SCHOOL OF ELECTRONIC AND ELECTRICAL ENGINEERING

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New UK Developments in THz Technology for Earth Observation

Edmund Linfield, Giles Davies, Paul Dean, John Plane

University of Leeds

Simon Rea, Brian Ellison, Hui Wang, Manju Henry, Olivier Auriacombe, Tom Rawlings, Martin Crook, Tom Bradshaw, Bruce Swinyard (also UCL)

RAL – RAL Space & Technology Departments

Steve Parkes, Alex Mason

Star Dundee Ltd

Funded by CEOI 7th EO Technology Call

LOCUS Mission

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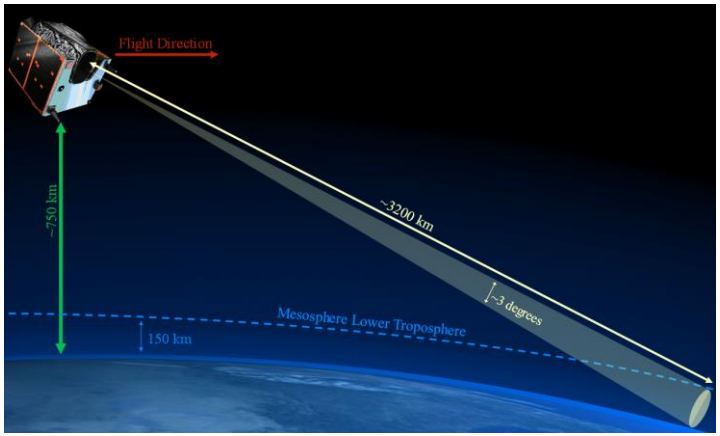
LOw-Cost Upper-atmosphere Sounder

Compact payload on small satellite to observe key species in mesosphere and lower thermosphere (MLT)

- *MLT is the 'gateway' between Earth's atmosphere and the near space environment*
  - Strongly affected by both natural and anthropogenic sources from below, and solar and space-weather impacts from above
- *Key indicator for global climate change but largely unobserved*
- *Discrepancies between existing models and sparse datasets*
  - Many open questions
  - Clear need for further observations



Small satellite sounder from LEO

LOCUS Science

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Detection of emission signatures of: O, OH, NO, CO, O_2, H_2O, HO_2, O_3

- *O and OH are critical in understanding the chemistry / energy balance of MLT*
- *NO provides understanding of the effects of energetic solar particles on the atmosphere*

- *4 receivers @ 4.7 THz, 3.5 THz, 1.1 THz, 0.8 THz*
- *Limb-sounding geometry providing height-resolved profiles*
- *High spectral resolution (1 MHz) for detection of weak signatures*

Designation	Band Centre	Primary Species	Secondary Species
Band 1	4.7 THz	O	O_3
Band 2	3.5 THz	OH	CO, HO_2
Band 3	1.1 THz	NO, CO	H_2O, O_3
Band 4	0.8 THz	O_2	O_3

LOCUS Receiver Bands and Detectable Species

LOCUS Technology

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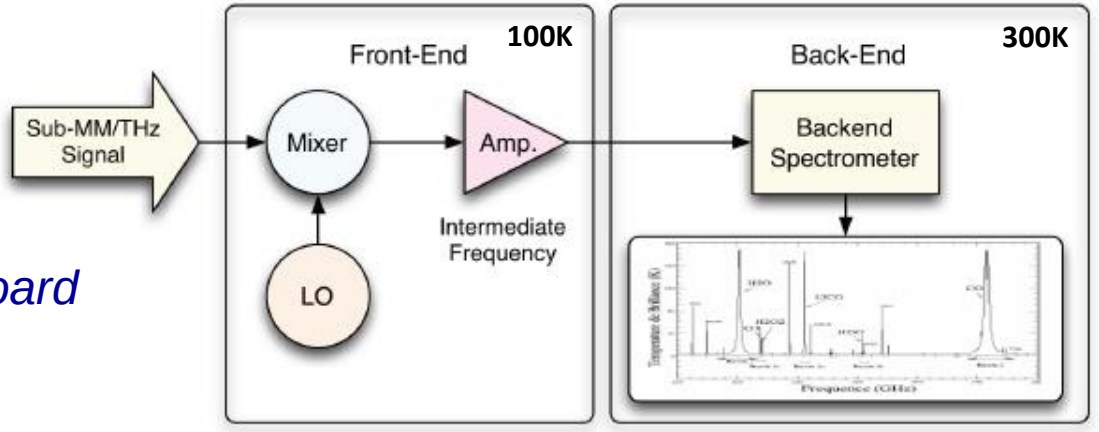
Technology under development for LOCUS

