

Fully integrated Laser Heterodyne Radiometer

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HOLLOWGUIDE LTD

Project Introduction

Ø Project objectives

- Develop the concept of a miniature Quantum Cascade Laser Heterodyne Spectro-radiometer for remote sounding
- Produce a first prototype for assessment

Ø Case for LHR

- High spectral resolution ($0.001 - 0.02 \text{ cm}^{-1}$)
 - Turns into altitudinal resolution
- High spatial resolution (100's m LEO / few km's GEO)
 - Local observations
- Miniaturized through integration
 - Lower cost, piggy backing, constellation

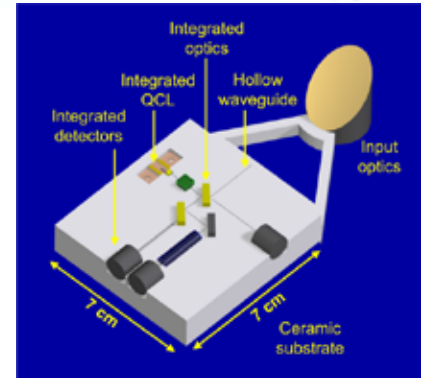
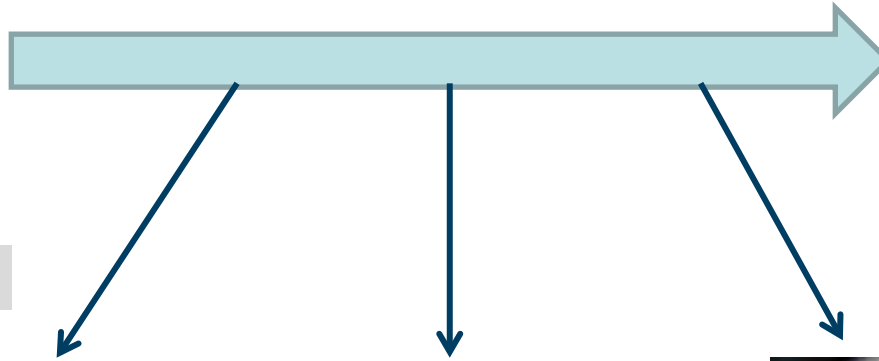
Ø Partners

