

Abstract for the ND 2008

The generation and applications of terahertz frequency radiation

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Abstract

Over recent years, researchers have made rapid progress in developing systems to exploit the so-called ‘Terahertz Gap’, with potential application areas ranging from medical and dental imaging, the monitoring of pharmaceutical products, and the detection of drugs-of-abuse and explosives, through to atmospheric physics and astronomy, *inter alia*. They have also studied nanoelectronic structures, in which the characteristic energy scales typically fall within the terahertz (THz) frequency range. Almost all of this research has made use of either broadband THz systems, based on pulsed, femtosecond, near-infrared laser excitation of photoconductive emitters/non-linear crystals, or continuous-wave, narrow-band, systems based on photomixing in a photoconductive antenna. Indeed, broadband, pulsed THz technology forms the basis of the commercial systems marketed today.

This invited talk will review recent research at the University of Leeds in two principal areas: the development of GaAs-AlGaAs THz quantum cascade lasers (QCLs), and the study of on-chip THz systems:

- THz QCLs are sophisticated semiconductor heterostructures, in which continuous-wave THz radiation is generated through inter-subband transitions as electrons cascade through the active region, which usually comprises over 100 repeat periods, each consisting of three or more quantum wells. Since the first demonstration of a THz QCL in 2002 [1], rapid developments have occurred in the field internationally, and some key highlights will be reviewed. These include a systematic increase in the operating temperature to its current maximum value of 178 K [2], and the progressive widening of the frequency range covered by THz QCL technology. The use of patterned grating structures to modify the THz QCL plasmon waveguide will be presented, and it will be shown how patterned gratings can lead to (a) well-defined, single-mode lasing, and (b) surface, rather than edge, emission [3]. The establishment of a diffuse reflection imaging system for studying polycrystalline powders will also be outlined [4].
- On-chip THz systems make use of the evanescent electric field extending above lithographically-patterned THz microstrip waveguides, and offer a range of advantages compared with, more conventional, free-space THz systems. Like free-space time-domain spectroscopy systems, they allow broadband pulses to be generated and detected coherently, permitting broadband dielectric sensing to be undertaken [5]. In addition, through inclusion of a set of cascaded resonant filters, it is possible to demonstrate imaging with a <20 μm spatial resolution (which is over an order-of-magnitude smaller than achieved with free-space, diffraction-limited optics), and this can form the basis of a THz microscope [6]. Furthermore, on-chip THz systems are generally far more suitable for studying nanoelectronic devices, owing to the increased THz interaction with the device under test, and such systems have already been demonstrated to operate successfully at cryogenic temperatures [7].

The talk will conclude with a discussion of the future prospects for both THz QCLs and on-chip THz systems.

- [1] R. Kohler, A. Tredicucci, F. Beltram, H.E. Beere, E.H. Linfield, A.G. Davies and D.A. Ritchie, R.C. Iotti and F. Rossi, *Nature*, **417** (6885), 156 (2002)
- [2] M.A. Belkin, J.A. Fan, S. Hormoz, F. Capasso, S.P. Khanna, M. Lachab, A.G. Davies and E.H. Linfield, *Optics Express*, **16** (5), 3242 (2008)
- [3] J.A. Fan, M.A. Belkin, F. Capasso, S.P. Khanna, M. Lachab, A.G. Davies and E.H. Linfield, *Optics Express*, **14** (24), 11672 (2006)
- [4] P. Dean, M.U. Shaikat, S.P. Khanna, S. Chakraborty, M. Lachab, A. Burnett, G. Davies and E.H. Linfield, *Optics Express*, **16** (9), 5997 (2008).
- [5] J. Cunningham, C.D. Wood, A.G. Davies, C.K. Tiang, P.A. Tosch, D.A. Evans, I.C. Hunter, and M. Missous, *Applied Physics Letters* **88**, 071112 (2006).
- [6] J. Cunningham, M.B. Byrne, P. Upadhyaya, M. Lachab, E.H. Linfield, and A.G. Davies, *Applied Physics Letters* **92**, 032903 (2008).
- [7] C.D. Wood, J. Cunningham, P. Upadhyaya, E.H. Linfield, I.C. Hunter, A.G. Davies, and M. Missous, *Applied Physics Letters* **88**, 0142103 (2006).