- *Schottky technology >1 THz (diodes and components) - RAL*
- *Quantum-cascade lasers (LO source technology >2 THz) - Leeds*
- *Wideband high-resolution spectrometer technology – STAR Dundee Ltd*
- *Space cooler technology – RAL*

CEOI project goals

- *Development of 1.1 THz breadboard*
  - Schottky components
  - WBS
  - Cooler
- *QCL packaging and testing*



Receiver schematic

1.1 THz Breadboard

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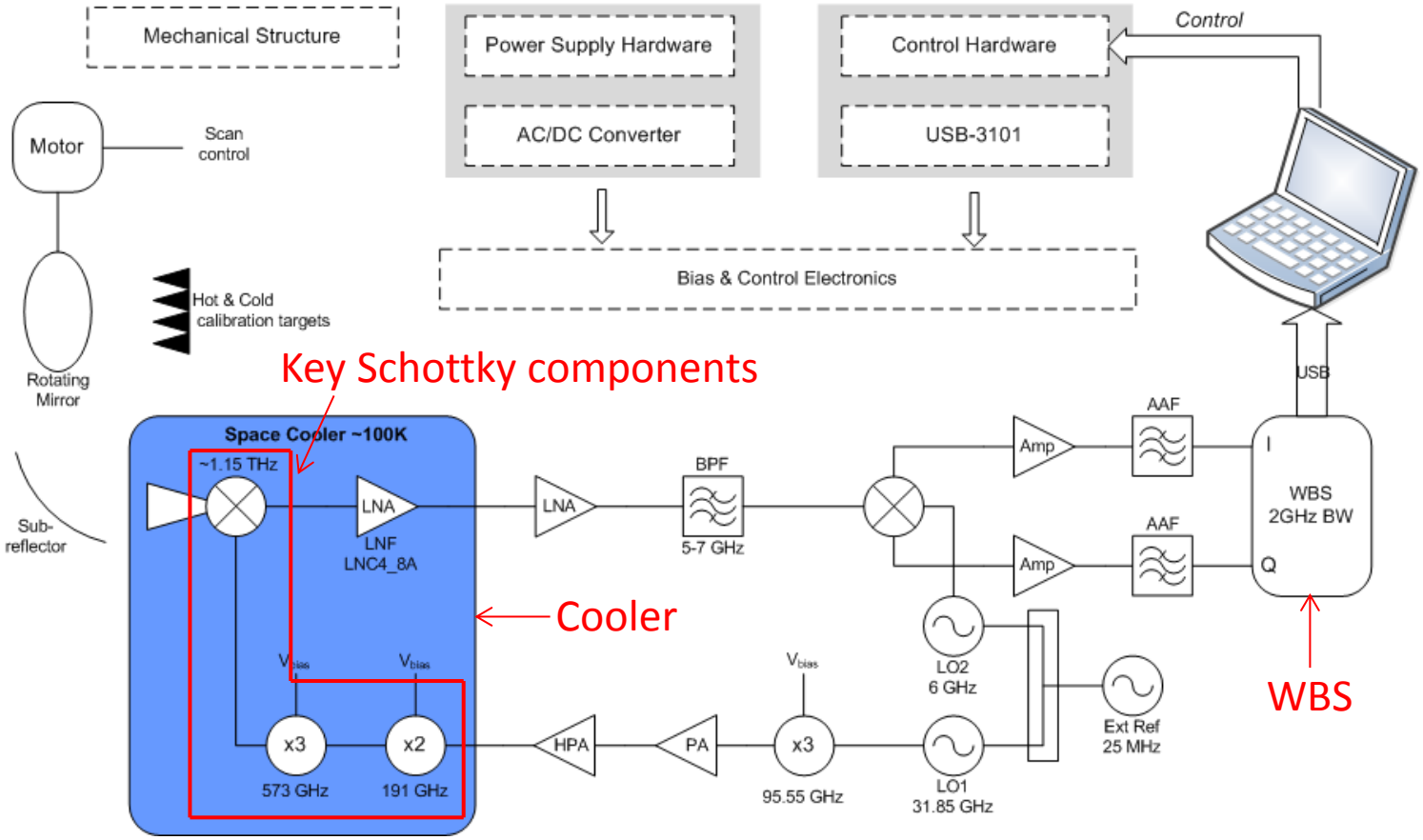
Development of stand-alone total-power radiometer similar to the SHIRM breadboard described in the previous talk



