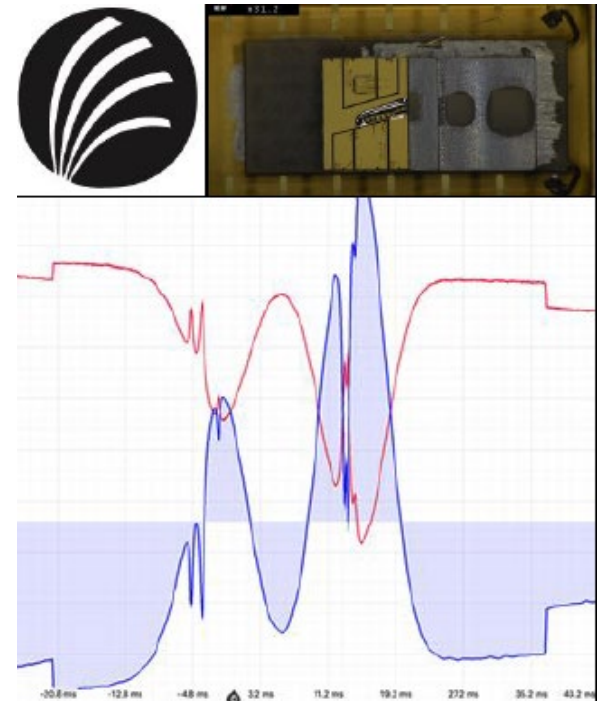
REMOTE LASER

- With changing current, the laser will mode-hop and lose its single-frequency operation
- Adjusting the internal TEC temperature will move the position of the mode-hop.
- The position of the mode-hops has been tuned so that they occur outside the region of interest.
- The REMOTE laser can address the whole of the Rb-87 and Rb-85 spectrum of interest.
- This corresponds to ~4 GHz mode-hop-free tuning range with current alone.

