Fully integrated
Laser Heterodyne Radiometer

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HOLLOWGUIDE LTD

RAL Space

Science & Technology Facilities Council
Rutherford Appleton Laboratory

Project Introduction

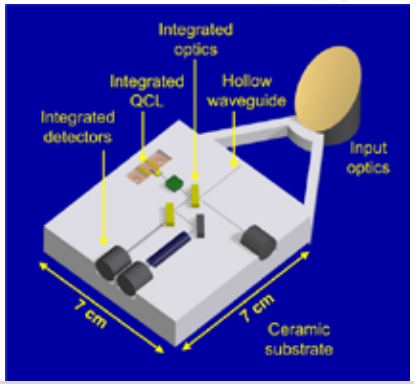
Ø Project objectives
- Develop the concept of a miniature Quantum Cascade Laser Heterodyne Spectro-radiometer for remote sounding
- Produce a first prototype for assessment

Ø Case for LHR
- High spectral resolution (0.001 – 0.02 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

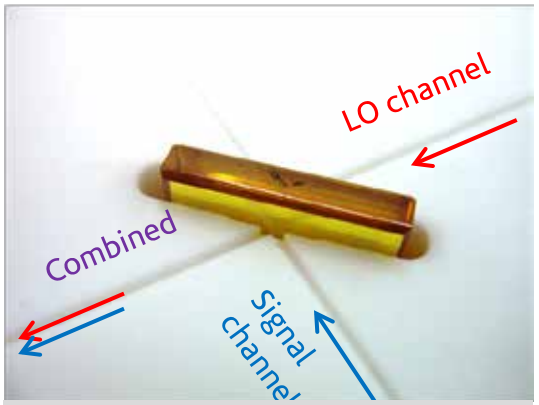
LHR Miniaturization Path

Bench-top 75x75cm²



Integrated 7x7 cm²

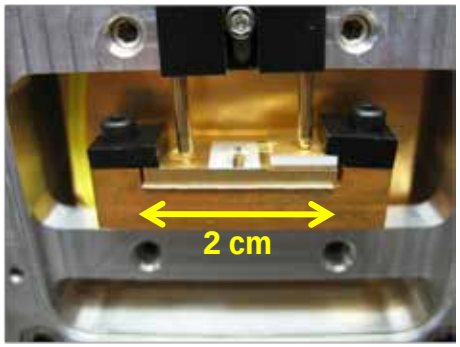
Hollow waveguide channels



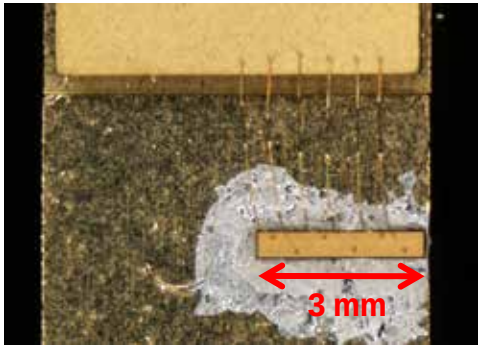
Passive component integration

Active component integration

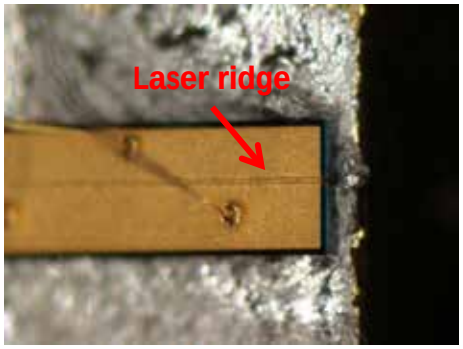
QCL Metrology / Free Space Test



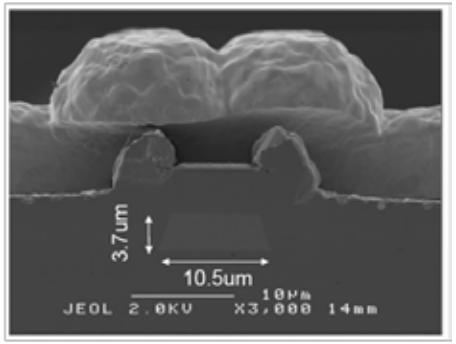
Laser in module



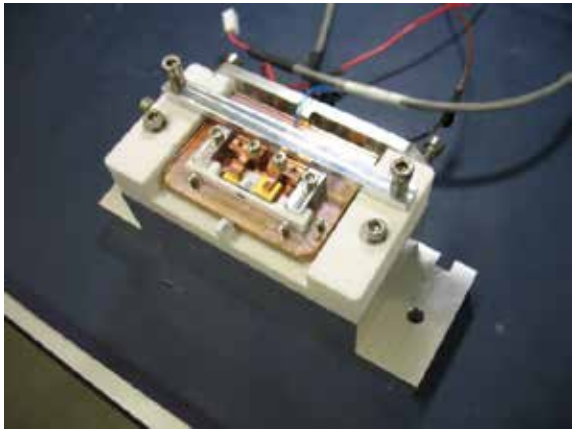
Laser chip on submount