1.1 THz Breadboard

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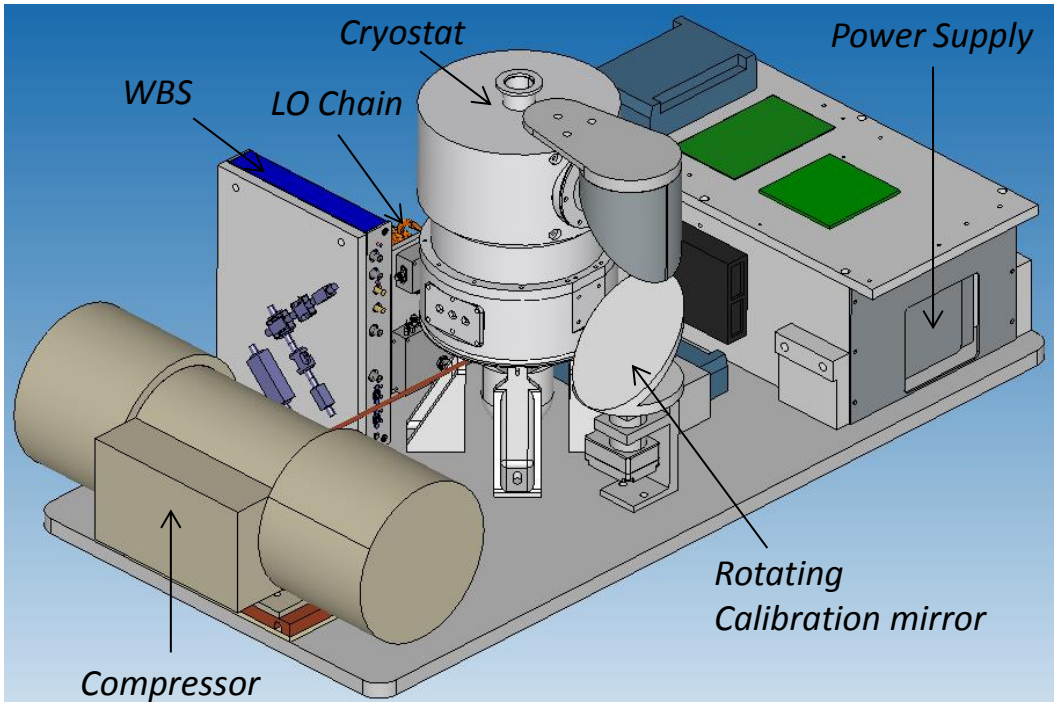
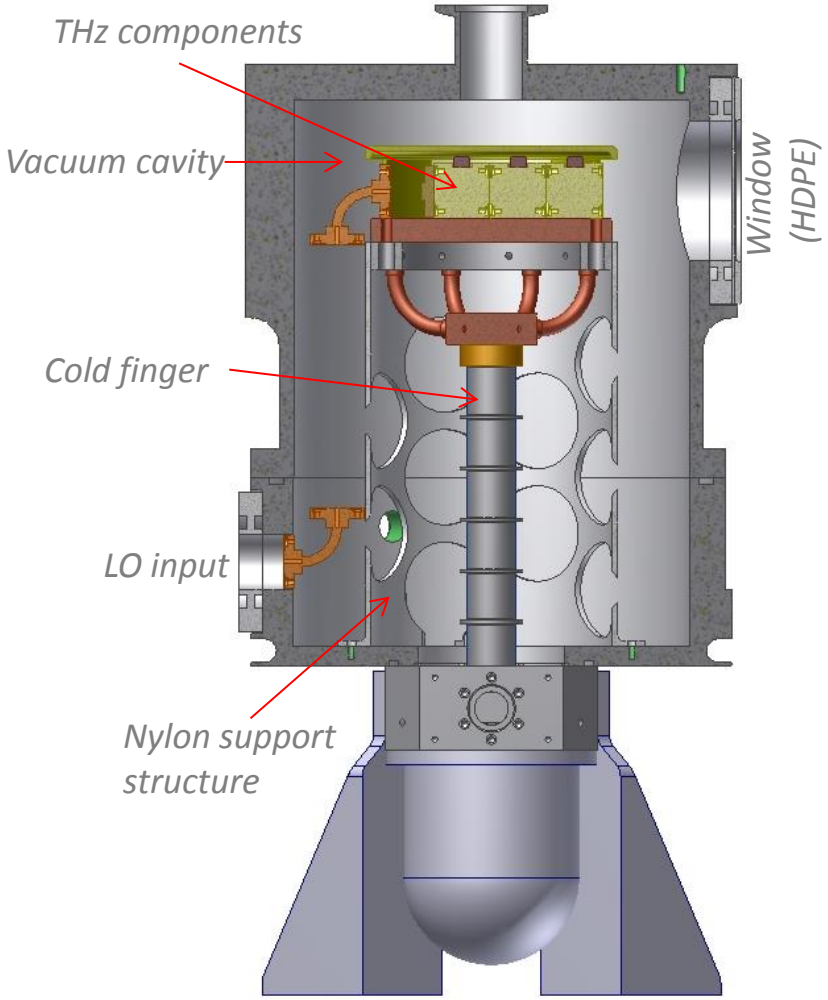
Preliminary Instrument Model