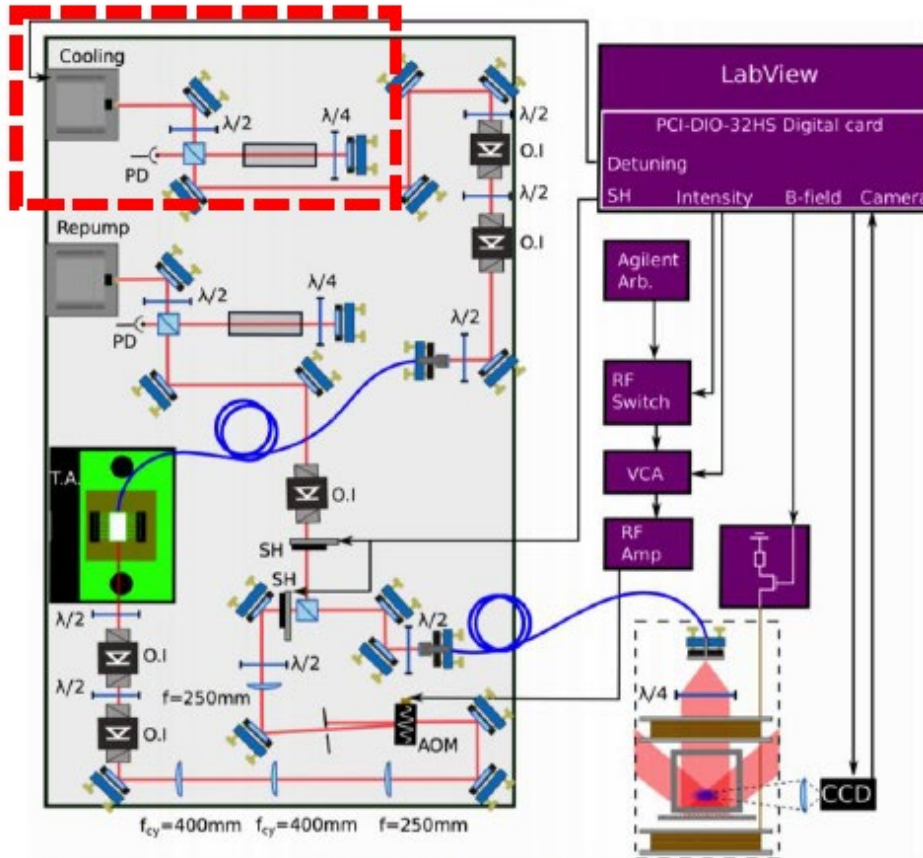
> 150 mW

780.24 nm

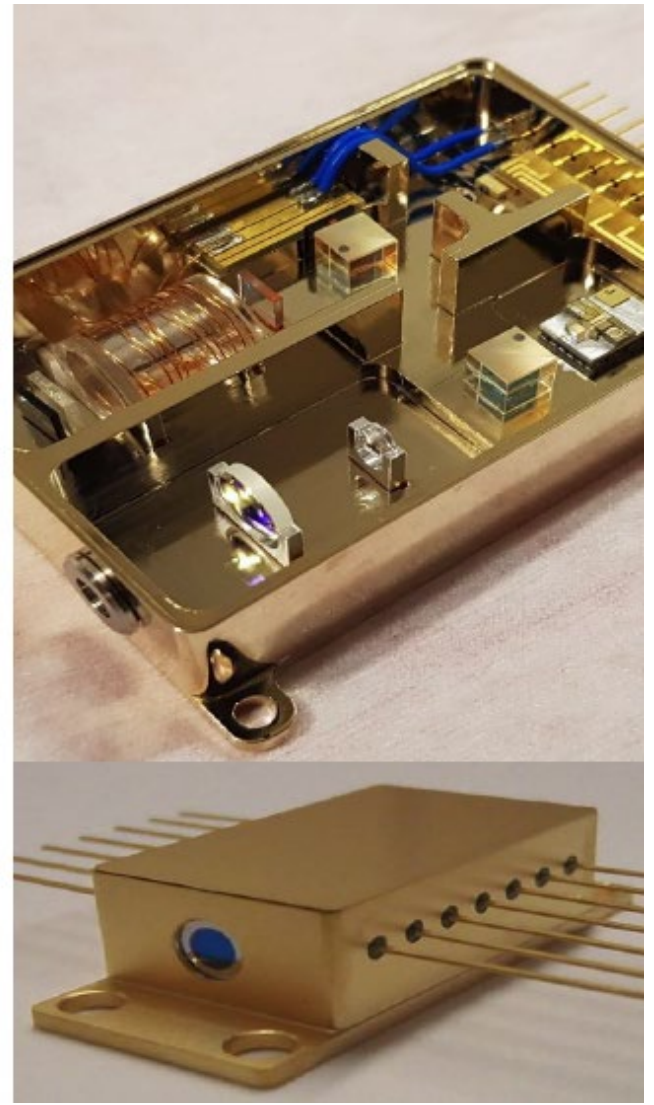
< 400 kHz linewidth



Optocap FLAME / REMOTE



Example of beam delivery system and sequencing and timing electronics
 J. P. McGilligan, "Micro-fabricated Diffractive Optics for Quantum Sensors and Atomic Clocks",
 PhD thesis (2017)



Other ATG Quantum Related Projects

Optocap - QUEST



Quantum Entangled Source for Quantum Communication

Quest-QKD is a feasibility study aimed at evaluating the potential of a device for the generation of entangled photons, targeting the emerging market of space quantum key distribution (QKD).

Quantum key distribution (in some of its protocols) directly exploits entanglement to allow the secure share of a cryptographic key for information encoding.

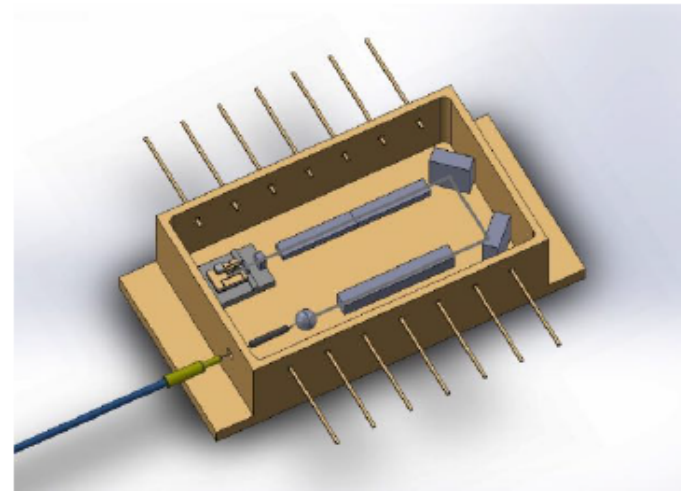
The technical feasibility will be assessed by developing, testing and packaging a polarisation entanglement source. This will allow to precisely evaluate the resources needed for the eventual commercialisation of the device.

Partners:

- Optocap (Lead)
- Fraunhofer Centre for Applied Photonics

Optocap Responsibilities:

- Project management
- Component drawing set
- Component procurement and process development
- Assembly and testing of packaged source
- Final reporting and road-mapping

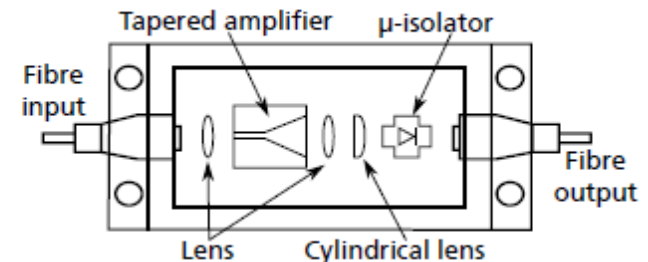


Other ATG Quantum Related Projects

Optocap rAmpart Project



- rAmpart we will develop packaged tapered amplifier with fibre-coupled input and output
- Notable integration benefits over discrete tapered amplifiers (C- and DHP-mount)
- Fibre-coupled output advantages over butterfly packaged devices
- Smaller footprint over complete systems
- Fibre-coupled output challenges
 - Changes in the mode field and beam steer as drive current is ramped
 - Damage to fibre facet from uncoupled light



Other ATG Quantum Related Projects

Optocap - SLAM

Squeezed Light quantum MEMS Gravimeter

The University of Glasgow & QuantIC (Glasgow QT hub) have already demonstrated a high sensitivity miniaturised MEMS gravimeter able to sense the Earth tides. With this project the device will see up to x40 improvement in performance via the development of an interferometric readout from the device using the superposition of light states inside a miniature vacuum package for thermal isolation of the sensor.