- Hollowguide Ltd / Mike Jenkins

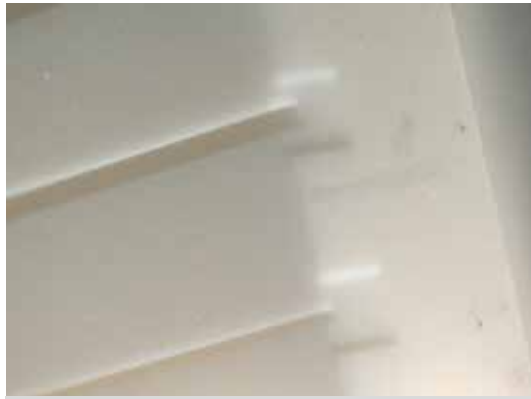
LHR Miniaturization Path



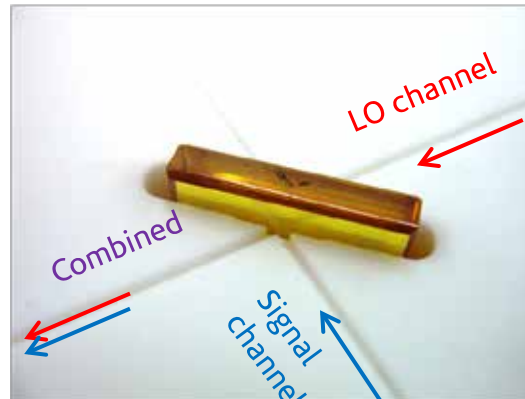
Bench-top 75x75cm²



Integrated 7x7 cm²



Hollow waveguide channels

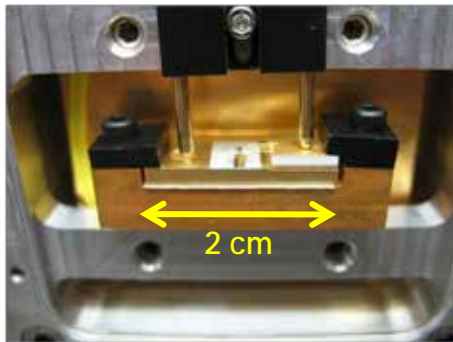


Passive component integration

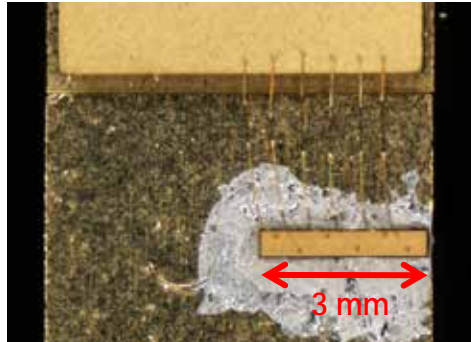


Active component integration

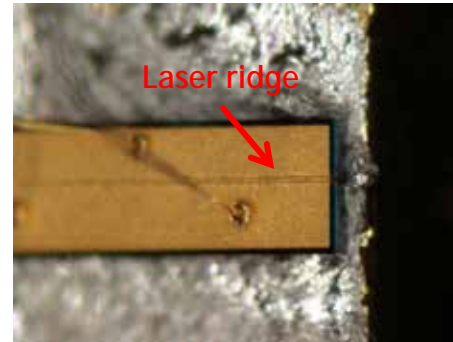
QCL Metrology / Free Space Test



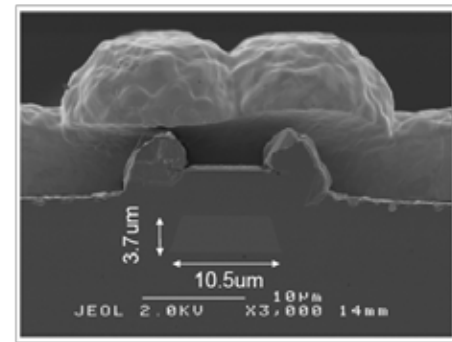
Laser in module



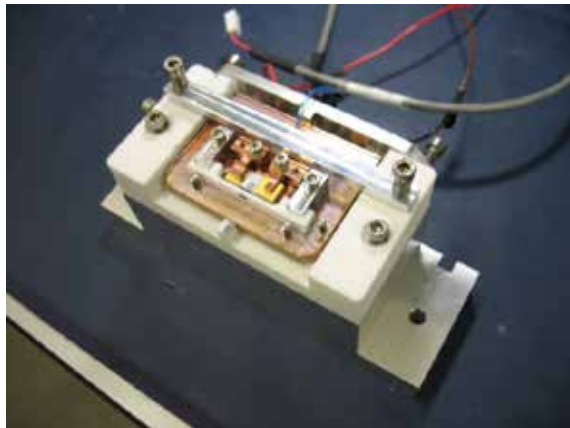