Cryostat for LOCUS Breadboard



Schottky Components

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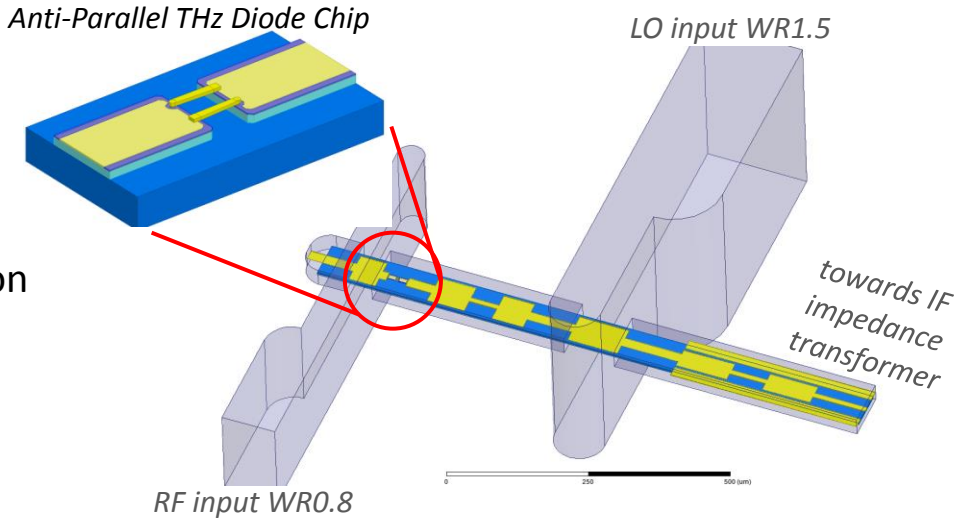
1.1 THz Mixer

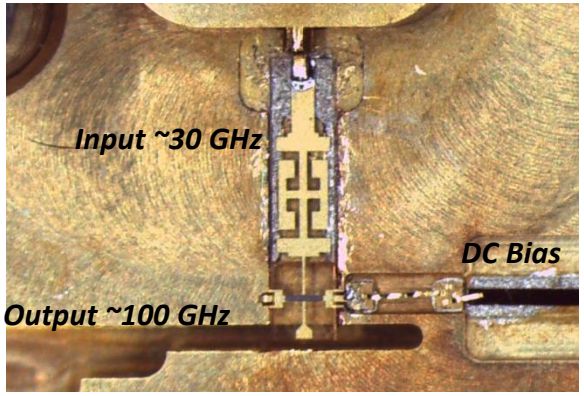
- *New diode chip required*
  - Smaller feature sizes to reduce parasitics
  - Anode diameters < 1um → New fabrication techniques required (E-beam lithography)
- *New sub-harmonic design complete*



1.1 THz Mixer Design

Frequency Multipliers

- *Existing diode designs should be sufficient*
  - High-power doubler demonstrated at RAL @ 166 GHz
  - Triplers demonstrated at 100 GHz – similar design topology at 573 GHz.



