Photonics with terahertz quantum cascade lasers

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Project Description
This is a unique and exciting opportunity to develop terahertz (THz) quantum cascade laser (QCL) with photonic functionality using novel aperiodic lattices. This research will form part of a wider research programme within the group and it is expected that the PhD students and PDRAs will work in partnership with other researchers, in Manchester and collaborating University(ies).

The THz QCL (Figure 1) employs sophisticated techniques for the control of electron propagation, with an MBE grown “active region” comprising a repeated superlattice of only a few atoms thick of one semiconductor material, interleaved with similarly thin barrier layers of another material. In these semiconductor nanostructures, the energy bands split into subbands and minibands, with energy separations of several tens to a few hundreds of millielectronvolts, which determine electronic transport and also enable new optical transitions. When a bias voltage is applied across the material, a periodic cascade of such intersubband transitions is established. The population inversion necessary for lasing is then achieved through electrical injection. Adjusting the specific sequence of quantum wells and barriers so as to form an electronic aperiodic lattice allows both the electronic and optical properties of the THz QCL to be tailored at will. A combined approach to integrate both electronic and photonic aperiodic lattices within a single THz QCL device is therefore another important aspect of this project.

The demonstration of a compact, coherent, tunable THz QCL arising from this research will act as a significant enabler in the advancement of THz photonics and will sow the seeds for some commercially very significant THz communication technology. For example, it will be possible to realize ultra-short-range wireless access, with data transfer rates greater than 60 Gbps. Indeed, 140 GHz (sub-Terahertz) is the last remaining atmospheric window and offers wireless communication capacities up to 100 Gbps, e.g. for 100 GbE. In optical communications, industry is already finalising standards for 100 GbE. We will also address some of the important issues involving a fusion of state-of-the-art technologies including optical telecommunication and tunable THz QCLs.

Further Information and Application
Potential candidates may wish to contact Dr Chakraborty for informal discussion on 0161 306 4831, or by e-mail s.chakraborty@manchester.ac.uk.
Nano-Photonically engineered “Tunable THz QCL”

Example of a novel design of modes elimination enabling multiple localized states, possible only with a periodic photonic lattice implemented within the surface plasmon waveguide, shown below.

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Figure 3: 3D graph showing the simulated emission spectra of THz QCL FP cavity with single defect photonic lattice as facet phase is scanned.

Figure 4: 2D (top) view showing mode position vs. facet phase.