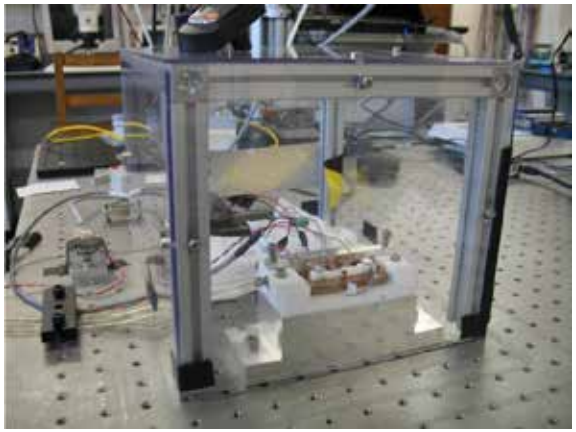
Front facet & laser ridge



Output facet



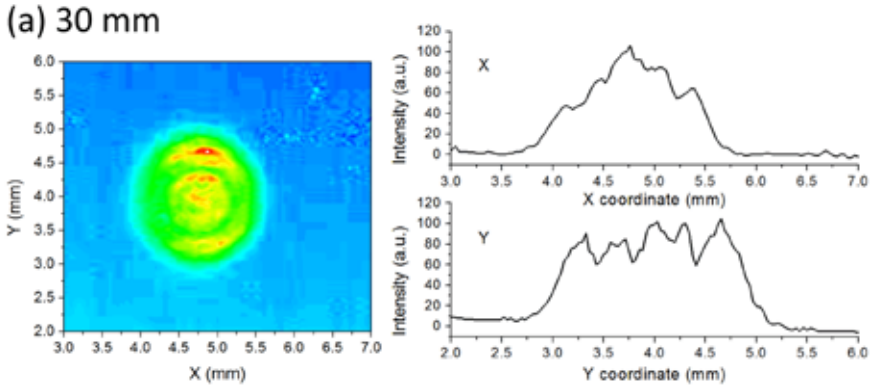
Integrated QCL for free space test



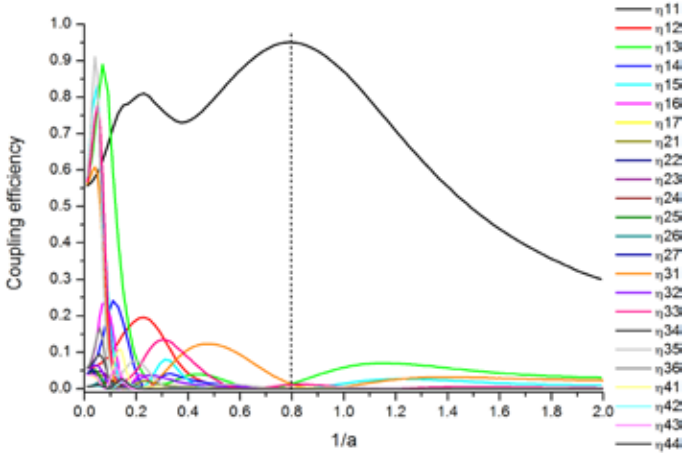
Fresnel Diffraction / Mitigation

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

Near field laser intensity profile

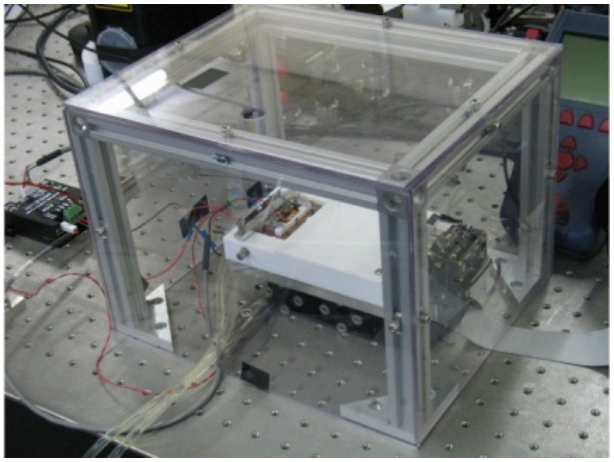


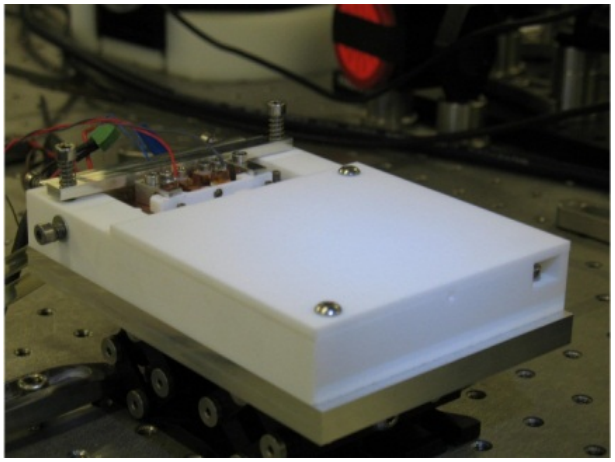
HW coupling of a diffracted beam



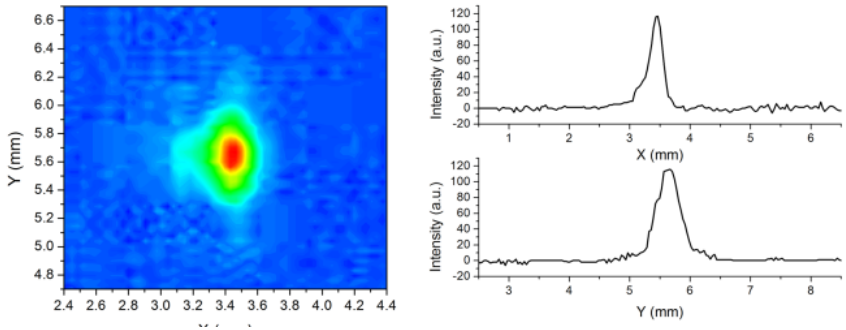
Integrated QCL Coupling Module