100 GHz Tripler

Wideband Spectrometer

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Research & Development

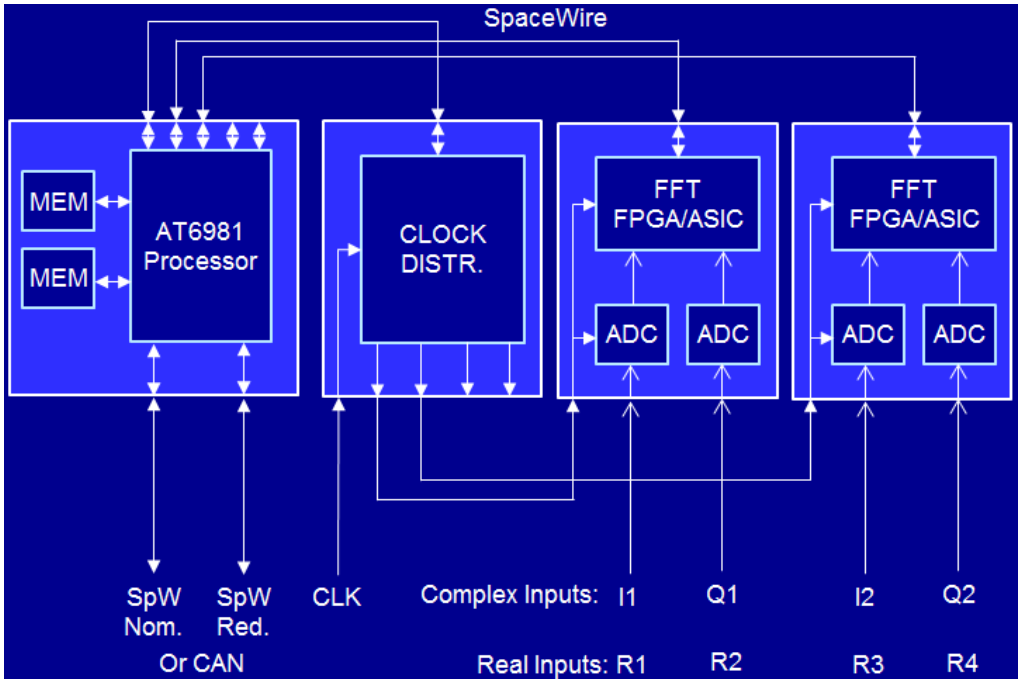
WBS III: Aircraft Flight

WBS II: 2 GHz BW

WBS I: 1 GHz BW

WBS IV Objectives

- *Reduced power consumption*
- *Increased performance*
- *Higher TRL*
- *Representative of a spaceflight unit*
- *Suitable for laboratory and airborne testing*



Terahertz Quantum Cascade Lasers

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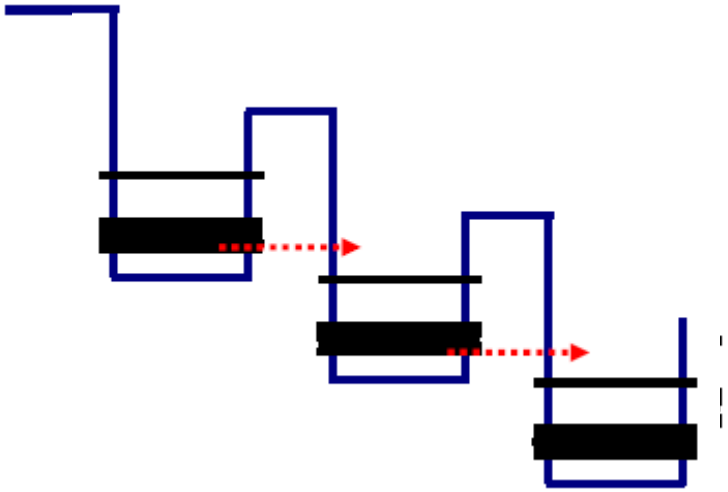
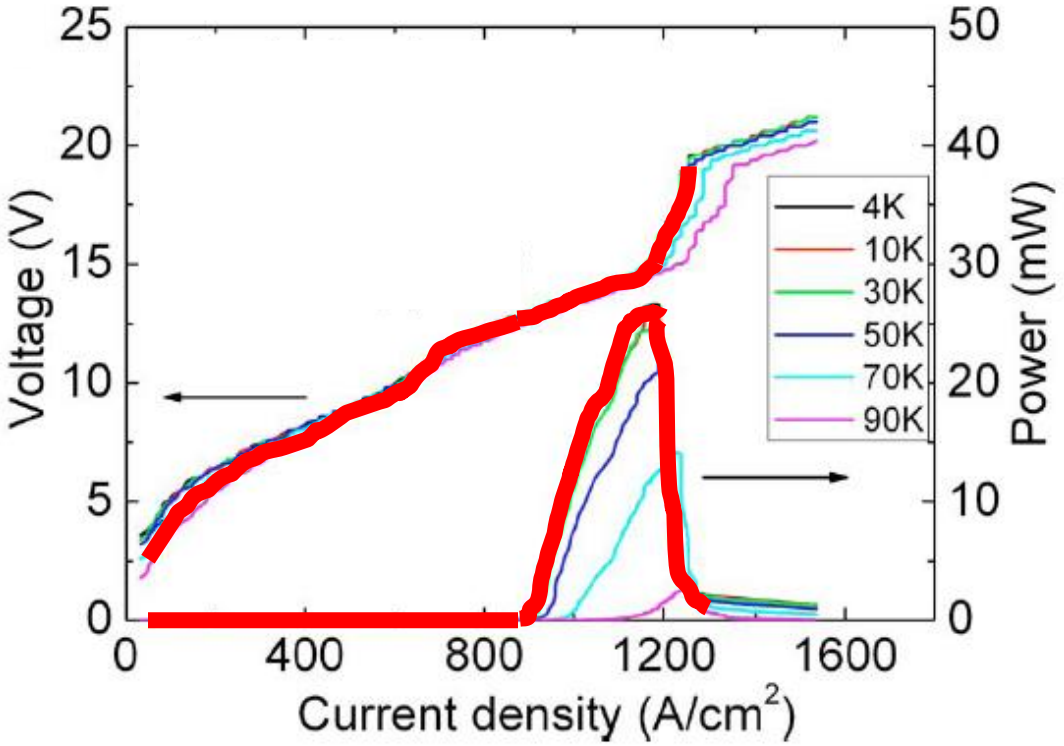
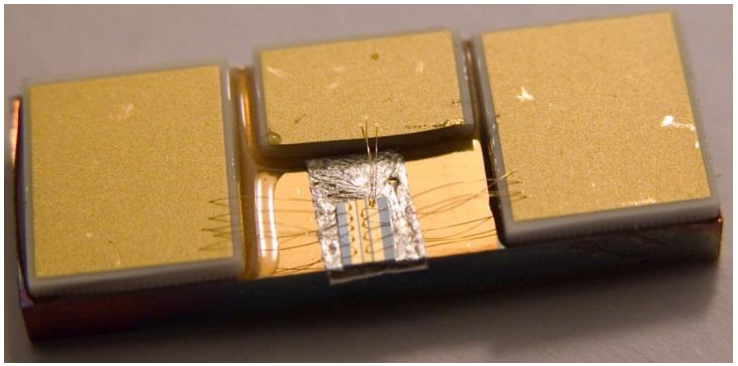