Laser chip on submount



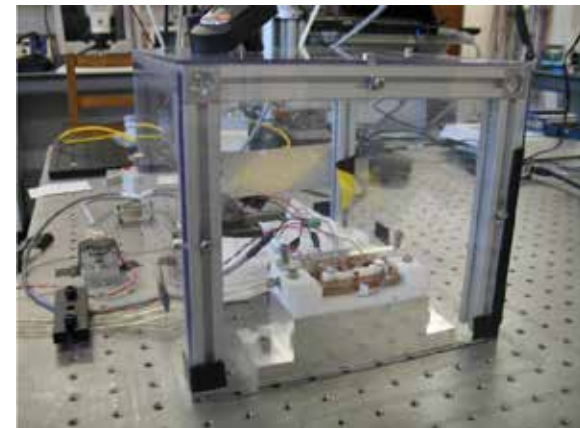
Front facet & laser ridge



Output facet



Integrated QCL
for free space
test

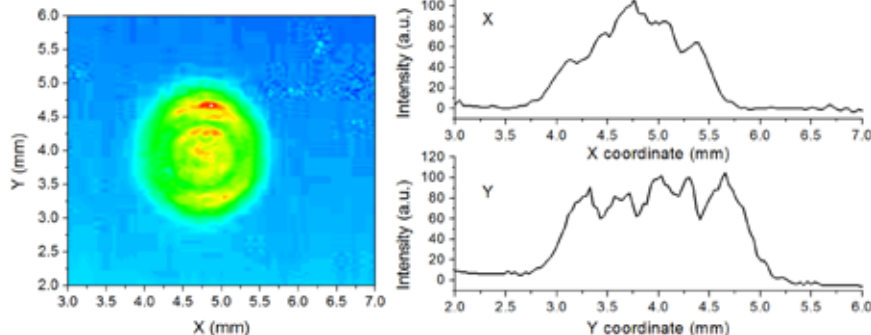


Fresnel Diffraction / Mitigation

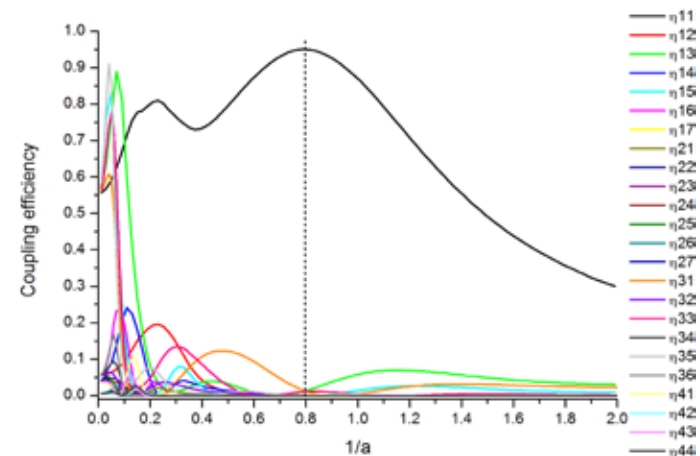
- ∅ All beam properties were found OK
 - Except near field Fresnel diffraction
 - HW coupling is in the near field

Near field laser intensity profile

(a) 30 mm

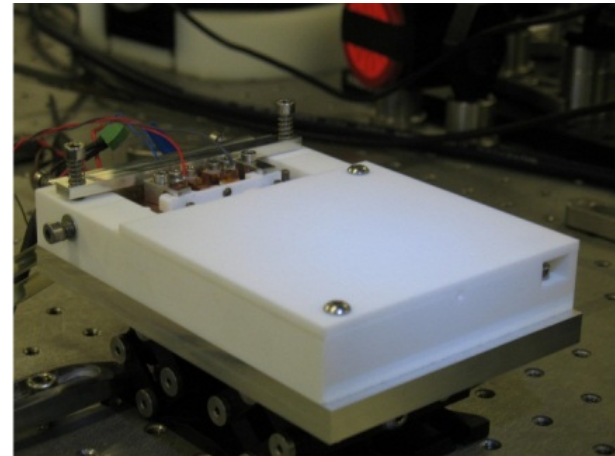
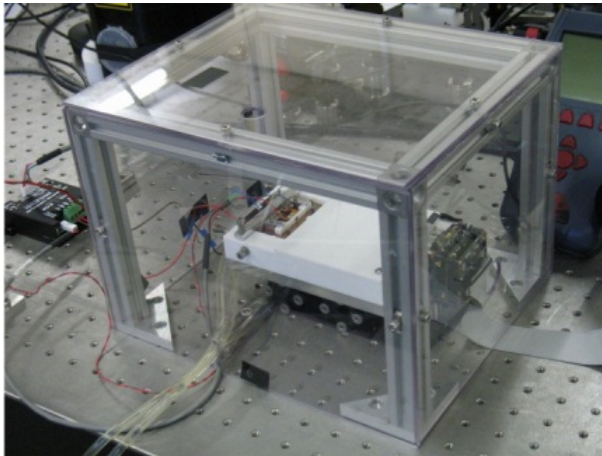