Ø New hollow waveguide substrate produce

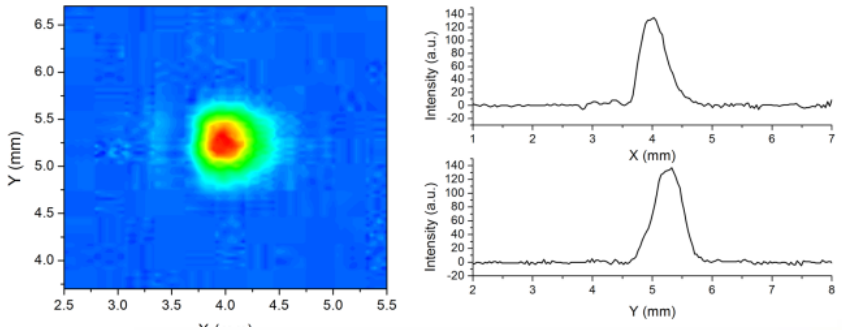




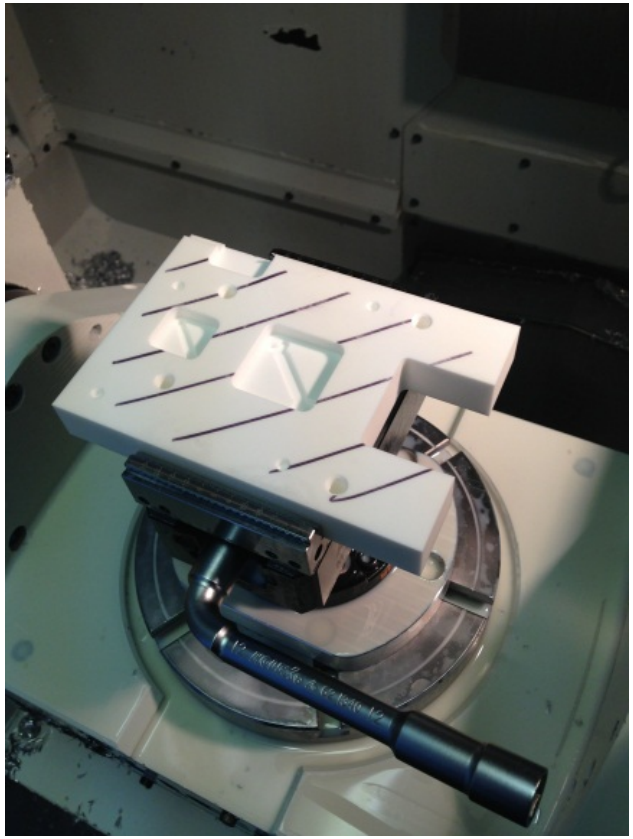
(a) 5 mm

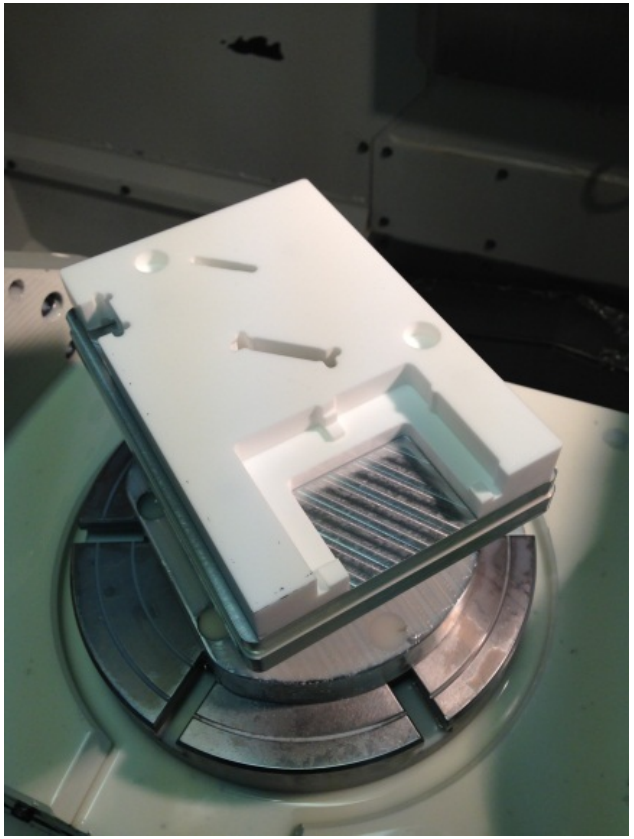


(d) 50 mm



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

- Ø QCL integration
  - – Metrology was challenging
    - Successful solution found but provoked delays
  - – Fresnel near field diffraction
    - Successful solution found but provoked delays
- Ø Key staff left early January
  - – Re-training provoked delays