- *Operation of lasers based on quantum engineering*
- *3.5 THz and 4.7 THz channels*
- *World-record peak powers of up to 1W demonstrated at Leeds*
- *Compact semiconductor structures (typically 1 mm x 100 μm x 10 μm).*



Terahertz Quantum Cascade Lasers – CEOI Developments

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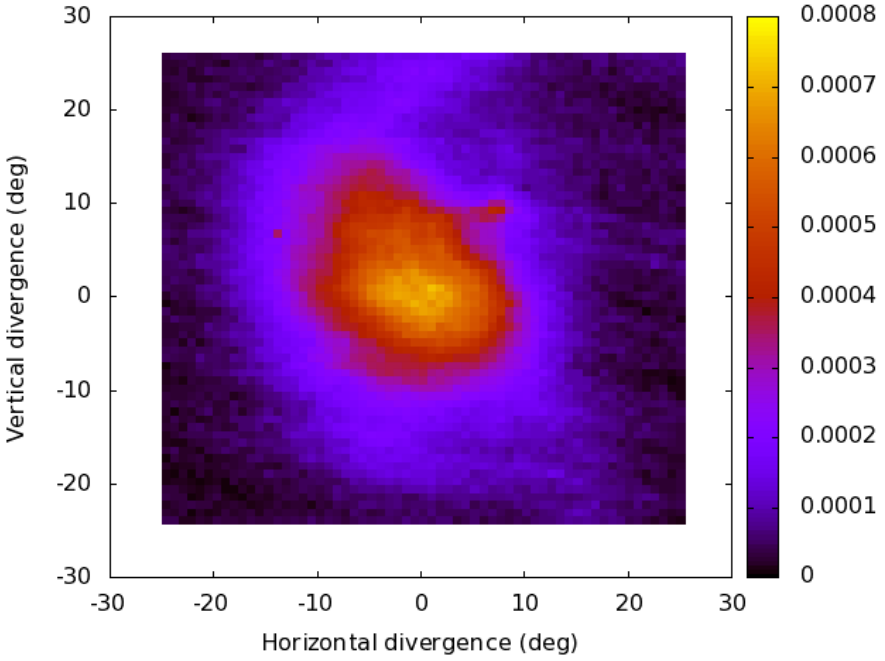
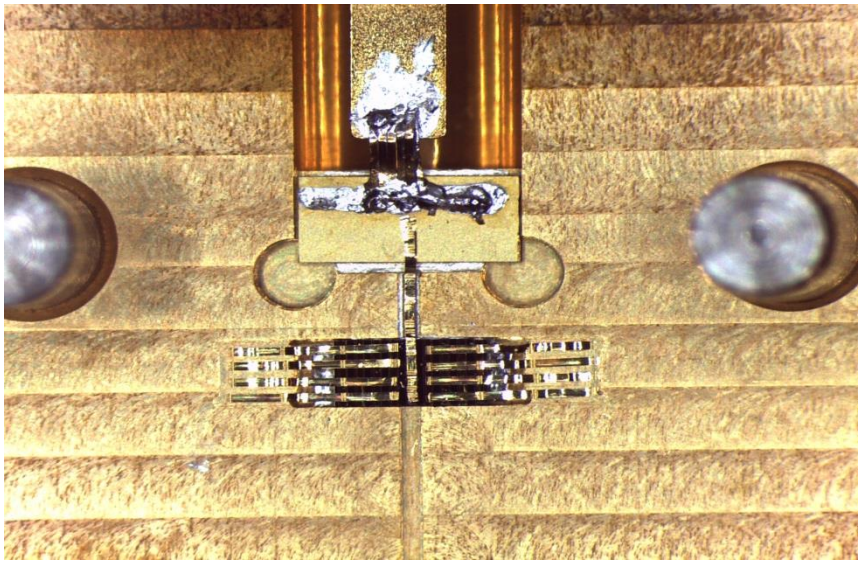
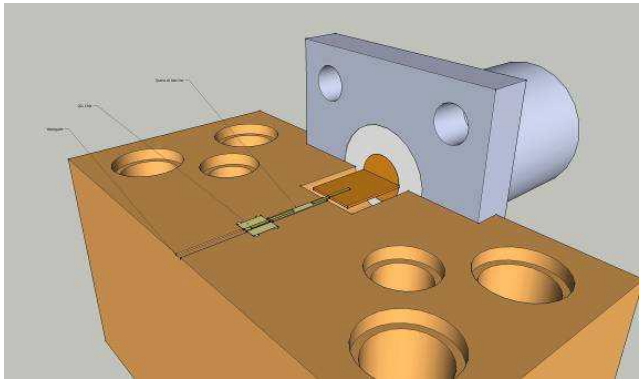
- *Operating frequencies demonstrated, at both 3.5 THz and 4.7 THz.*
- *But devices need cryogenic operation (~77 K), large input powers, and to be integrated with waveguides/packaged.*
- *Integration into micro-machined waveguides has occurred with RAL.*
- *First design operational in 2014.*