HW coupling of a diffracted beam

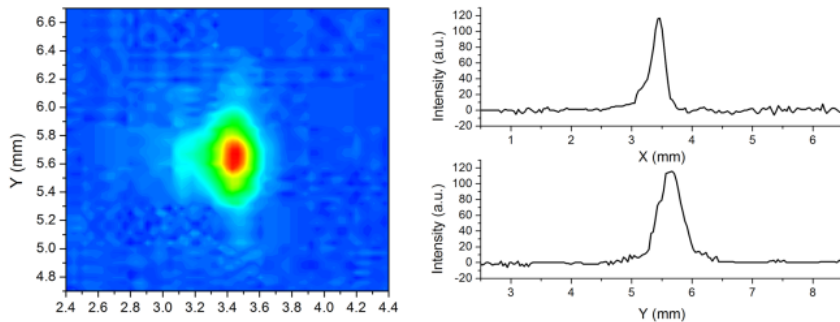


Integrated QCL Coupling Module

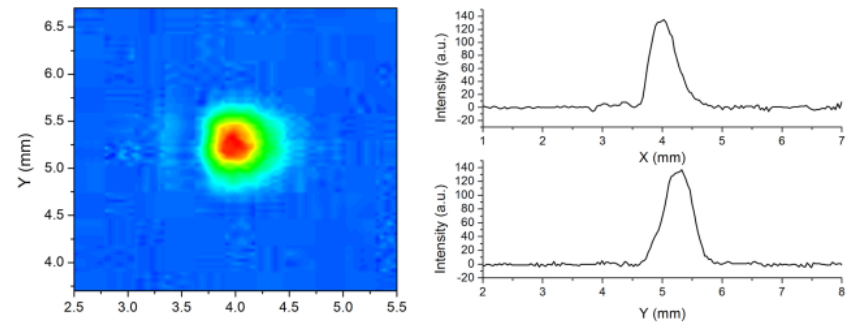
Ø New hollow waveguide substrate produce



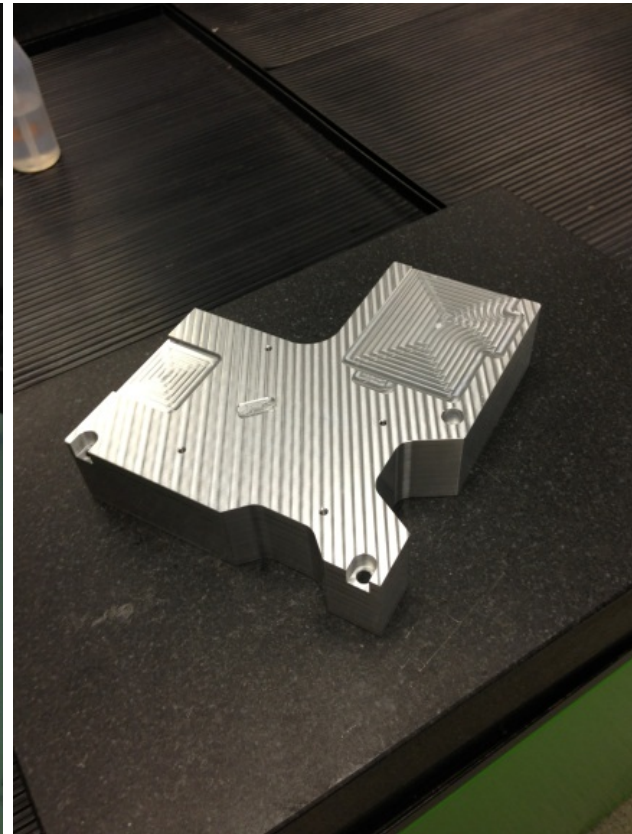
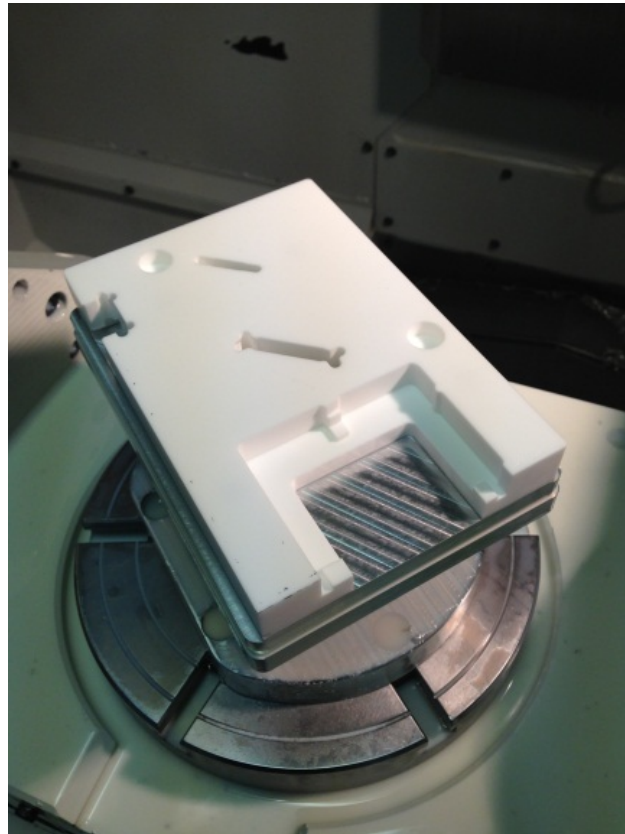
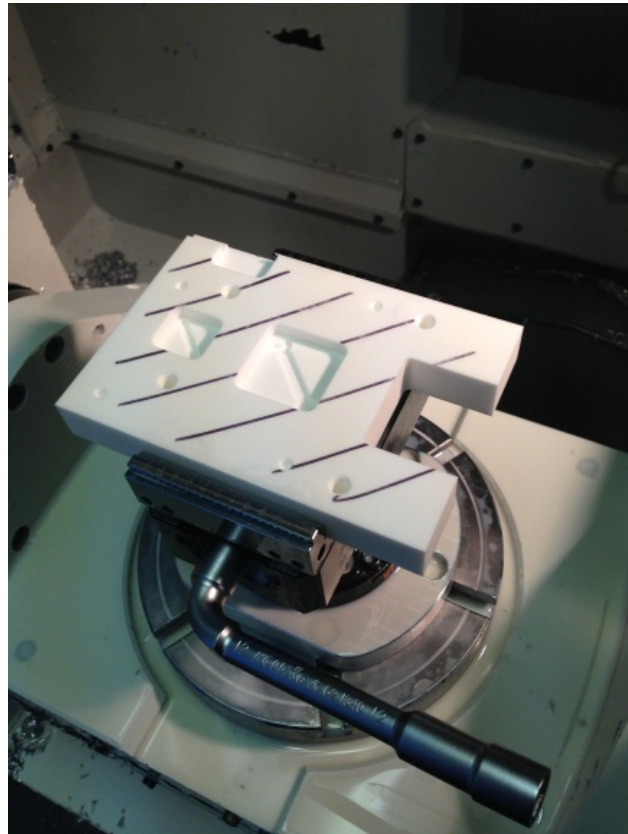
(a) 5 mm



