Guest Editorial
Mini-Special Issue on International Quantum Cascade Lasers School and Workshop (IQCLSW 2016)

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Quantum cascade lasers (QCLs) are unipolar optoelectronic devices that exploit optical transitions between engineered electronic subbands created in multiple coupled semiconductor quantum wells. The large number of nanometre thick semiconductor layers and the complexity of the overall structure, makes the QCL the most impressive demonstration of the capabilities offered by bandstructure engineering and state-of-the-art materials growth technologies.

Now 20 years from their first experimental realisation, QCLs have proven to provide outstanding performance across themed infrared and far-infrared (terahertz) spectral ranges. The QCL is the most efficient and compact source in the mid-infrared spectral range with multiWatt output powers, continuous wave and room temperature operation, and with wall-plug efficiencies exceeding 20% at room temperature. Although still requiring cryogenic cooling, terahertz frequency QCLs have a significant opportunity to impact technological applications in the far-infrared, owing to their high output powers (>1 W), broad operating frequency range, compact footprint, the use of photonic and plasmonic approaches to engineer the output beam profile, and the ability to stabilize their frequency, phase, and amplitude. The recent development of room temperature terahertz sources based on intracavity frequency mixing in mid-infrared QCLs, with the latest devices achieving nearly 2 mW of peak output power, and tunable across the 1–6 THz spectral range, further demonstrates the versatility and potential of QCL technology.

The QCL has already been commercialised by a number of companies internationally, and is the core photonic component in technology underpinning a variety of applications in, for example, fields such as: medical, environmental and security sensing; process and quality control; telecommunications; and, metrology. The QCL is also an exciting and versatile vehicle for the pursuit of fundamental blue-sky research, including developing coherent control in condensed matter systems, developing quantum technologies, and understanding the origins of the lasing process itself.

The International Quantum Cascade Lasers School and Workshop (IQCLSW 2016) held at Selwyn College, Cambridge, U.K., in September 2016, was the seventh conference in the successful biennial IQCLSW series. With around 120 delegates, the Workshop comprised four keynote talks, seven invited talks, 32 contributed talks, and 61 poster presentations, in additional to the nine invited tutorial speakers that comprised the associated School. The three representative papers presented here cover three different contemporary aspects of the field, namely frequency comb generation, frequency tunability, and the development of robust QCL models for device optimization. The paper by Tzenov *et al.* considers the generation of frequency combs in terahertz frequency QCLs, and investigates the interplay between the various physical mechanisms that determine whether a given QCL will emit a comb-like spectrum or not. The authors consider the roles of four-wave mixing, the group velocity dispersion, and spatial hole burning, and conclude that the latter is particularly influential on the laser dynamics, inducing phase and amplitude instabilities that can impede the generation of a comb-like spectrum.

The paper by Kundu *et al*. reports on an experimental and theoretical investigation in the use of photonic lattices to control the spectral emission of terahertz frequency QCLs. By incorporating a central π-phase adjusted defect into the photonic lattice, three distinct spectral behaviours were found to result: single mode emission exhibiting continuous frequency tuning through control of the driving current and heat sink temperature; discrete tuning between two engineered emission lines; and, multiple- mode emission with an engineered mode spacing. The authors propose that such QCLs could find use in applications including gas spectroscopy, and laser feedback interferometry imaging, for example.

Finally, the paper by Demić *et al.* discusses the challenges that can arise in commonly employed semiclassical QCL modelling approaches, such as self-consistent rate-equation modelling. The authors discuss how such models often fail to describe the transport between adjacent QCL periods because they do not take the injection barrier thickness into account, leading to the prediction of instantaneous transport between periods. Here a density matrix approach is used instead to model the QCLs, and in particular, when applied to common bound-to-continuum active region QCLs, good agreement is found with experimental data in terms of the current-voltage characteristics and lasing frequency.