Summary – LOCUS Technology

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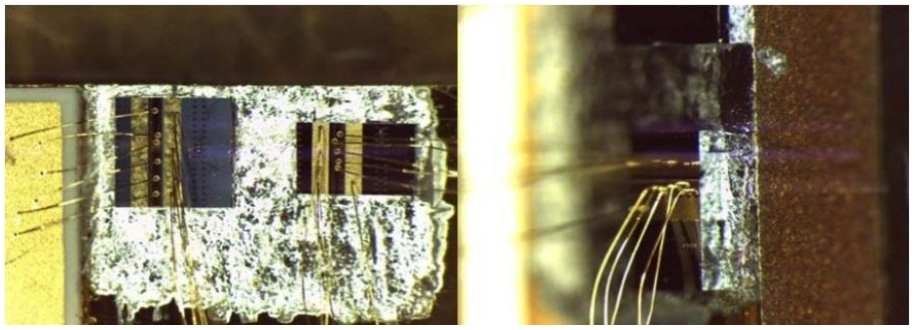
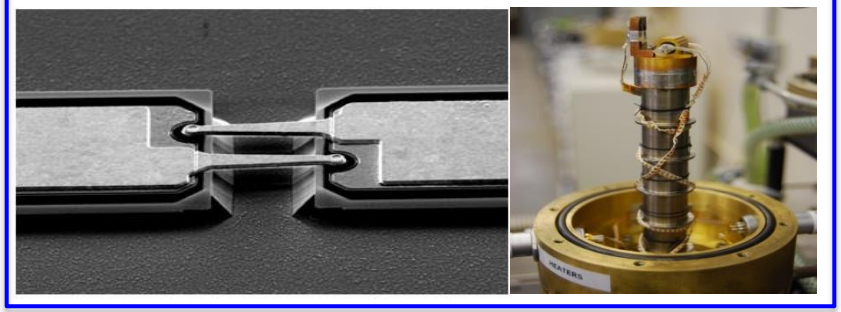
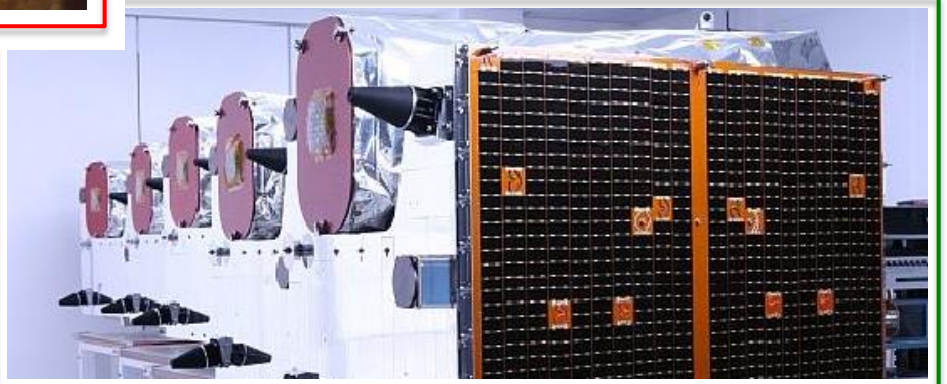
QCL Local Oscillator
University of Leeds