Positioning

Ø 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

Ø Publication

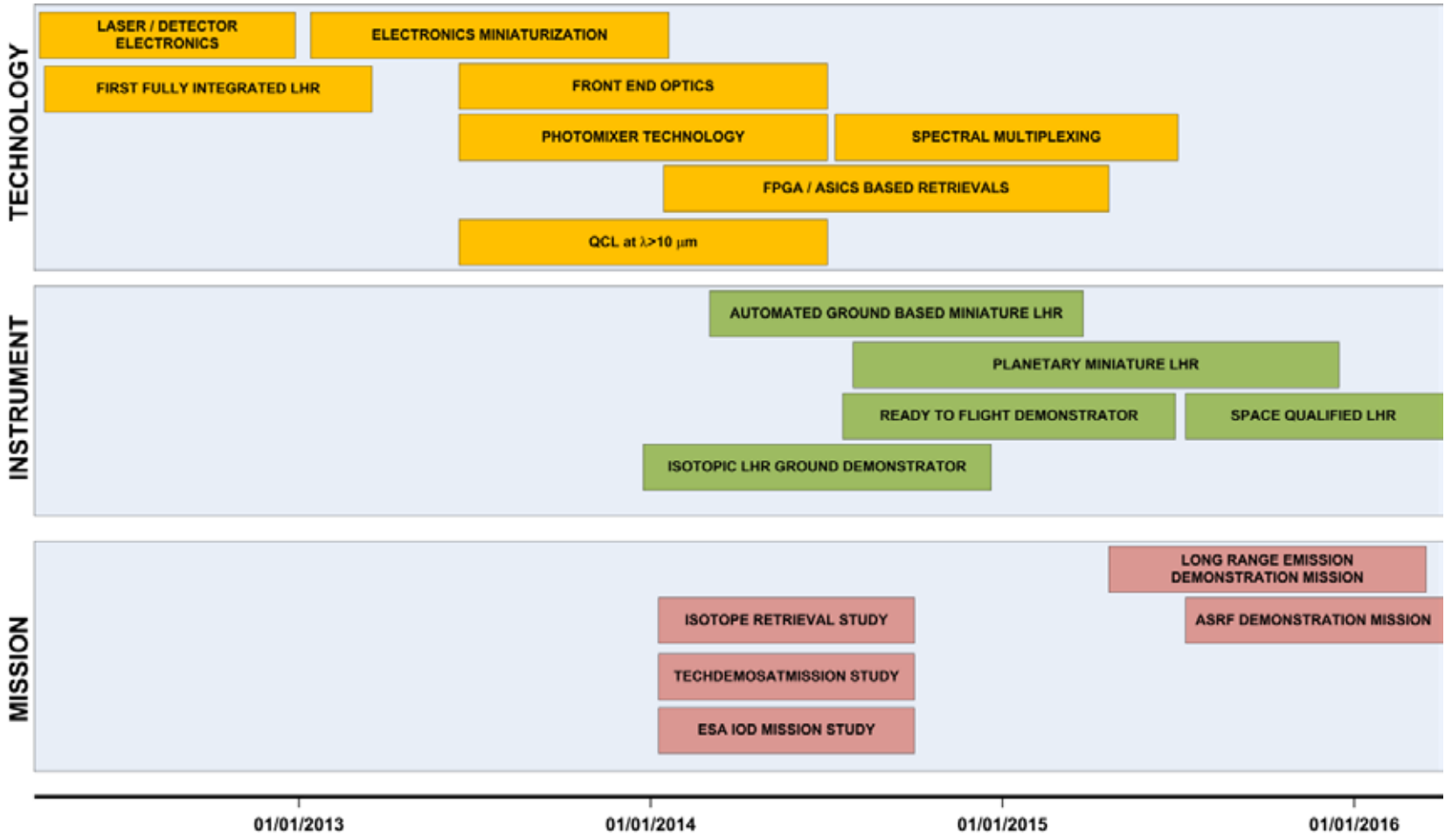
- "Atmospheric vertical profiles of O3, N2O, CH4, CCl2F2, and H2O retrieved from external-cavity quantum-cascade laser heterodyne radiometer measurements" , Tsai et al. Applied Optics, 51, 36, 8779-8792, 2012

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 (~µm)
  - Associated metrology
  - Laser spectroscopy sensing instruments
  - Simulations
- Miniaturization enables planetary missions

Roadmap


TECHNOLOGY
LASER / DETECTOR ELECTRONICS
ELECTRONICS MINIATURIZATION
FIRST FULLY INTEGRATED LHR
FRONT END OPTICS
PHOTOMIXER TECHNOLOGY
SPECTRAL MULTIPLEXING
FPGA / ASICS BASED RETRIEVALS
QCL at λ>10 μm
INSTRUMENT
AUTOMATED GROUND BASED MINIATURE LHR
PLANETARY MINIATURE LHR
READY TO FLIGHT DEMONSTRATOR
SPACE QUALIFIED LHR
ISOTOPIC LHR GROUND DEMONSTRATOR
MISSION
LONG RANGE EMISSION DEMONSTRATION MISSION
ISOTOPE RETRIEVAL STUDY
ASRF DEMONSTRATION MISSION
TECHDEMOSATMISSION STUDY
ESA IOD MISSION STUDY
01/01/2013
01/01/2014
01/01/2015
01/01/2016