TERA-MIR radiation: materials, generation, detection and applications

M. F. Pereira

Received: 22 January 2014 / Accepted: 23 January 2014 / Published online: 8 February 2014
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Abstract This special edition is dedicated to original papers covering topics with the areas of interest of COST ACTION MP1204 whose main objective is to advance novel materials, concepts and device designs for generating and detecting THz (0.3–10 THz) and Mid Infrared (10–100 THz) radiation using semiconductor, superconductor, metamaterials and lasers and to beneficially exploit their common aspects within a synergetic approach. The results achieved benefit from the unique networking and capacity-building capabilities provided by the COST framework to unify these two spectral domains from their common aspects of sources, detectors, materials and applications. We are building a platform to investigate interdisciplinary topics in Physics, Electrical Engineering and Technology, Applied Chemistry, Materials Sciences and Biology and Radio Astronomy. In this sense THz and MIR are considered jointly, the driving force for both regimes being applications. The main emphasis of the research presented here is on new fundamental material properties, concepts and device designs that are likely to open the way to new products or to the exploitation of new technologies in the fields of sensing, healthcare, biology, and industrial applications. End users are: research centres, academic, well-established and start-up companies and hospitals. The strong coupling of THz radiation and material excitations has potential to improve the quantum efficiency of THz devices.

Keywords TERA-MIR · Midinfrared · Terahertz · Sources · Detectors · Materials · Polaritons · Antipolaritons

In the last few years, MIR lasers, light-emitting diodes, detectors and frequency converters have featured significantly improved wavelength tunability, high spectral purity, higher powers and room temperature operation, which are necessary for commercial applications (Tittel et al. 2011; Razeghi 2013). However, whereas miniaturised and cost-efficient optical technology for wavelengths up to about $2.5\text{ }\mu\text{m}$ has become readily available at a very high standard, sources for longer wavelength applications have not yet reached the desired

M. F. Pereira (✉)
Material and Engineering Research Institute, Sheffield Hallam University, Sheffield, UK
e-mail: M.Pereira@shu.ac.uk

standards. From the MIR detection point of view, there is a need for phase sensitive, and near single-photon sensitivity similar to that found in the near-IR (optical metrology and telecommunications) and conventional bolometric detection is one of the technologies to be ultimately replaced. At the lower end of THz frequencies, the microelectronic technologies with key components such as Gunn diodes, multipliers, Schottky detectors are quite successful, but at the high-frequency side, the THz-generation and detection efficiencies decrease because of RC and possibly transit-time limitations in the devices. Therefore, such devices will probably not be able to get deep into the THz frequency range. Additionally, the devices have a rather narrow tuning bandwidth, which makes them not very practical in many situations. There is much hope that intersubband devices like quantum cascade lasers (QCLs) will be the main compact THz source but they currently require cryogenic cooling. We will stimulate the development of more efficient simulation tools ([Schmielau and Pereira 2009a,b](#); [David 2012](#)) and Round Robin actions for a systematic comparison of theory and experiments ([Pereira et al. 2007](#)). Thus out of the box solutions for THz QCLs such as lasing without inversion ([Pereira 2008](#); [Pereira and Tomić 2011](#)) as well as alternative generation methods will be investigated. From the detection point of view, more advanced solutions of e.g. QuantumWell detectors for the THz range (QWIPS) require further investigation and optimization for lower costs and efficiency in a broad range. Recent Field Effect Transistor based THz detectors open new possibilities of construction of real time THz imaging systems. Their efficiency in comparison with (QWIPS) or Schottky detectors needs still be confirmed. Another possibility for room temperature THz sources or detectors are nitride based high electron mobility transistors (HEMT). Nitride-based devices are very prospective for device applications, since the structures are robust and can work in harsh environments and elevated temperatures. New concepts based on bismides for MIR and THz will also be investigated as well MIR applications of Chalcogenide glasses, which are based on one or more of the Chalcogen Group elements other than Oxygen, such as S, Se, and Te. They are amorphous semiconductors and have high linear and non-linear refractive indices, with large third order non-linear susceptibilities, low phonon energies. Their wide transmission window, which extends from the mid-visible to MIR, makes them very promising candidates for integrated devices for all-optical processing and biosensing. GaAsBi structures exhibit sub-picosecond carrier lifetimes and have been already used effectively as photoconductors for generating THz radiation using pulsed lasers. However, GaSb-bismide-based materials and structures are far less known and will be grown and investigated for MIR applications ([Song et al. 2013](#)). The limits of QCL science and technology ([Miriam 2012](#)) will be investigated combining academic and industrial teams. Graphene is also emerging as a spectacular THz material and we plan to further stimulate joint efforts within the action ([Vicarelli et al. 2012](#)). Finally, integrating MIR components on a single chip to create a sensor system-on-a-chip and evaluating it is a task are also spectacular goals that we hope to see come through in the near future and that will be stimulated by our network.

This special edition summarizes some of the recent results of our network from fundamental Physics to applications. A wide range of related topics are covered such as: Numerical investigations of mid-infrared emission from Pr³⁺ doped GeAsGaSe fibre, studies of Fused fibre components for the eye-safe spectral region around 2 μm ; Validation of protein structural models using THz spectroscopy, which is a promising approach to solve three-dimensional structures; Detailed non-destructive evaluation of UHMWPE composites in the THz range; Development of a rapid-scan fibre-integrated terahertz spectrometers; Temperature dependent nonlinear response of quantum cascade structures; Preliminary Studies of the Raman Spectra of Ag₂Te and Ag₅Te₃; Fabrication and characterization of microlenses made of telluride and heavy metal oxide glass developed with hot embossing technology; Spontaneous

generation of entangled exciton in quantum dot systems; Performance limits of the mid-wave InAsSb/AlAsSb nBn hot infrared detectors; Characterization of a large core photonic crystal fibre made of lead-bismuth-gallium oxide glass for broadband infrared transmission; Mid-infrared supercontinuum generation in soft-glass suspended core photonic crystal fibre and the Coupling of THz radiation with intervalence band transitions in microcavities.

This special edition marks the kick-off our Networks' scientific activities. I thank my co-Guest Editors Anna Wójcik-Jedlinska, Trevor Benson and Marian Marciniak for their assistance in the preparation of this Special issue and we hope that our COST ACTION MP1204 initiative will help our research dreams become true.

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