Surface-profiling through self-mixing in a THz quantum cascade laser

R. Alhathlool[1,a], P. Dean[1], A. Valavanis[1], Y. L. Lim[2], R. Kliese[2], M. Nikolić[2], S. P. Khanna[1], L. H. Li[1], D. Indjin[1], J. Cunningham[1], S. J. Wilson[2], A. D. Rakić[2], A. G. Davies[1] and E. H. Linfield[1]

[1]*School of Electronic and Electrical Engineering, University of Leeds, Leeds LS2 9JT, UK*
[2]*School of IT and Electrical Engineering, The University of Queensland, QLD 4072, Australia*
[a] *elrhsa@leeds.ac.uk*

Terahertz frequency quantum cascade lasers (THz QCLs) are semiconductor sources of coherent THz radiation, and have numerous potential applications in chemical sensing and industrial inspection, as well as security and biomedical imaging [1]. However, these applications require a compact and sensitive detection system. We address this by using a THz QCL as both the radiation source and as an interferometric detector.

Self-mixing (SM) occurs when radiation is reflected from an external object back into the QCL cavity. The resulting interference modulates the emitted power and QCL voltage [2], depending on the amplitude and phase of the reflection. This allows simple, 'detector-free', sensing of displacement and reflectivity, with high-sensitivity owing to its coherent nature [3, 4]. We demonstrate 3D imaging using SM in a THz QCL. Fig. 1(a) shows a 3D image of a stepped GaAs structure fabricated by wet chemical etching, in which the surface height has been extracted from the phase of the SM signal. Although the SM signals in [3, 4] were obtained from changes to the laser voltage, we show that SM signals can also be obtained from the THz emission from the back laser-facet. Fig. 1(b) shows the equivalence of electrical and optical SM signals, resulting from reflections from an oscillating object. Owing to the high SM sensitivity, we have been able to demonstrate stand-off imaging at round-trip distances of up to 20 m through air.

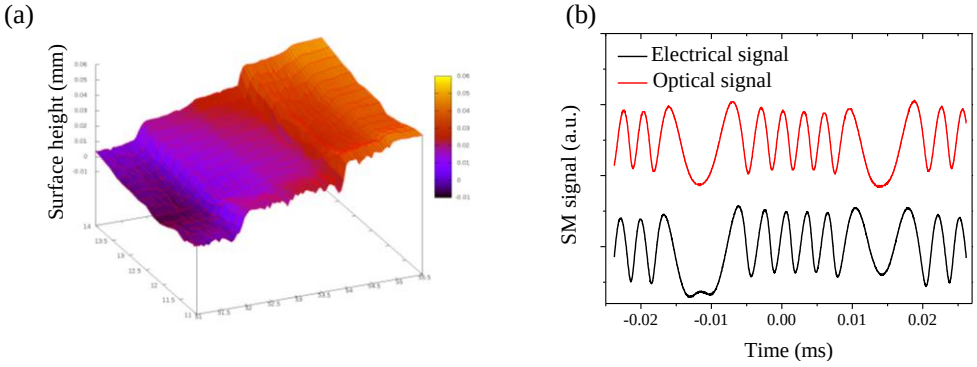

Fig. 1: (a) Exemplar 3D image of steps etched in GaAs. (b) Electrical and optical SM signals obtained in response to a moving target.

1. R. Kohler *et al.*, Nature **417**, 156 (2002).
2. R. Lang and K. Kobayashi, IEEE J. Quant. Electron. **16**, 347 (1980).
3. Y. L. Lim *et al.*, Appl. Phys. Lett. **99**, 081108 (2011).
4. P. Dean *et al.*, Opt. Lett. **36**, 2587 (2011).