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Gas spectroscopy with integrated frequency monitoring, through self-mixing in a terahertz quantum-cascade laser

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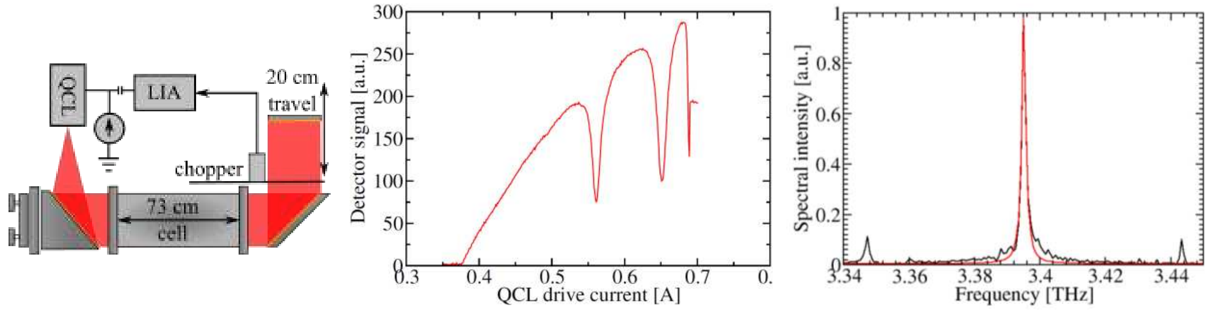
Terahertz-frequency quantum cascade lasers (THz QCLs) [1] have been used as compact, yet powerful sources of THz radiation in a range of gas spectroscopy techniques [2], including both in situ active sensing [3] and heterodyne radiometry [4]. A novel approach has recently been demonstrated, based on self-mixing interferometry (SMI) in a QCL [5]. This effect occurs when radiation is fed back into the QCL from an external reflector [6]. The resulting interference within the QCL perturbs the terminal voltage, and the absorption spectrum of a gas within the external cavity may be inferred from the amplitude of these perturbations. This eliminates the need for an external THz detector, doubles the interaction-length for absorption spectroscopy, and the scanning speed can potentially be raised to the time-scale of the QCL lasing dynamics (~10 GHz).

A limitation reported in the previously published work is that the QCL emission frequency was inferred from prior FTIR measurements of the unperturbed laser. However, the actual system QCL frequency is perturbed by SMI feedback effects and is therefore dependent on the gas absorption cross-section, leading to apparent frequency shifts in the measured spectral lines. In this work, we demonstrate a technique to measure the frequency directly by extending the external cavity length modulation to 200-mm using a motorised linear translation stage [Fig. 1(a)]. The QCL in this system can be tuned by adjusting the drive current, over a 1.5 GHz bandwidth, around a centre frequency of 3.394 THz. Fig. 1(b) shows the transmitted radiation intensity through a 73-cm gas cell with TPX windows, filled with methanol vapour at a pressure of 2 Torr, as a function of drive current, measured using a pyroelectric detector. Two absorption lines are clearly resolved. By replacing the detector with a planar mirror, and recording the QCL voltage modulation as a function of stage position, a full interferogram can be acquired, and a Fourier transform can then be used to determine the laser frequency and the amplitude of the transmitted signal [Fig. 1(c)]. In this paper, we will demonstrate the reconstruction of the methanol absorption spectrum, with direct measurement of the laser frequency using this technique.



(a) (b) (c)

Figure 1 (a) Schematic of SMI system (LIA = lock-in amplifier) (b) transmitted THz power through methanol as a function of QCL drive current, recorded using a pyroelectric detector. (c) Exemplar QCL emission spectrum obtained from SMI interferogram

References

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