(d) 50 mm



Manufacturing in progress...



Achievement Against Goals

Ø Through iterative steps integration of active components was achieved

Ø Iterative design with tests and metrology has allowed the miniature LHR final design to be produced

Ø Full assembly and testing scheduled in the next quarter

Issues & Problems

∅ QCL integration

- Metrology was challenging
 - Successful solution found but provoked delays
- Fresnel near field diffraction
 - Successful solution found but provoked delays

∅ Key staff left early January

- Re-training provoked delays

Positioning

∅ Presentations

- “A Fully Integrated, Miniaturised Quantum Cascade Laser Heterodyne Radiometer for Earth Observation”, Joint NCEO/CEOI conference, Nottingham, 2012
- “Getting QCL-based Remote Sensors to the Harsh Real World of Space”. NSF Mid Infrared Technologies for Health and Environment Engineering center, Workshop, Baltimore, USA, 2012
- “Mid-Infrared Laser Heterodyne Systems From Earth Observation to Security and Defence”, CEOI showcase conference, 2013
- Posters at the NCEO/CEOI conference and CEOI showcase

∅ Publication

- “Atmospheric vertical profiles of O₃, N₂O, CH₄, CCl₂F₂, and H₂O retrieved from external-cavity quantum-cascade laser heterodyne radiometer measurements”, Tsai et al. Applied Optics, 51, 36, 8779-8792, 2012

Positioning

Ø Leverage

- STFC centre for instrumentation, advanced optics funding
- STFC CLASP project for security and defence applications
- Collaboration with central Laser Facility for using hollow waveguide for ultrafast spectroscopy

Ø UK capability enhancement

- Development of unique expertise and know how in hollow waveguide integration of laser sensing instruments
 - High accuracy machining of ceramic ($\sim\mu\text{m}$)
 - Associated metrology
 - Laser spectroscopy sensing instruments
 - Simulations
- Miniaturization enables planetary missions

Roadmap

