Conference or Workshop Item:

Valavanis, A orcid.org/0000-0001-5565-0463, Auriacombe, O, Rawlings, T et al. (12 more authors) An Integrated 3.5-THz QCL Optical Breadboard System for the LOCUS Atmospheric Sounder. In: 8th International Quantum Cascade Lasers School and Workshop (IQCLSW), 02-07 Sep 2018, Cassis, France.

An Integrated 3.5-THz QCL Optical Breadboard System for the LOCUS Atmospheric Sounder

A. Valavanis[1,*], O. Auriacombe[2], T. Rawlings[2], Y. Han[1], S. P. Rea[2], M. Crook[2], D. Brooks[3], C. Arena[3], D. Walker[4], G. Yu[4], L. H. Li[1], A. G. Davies[1], G. Savini[3], E. H. Linfield[1] and B. N. Ellison[2]

[1] School of Electronic and Electrical Engineering, University of Leeds, Leeds, LS2 9JT, UK
[2] STFC Rutherford Appleton Laboratory, Harwell Oxford, Didcot, OX11 0QX, UK
[3] Department of Physics and Astronomy, University College London, London, WC1E 6BT, UK
[4] National Facility for Ultra Precision Surfaces, OpTIC Centre, St. Asaph, LL17 0JD, UK
**Contact Email: a.valavanis@leeds.ac.uk*

Introduction

An "elegant breadboard" system has been developed, which demonstrates the integration of terahertz-frequency (THz) sources, optics and compact cryocooler technology for the LOCUS satellite (Linking Observations of Climate, the Upper Atmosphere and Space Weather) [1]. This proposed satellite instrument has the aim of providing the first global mapping of key molecular species within the mesosphere and lower thermosphere (MLT) from low-earth orbit (LEO), using compact radiometers operating in the 0.8–4.7-THz band and a set of infrared detectors. The LOCUS THz radiometers will incorporate planar-Schottky-diode (SD) mixers, driven using waveguide-integrated local-oscillators (LOs). The LOs will be based on SD multipliers operating at 0.8 and 1.1 THz, and THz quantum-cascade lasers (QCLs) operating at 3.5 and 4.7-THz. A key technological challenge, addressed by the LOCUS elegant breadboard, is the integration of these components into a compact and robust satellite payload, including space-qualified cryocooler technology, and suitable fore-optics. In this paper, we discuss recent progress in QCL integration within the 3.5-THz channel.

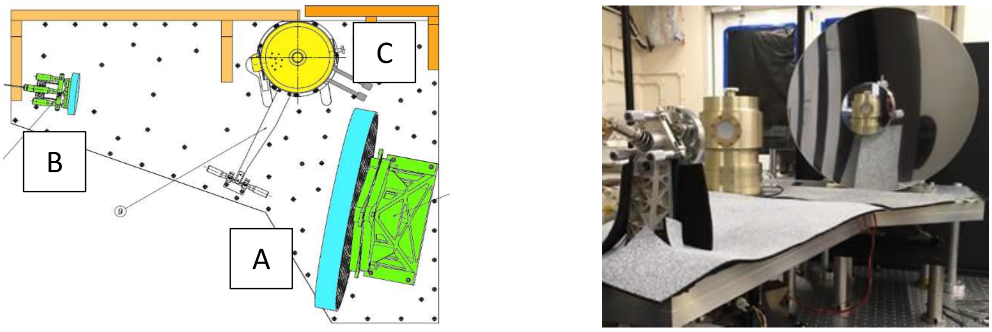

Fig. 1: (Left) Top-down CAD illustration of LOCUS breadboard: A, B = telescope optics, C = cryocooler. (Right) Photograph of fully-constructed system.

1. System architecture

Figure 1 shows a CAD illustration and photograph of the LOCUS elegant breadboard system, which is constructed on a custom-machined aluminium supporting plate. A Cassegrain telescope configuration (A,B) is used for the fore-optics to yield a compact instrument envelope (< 1 m^3). A 480-mm-diameter diamond-turned concave primary mirror, and 100-mm convex secondary were designed to yield 2-km atmospheric-layer resolution from an 800-km altitude, and onto a 25-mm focal plane diameter. The optical focal-plane lies within a compact, space-qualified Sterling-cycle cryocooler. Within a flight-ready system, the mixer and LO for each channel will be mounted within the cooler. In the present configuration, however, the LO source under-test has been mounted individually, and used as an emitter to test the optical system integration.