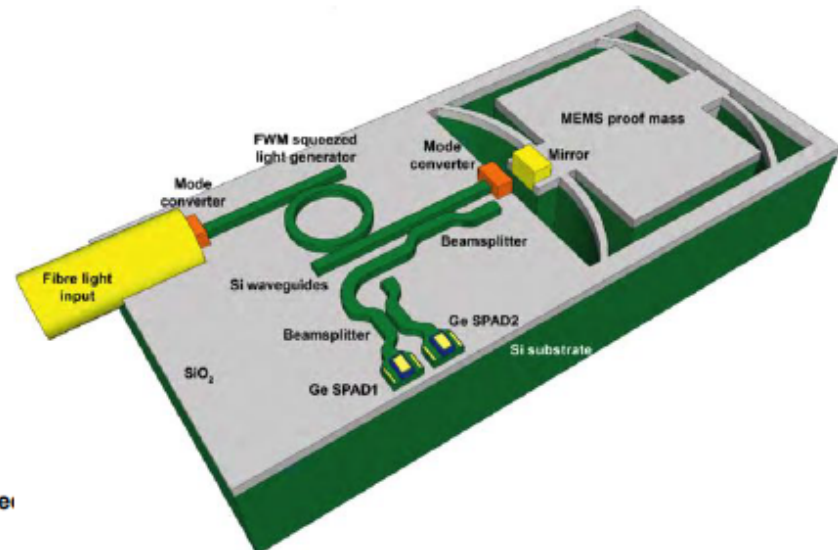
Market sectors for the technology include: Oil & Gas, Defense & Security, Navigation & environmental monitoring, UK Hub network.

Partners:

- Optocap (Lead)
- University of Glasgow
- IQE SILICON COMPOUNDS LIMITED

Optocap Responsibilities:

- Component drawing set
- Assembly process definition
- MEMS vacuum package design
- Demonstration of MEMS vacuum package with optical fibre feed



Other ATG Quantum Related Projects

Optocap - Single Ion Microtraps

Atomic quantum technology experimentation & development

The use of microfabricated ion traps coupled with scalable entanglement techniques facilitate advances in atomic clocks and quantum processors.

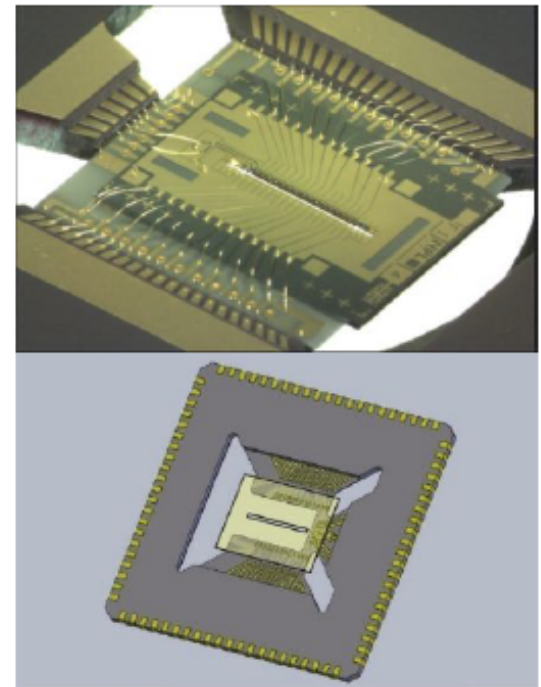
The aim of this development was to achieve a repeatable low cost, high volume design and repeatable sub-assembly process solution for a double sided MEMS ion trap devices for use in UHV (ultra high vacuum) applications

Partners:

- Optocap,
- NPL, (lead)
- Kelvin Nanotechnology

Optocap Responsibilities:

- Design and manufacture of a bespoke ITCC (Ion-Trap-Chip-Carrier) to hold a double sided MEMS silicon chip.
- Development of bespoke and scalable assembly processes
- Demonstrate confidence test data showing compliance to withstand UHV (ultra high vacuum) application requirements
- Materials analysis and procurement
- Pilot assembly of assembly solution



Conclusion

- ALTER Technology Group companies, and mainly Optocap are participating in several Quantum related projects
- Synergies of the ATG companies:
 - Photonic and Microelectronic Packaging
 - Photonic testing capabilities
 - Complex Radiation tests



ALTER

TECHNOLOGYGROUP

Web Project Office



**The INNOVATION department is open to new challenges and
developments in collaboration with customer
requirements**

Thank you

for your attention

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Demetrio.lopez@altertechnology.com***