Terahertz quantum cascade lasers with externally biased photonic lattices for electronic tuning

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Single-mode (SM) operation of terahertz (THz)-frequency quantum cascade lasers (QCLs) is essential for their use in gas sensing [1] and as local oscillators. Whilst SM operation has been demonstrated previously using distributed feedback (DFB) gratings [2] and photonic lattices (PLs) [3], an ability to tune SM THz QCLs electronically would be highly desirable for many applications. We have fabricated THz QCLs with electronically-controlled PL gratings. Our THz QCLs, based on a bound-to-continuum active region design [4], were processed into 150-µm-wide semi-insulating surface plasmon ridge waveguides with lengths 2.5–4.5 mm. The upper waveguide was then patterned into three sections. The outer sections were fully metallised. In the central 530-µm-long section, however, the top n-doped layer was etched away and metallic PLs fabricated using electron-beam lithography, with grating pitch 14.60–15.65 µm. In each device, both the PL and the outer sections were bonded separately to allow independent biasing [Fig. 1(a)]. Devices were cooled in a continuous-flow helium cryostat and emission spectra measured using a Fourier-transform infrared spectrometer. Standard (unpatterned) devices lased with multiple Fabry–Pérot modes in the range 2.70–2.83 THz, whilst single mode emission was observed for devices patterned with a PL. The emission spectra recorded from devices with PLs of different grating pitch showed stop-band behaviour [5], with an experimentally-determined stop-band bandwidth of around 25 GHz in agreement with the value of 23 GHz calculated using finite-element modelling. A bias of 2 V applied to the PL led to a change in the spectral features in a number of devices, an example of which is shown in Figs 1 (b) and (c).

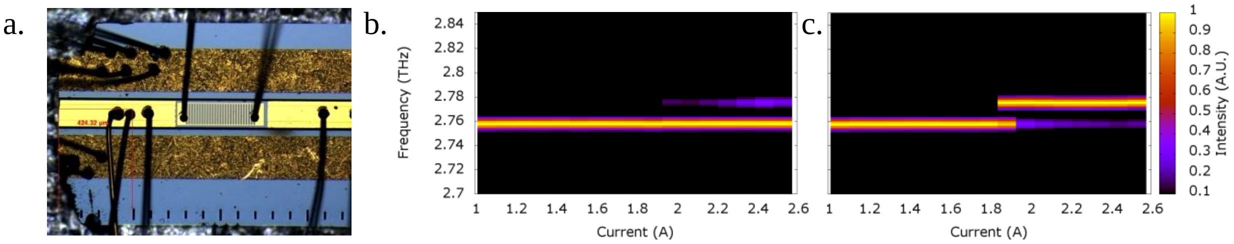

Fig. 1: (a) Optical image of a fabricated device. Spectra obtained with (b) an unbiased PL and with (c) a 2 V bias applied to the PL.

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