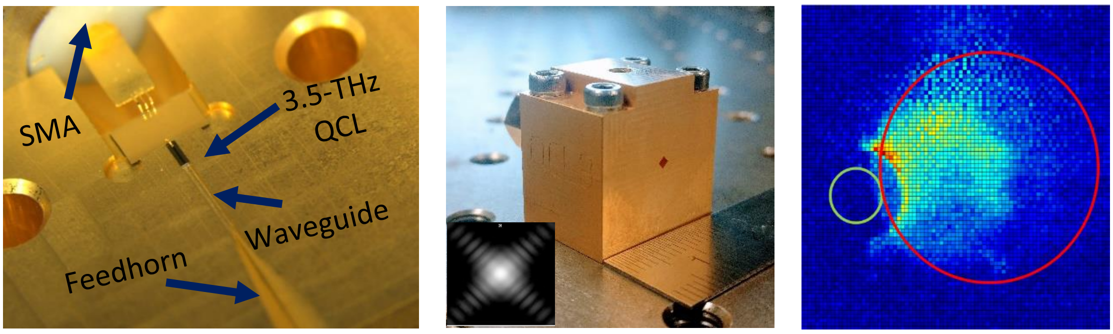

Fig. 2: (Left) 3.5-THz QCL mounted within a 150-µm-wide waveguide channel. (Centre) Complete assembled QCL/waveguide enclosure, with diagonal feedhorn aperture visible. Inset: Simulated far-field beam pattern. (Right) Measured near-field profile from Cassegrain optics showing location of primary and secondary mirrors (large and small circles, respectively).

For the LO, a 3.5-THz QCL, based on the active region in [2] has been processed into a double-metal ridge waveguide with 75-µm width, and the substrate reduced through mechanical and chemical etching to a thickness of 90 µm. The device was cleaved to a length of 980-µm and diced into a 110-µm-wide chip. The QCL was subsequently solder-mounted within a precision micro-machined 130-µm-wide × 75-µm-deep channel within an oxygen-free copper enclosure (Fig. 2:left), and ribbon-bonded to an integrated SMA connector. A second, symmetrical copper section was attached above the QCL to form a rectangular waveguide enclosure around the device. In contrast to our previous work [3], a single QCL ridge has been used, and a diagonal feedhorn (Fig. 2:centre) has been integrated into the waveguide structure to improve free-space coupling.

2. Results and conclusion

The QCL waveguide block was mounted within the cryocooler and driven in continuous-wave (cw) operation using a dc current source. The cryocooler was found to provide sufficient heat-lift at the optimal QCL bias (3 W) and maintained a stable temperature of 60 K. The THz output power was measured using a photoacoustic power meter as > 8 mW, and the beamwidth was found to be 5–8°, using a raster-scanned Golay detector positioned in the far-field of the feedhorn antenna. The telescope optics were positioned and aligned on the breadboard, and the THz beam was measured, using the same technique, in the near-field of the primary mirror. Absorbing media were placed adjacent to the beam-path to eliminate stray reflections. Fig. 2:right shows that successful propagation of the 3.5-THz signal along the complete optical path has been achieved. Subsequent alignment optimisation is expected to eliminate the slight field-truncation caused by the positioning of the secondary mirror, and beam-spillover from the QCL source.

In conclusion, we have integrated a 3.5-THz QCL-LO, waveguide and feedhorn within a space-qualified cooler, and demonstrated successful propagation of radiation through a custom-machined Cassegrain optical system. This is a key step in raising the technology-readiness level of core system components for the proposed LOCUS satellite instrument.

References

[1] S. P. Rea *et al.*, "The Low-Cost Upper-Atmosphere Sounder (LOCUS)," in *26th international symposium on space terahertz technology*, Cambridge, MA, 2015.

[2] G. Scalari *et al.*, "Far-infrared ($\lambda \approx 87\,\mu$m) bound-to-continuum quantum-cascade lasers operating up to 90 K," *Appl. Phys. Lett.*, vol. 82, no. 19, pp. 3165–3167, May 2003.

[3] A. Valavanis *et al.*, "Mechanically robust waveguide-integration and beam shaping of terahertz quantum cascade lasers," *Electron. Lett.*, vol. 51, no. 12, pp. 919–921, Jun. 2015.