URSI AP-RASC 2019, New Delhi, India, 09 - 15 March 2019

On the Development of Intense THz sources for nonlinear optics and spectroscopy

Sunil Kumar
Department of Physics, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016
e-mail: kumarsunil@physics.iitd.ac.in

In last couple of decades, the THz science and technology has made huge leap of progress and THz sources and detectors in limited field strength and frequency bandwidth are being made available commercially for applications in spectroscopy, sensing, imaging and medical diagnostics. This is primarily because of the mature NIR femtosecond laser technology and the coherent nature of the THz radiation allowing researchers to create simple table top experimental tools for their THz studies. However, there is a growing demand for intense THz sources which can allow perform nonlinear optics and spectroscopy and develop new methodologies. For nonlinear THz radiation and matter interaction, one needs typically THz-fields comparable to the atomic fields (~10^6 V/cm) such as those provided by lasers in other regions of the electromagnetic spectrum. Photoconductive antennas based on narrow band-gap materials such as InGaAs have seen a great improvement in their performances in terms of optical-to-THz efficiencies and maximum output pulsed THz radiation powers at frequencies above 1 THz due to the availability of high power laser sources operating at the optical telecommunication wavelengths. Even more powerful THz emitters have generally been developed by using nonlinear optical crystals where optical rectification of intense near infrared femtosecond laser pulses produces broadband THz radiation of field strengths reaching few hundreds of kV/cm to even few thousands kV/cm. Zinc telluride and lithium niobate crystals are very popular in this case [1]. Another popular mechanism for generating strong THz fields is by creating plasma in air and phase mismatch between the fundamental and the second harmonic fields of NIR femtosecond pulses [2]. Hetero-structures of layers of ferromagnetic materials and non-ferromagnetic films have recently been used to produce THz radiation by excitation with femtosecond laser pulses [3].

Our research group utilizes the above techniques for the generation of intense and broadband THz radiation for applications in nonlinear THz optics and spectroscopy. Primarily, we are working to develop THz sources of strong, tunable in broad range pulsed THz radiation by employing hetero-structures of ferromagnetic/antiferromagnetic and non-ferromagnetic films and physics of inverse spin Hall effect. The application of a charge current through a non-magnetic material results in the generation of a transverse spin current due to the spin-orbit interaction [4]. This spin current can be used to precess the magnetization. Also, we study microstructured waveguides as potential THz sources where four wave mixing processes are utilized in the fibers for efficient THz generation [5]. The fiber structures have the additional advantage of guiding the THz radiation.

1. J. Hebling, K.-L. Yeh, M. C. Hoffmann, and Keith A. Nelson, “High Power THz Generation, THz Nonlinear Optics, and THz Nonlinear Spectroscopy,” *IEEE J. Selected Topics in Quantum Electronics* **14**, 2008), pp. 345-353.

2. K. Y. Kim, J. H. Glownia, A. J. Taylor, and G. Rodriguez, “Terahertz emission from ultrafast ionizing air in symmetry-broken laser fields,” *Opt. Exp.,* **15**, April 2007, pp. 4577-4584.

3. T. Seifert, S. Jaiswal, U. Martens, J. Hannegan, L. Braun, et al., “Efficient metallic spintronic emitters of ultrabroadband terahertz radiation,” *Nature Photon*. **10**, 2016, pp. 483-488.

4. M. I. Dyakonov and V. I. Perel, “Current-induced spin orientation of electrons in semiconductors,” *Phys. Lett. A* **35**, 1971, pp. 459-460.

5. Vikas Kumar, R. K. Varshney, and Sunil Kumar, “Efficient THz generation by four-wave mixing and propagation in Bragg patterned microstructure fibers,” *To be communicated*.