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

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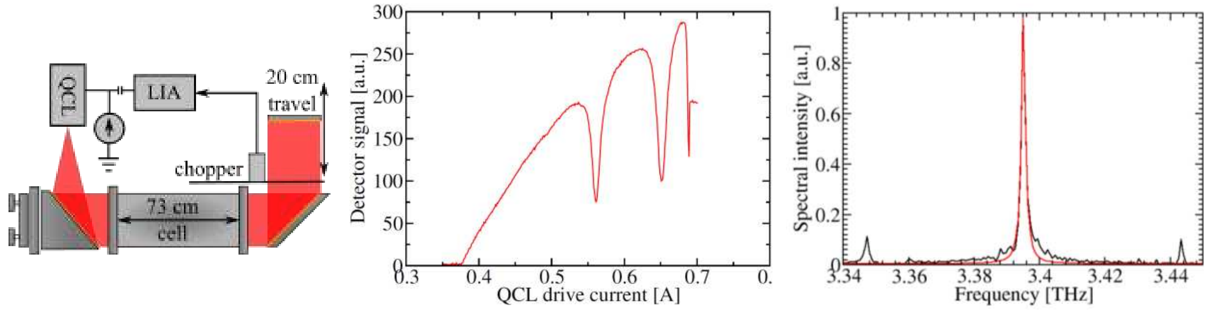
Terahertz-frequency quantum cascade lasers (THz QCLs) [1] have been used as compact, yet powerful sources of THz radiation in a range of gas spectroscopy techniques [2], including both *in situ* active sensing [3] and heterodyne radiometry [4]. A novel approach has recently been demonstrated, based on 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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