Conference or Workshop Item:

Zafar, E, Auriacombe, O, Rawlings, T et al. (9 more authors) Electromagnetic modelling of a terahertz-frequency quantum-cascade laser integrated with dual diagonal feedhorns. In: 2019 Infrared Terahertz Quantum Workshop (ITQW 2019), 15-20 Sep 2019, Ojai, California, USA.

Electromagnetic modelling of a terahertz-frequency quantum-cascade laser integrated with dual diagonal feedhorns

Esam Zafar[1*], O. Auriacombe[2], T. Rawlings[2], N. Brewster[2], M. L. Oldfield[2], Y. Han[1], L. H. Li[1], E. H. Linfield[1], A. G. Davies[1], B. N. Ellison[2], P. Dean[1] and A. Valavanis[1,*]

[1] School of Electronic and Electrical Engineering, University of Leeds, Leeds LS2 9JT, U.K.
[2] RAL Space Department, UKRI–STFC, Harwell Oxford, Didcot OX11 0QX, U.K.
*Contact Email: a.valavanis@leeds.ac.uk

Short Abstract We present an electromagnetic model of a THz QCL, integrated with a micro-machined waveguide and dual diagonal feedhorns, enabling simultaneous access to both facets of the QCL. A hybrid finite-element/Fourier transform approach enables analysis of both the near and far-fields in agreement with experimental observations. The far-field pattern shows enhancement of the beam profile when compared with an unmounted QCL, in terms of beam divergence and side-lobe suppression ratio.

1. Introduction

There is considerable scientific interest in studying the abundance of key gas species (primarily O and OH) within the mesosphere–lower thermosphere (MLT) region of the Earth's atmosphere, in part because there is a strong indication that these provide a highly sensitive indicator of climate change. The proposed Linking Observations of Climate, the Upper Atmosphere and Space weather (LOCUS) satellite mission aims to observe these gases by limb-sounding from low-Earth orbit to record their emission spectra using four receiver channels in the 0.8–4.7 THz band [1]. The system comprises two novel terahertz-frequency (THz) radiometers, in which THz quantum-cascade lasers (QCLs) will be exploited as local oscillators (LOs) at 3.5 and 4.7 THz, owing to their high THz output power (> 1 mW continuous-wave), narrow intrinsic linewidths (~20 kHz) and compact size (~1 mm). Moreover, they have been integrated successfully into precision-micro-machined waveguide blocks and operated in space-qualified Sterling-cycle cryo-coolers (~60 K) [2]. Key development challenges remain though, including stabilizing the emission frequency of the QCL, and improving the beam-profile and the coupling of THz radiation between the QCL and other system components.

To address these challenges, we have developed a dual-feedhorn integration technique, which enables access to both QCL facets simultaneously. Fig. 1(a) shows the internal structure of a precision micro-machined copper block containing a 3.5 THz QCL mounted in a waveguide with a diagonal feedhorn at either end, enabling the THz emission to be coupled simultaneously to a mixer and a frequency-stabilization subsystem. In addition, the feedhorn has been shown to improve power outcoupling and beam divergence [3], but in order to optimize the far-field beam-profile, an electromagnetic model is needed.

2. Results

A hybrid modelling approach has been developed, to enable accurate yet fast simulation: an HFSS finite-element model of the field within the waveguide has been used to determine the near-field pattern, while a 2D Fourier transform approach has been used to find the far-field pattern. Fig. 1(b) and (c) show the simulated near-field and far-field (at 70-mm) beam patterns for a single feedhorn respectively. Since an over-moded waveguide has been used, this yields a highly non-uniform near-field profile. However, the far-field pattern is found to exhibit a well-defined central lobe, with 4.0384° divergence and 17.5 dB side-lobe suppression, in good agreement with the experimental results as shown (for both feedhorns simultaneously reflected onto the measurement plane) in Fig. 1(d). We show also that this modelling technique enables an analysis of the impact of waveguide and feedhorn geometry on the far-field pattern, providing a means of optimizing the coupling of THz radiation between a QCL and other system components.

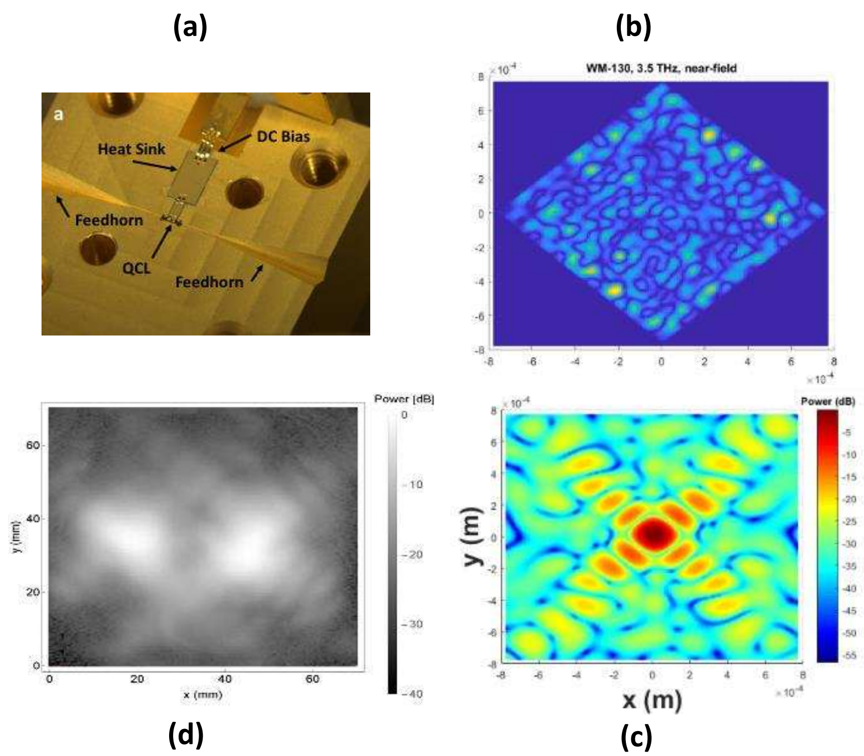

Figure 1: (a) QCL mounted within a dual-feedhorn waveguide block (b) Simulated beam-profile for the emission from a single feedhorn in the near-field, (c) simulated emission beam-pattern obtained at 70 mm away from the feedhorn aperture, (d) experimental results of the beam-pattern of dual-diagonal feedhorn.

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] 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.

[3] B. N. Ellison et al., ‘3.5-THz quantum-cascade laser emission from dual diagonal feedhorns’, in 12th European Conference on Antennas and Propagation (EuCAP 2018), 2018, pp. 1–4.