Schottky Barrier Diode
& Space Coolers RAL





Digital Spectrometer
STAR-Dundee

UK also leading LOCUS science definition via
Leeds, UCL and RAL

Small Satellite
Surrey Satellites Ltd

Summary – LOCUS Roadmap

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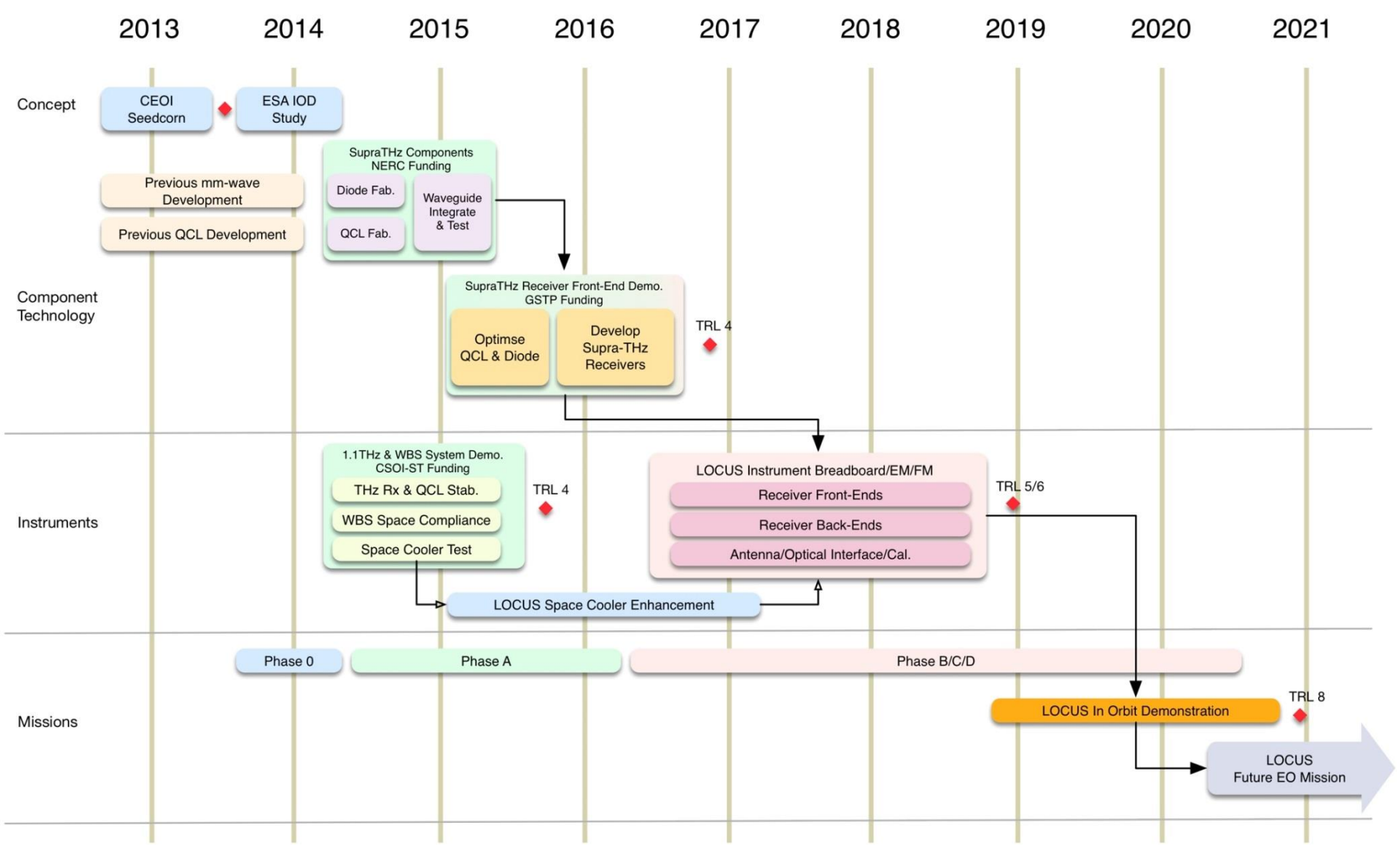

LOCUS Team Members

UNIVERSITY OF LEEDS

RAL Space

SURREY SATELLITE TECHNOLOGY LTD

UNIVERSITY OF LEEDS

UCL

STAR-Dundee