Magnetic-field-controlled THz Quantum Cascade Laser Operating Up to 225K

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Introduction

The first THz Quantum Cascade Laser (QCL), emitting at 4.4 THz, was first reported in 2002. THz QCLs are able now to cover the spectral range from 5 THz down to 1.2 THz, though cryogenic cooling is still required [1]. Further progress towards the implementation of QCLs operating at higher temperatures (eventually at room temperature) and emitting at longer wavelengths (sub-THz QCLs) becomes ever more difficult because it requires maintaining a population inversion between closely-spaced electronic subbands (1THz ~ 4meV). Strong magnetic field (B⊥2DEG) breaks the energy spectrum into a ladder of discrete Landau levels (LLs), and finally allows to achieve lasing between quasi-0D LL states [2]. Here we exploit this approach of "LL engineering" to explore the ultimate limits of THz QCL operation [3].

Experimental

The samples studied are two GaAs/$Al_{0.15}Ga_{0.85}As$ THz QCLs. The structures designed to emit at ~3 THz (~12.4 meV) utilize LO-phonon scattering for fast depopulation of the lower state of the laser transition. The QCLs were measured in DC magnets up to B=35T. Measurements were performed from liquid helium temperatures to 300 K with a current pulser. Spectra were taken with a Bruker 66 spectrometer.

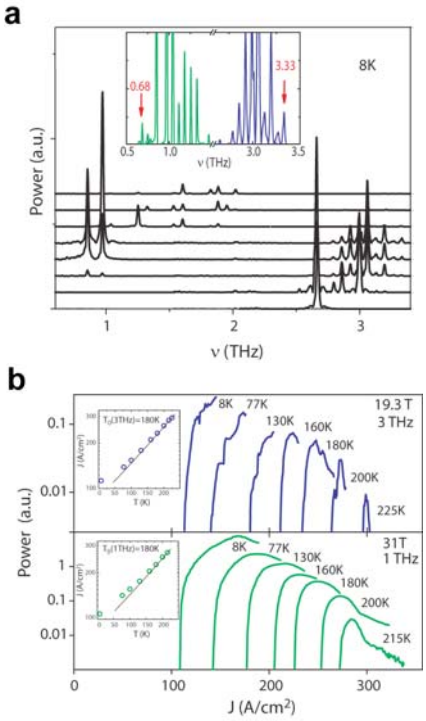

Fig. 1. a, Spectral coverage of the QCL device with increasing voltage bias and magnetic field (bottom curve 13T; top curve 25T). The inset shows the QCLs spectral extremes: 0.68THz (31.2T) and 3.33THz (19T). b, Temperature dependence of P(J) at two enhanced lasing positions at 19.3T and 31T. The inserts show the current density threshold as a function of the temperature.

Results and Discussion

At B=0, the QCLs exhibits laser action at ~3 THz. As an external magnetic field up to 15T is applied, the QCLs behave similarly save for a decrease in the current threshold. Above 15 T the laser behavior changes dramatically. Applying appropriate bias and magnetic field, one achieved laser emission from a single device in an unprecedented range of frequencies: 3.3 to 2.6 and 1.9 to 0.68 THz. In a narrow range of magnetic fields of about 20T, we observed strong dual-frequency lasing (0.97THz and 3THz) that originates from the simultaneous emission from two cascaded optical transitions in each QCLs period. Moreover, 1THz laser action is observed at temperatures up to 215K (19T), and 3THz lasing up to 225K (31T). This is the longest wavelength, the widest spectral coverage, and the highest operational temperatures of any single THz solid state laser to date.

Conclusions

We demonstrate magnetic field-assisted, (sub)THz QCL operating above 200K. This is achieved through the application of strong magnetic fields which provide an additional lateral confinement in order to suppress non-radiative intersubband scattering. Furthermore, these results bear out the prediction that lateral quantum confinement, provided either magnetically, electrostatically, or structurally (i.e. a quantum box), is a route to higher temperature operation for THz QCLs.

Acknowledgements

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References

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[3] Wade, A., *et al.*, Nature Photonics, **3**, 41 (2009).