frontiers in Physics

EDITORIAL
published: 25 March 2021
doi: 10.3389/fphy.2021.671647

Editorial: Terahertz Radiation: Materials and Applications

Longqing Cong[1]*, *Sreekanth Kandammathe Valiyaveedu*[2], *Jinhui Shi*[3] and *Xueqian Zhang*[4]

[1] Department of Electrical & Electronic Engineering, Southern University of Science and Technology, Shenzhen, China, [2] Division of Physics and Applied Physics, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore, Singapore, [3] Key Laboratory of In-Fiber Integrated Optics of Ministry of Education, College of Physics and Optoelectronic Engineering, Harbin Engineering University, Harbin, China, [4] Center for Terahertz Waves, Key Laboratory of Optoelectronic Information Technology, Ministry of Education, College of Precision Instrument and Optoelectronics Engineering, Tianjin University, Tianjin, China

Keywords: terahertz, active metamaterials, metalens, terahertz antennas, sensors, beamsplitter, beam scanning, THz switches

Editorial on the Research Topic

Terahertz Radiation: Materials and Applications

This Research Topic has collected seven reports of recent progress in the area of terahertz (THz) devices that are designed by using metamaterials and metasurfaces operating in either passive or active mode, with applications covering terahertz antennas, beam splitters, sensors, and lenses. With the powerful capability of electromagnetic wave control, the focus in metamaterials and metasurfaces with both passive and active approaches have found a plethora of promising applications [1–5].

As summarized in the review article written by Tian et al. from Tie Jun Cui's group at Southeast University, passive metasurfaces have exhibited fascinating functionalities for electromagnetic wave manipulation, and active metasurfaces can further widen the application scopes. In this Review article, authors briefly introduced the recent progress of monofunctional and multifunctional passive metasurface devices and then elaborated the active metasurface devices that would exhibit more powerful applications. We note that relevant devices are still lacking in the terahertz spectral band, and efficient active THz devices are also important for reconfigurable photonic applications. Significant progress has been reported in this Research Topic where we mainly focused on the terahertz band. The works in this Topic are divided into two categories: *passive* and *active* metamaterial devices, which are related to applications in terahertz lenses, polarizing components, antennas, sensors, beam scanners, and switches.

In the category of passive metamaterial devices, one of the very important components is the lens. The current research hotspot of dielectric metasurfaces has shown a great potential to replace conventional bulky lens with thin-film metalens. Metalens can not only reduce the size but also correct certain aberrations. Here researchers from the group at Tianjin University reported the achromatic terahertz metalens with excellent performance covering the band from 0.6 to 1.0 THz. Polarization is one of the most important properties of electromagnetic waves, and its flexible manipulation is of another essential importance. The article written by the same group at Tianjin University presented a very simple modal method that can accelerate the inverse design process of polarizing devices. On the basis of the modal method, they proposed an efficient polarization beam splitter with over 63% diffraction efficiencies and over 12 dB extinction ratio at 0.9 THz.

Regarding the antenna performance, Gao et al. from Guangxi University of Science and Technology proposed an idea to surround the antenna with high refractive index superstrates that are accurately designed by suppressing the diamagnetic response and enhancing the capacitance coupling in the metamaterial cavity. Such a design can significantly improve the antenna

Edited and reviewed by:
Lorenzo Pavesi,
University of Trento, Italy

****Correspondence:***
Longqing Cong
CONG0006@e.ntu.edu.sg

Specialty section:
This article was submitted to Optics and Photonics, a section of the journal Frontiers in Physics

Received: *24 February 2021*
Accepted: *01 March 2021*
Published: *25 March 2021*

Citation:
Cong L, Valiyaveedu SK, Shi J and Zhang X (2021) Editorial: Terahertz Radiation: Materials and Applications. Front. Phys. 9:671647. doi: 10.3389/fphy.2021.671647

performance and reduce the profile below $0.19\lambda_0$. The strategy is scalable and thus can easily be applied to the design of terahertz antennas. Another very important application area of terahertz radiation is the sensing with extraordinary spectral properties. The sensing performance can be improved by employing high quality factor modes, and a typical and well-known mode is Fano resonance that can be induced by introducing asymmetry in the unit cell of metamaterials. In the article from Jianyuan Qin's group from China Jiliang University, Wang et al. showed a design with tunable Fano resonances and demonstrated its excellent sensing performance in the terahertz band that would be very promising for biosensing applications.

In the category of active metamaterial devices, the paper by Yang et al. from Hefei University of Technology reported a novel design of active terahertz beam-scanning reflectarray that is reconfigurable by electrically actuating effective refractive index change of liquid crystals. The major contribution of this work is the design of a very simple wiring scheme to address each 3×3 subarray in a 39×39 reflectarray so that a 2D beam scanning becomes possible. With the proposed scheme, they reported electrically controlled 2D beam scanning with a maximum gain of 16.55 dBi, scanning range of 20°, and overall half-power beamwidth below 6.5°. In another work, Lin Chen's group from University of Shanghai Science and Technology reported a smart design of active metamaterials by integrating with tunable Dirac semimetals. In the initial state of the device, a special resonance mode termed as "toroidal dipole" was excited by the metallic metamaterials, and the toroidal dipole was switched to a classic plasmonic mode once the Fermi level of the semimetal layer was tuned. Such a mode switching scheme would be promising for applications such as terahertz communications and imaging.

Although terahertz radiation has exhibited unlimited potentials in applications ranging from security, imaging, communications, to biosensing, current development of modulators, sources and detectors in this band is still limited [6]. We envision that metamaterials and metasurfaces would be one of the most feasible solutions to accelerate the process of terahertz technology from lab to life.

AUTHOR CONTRIBUTIONS

LC drafted the Editorial and leaded the Topic. All authors contributed to editing the Topic and writing the Editorial.

REFERENCES

1. Cong L, Xu N, Gu J, Singh R, Han J, Zhang W. Highly flexible broadband terahertz metamaterial quarter-wave plate. *Laser Photonics Rev.* (2014) 8:626–32. doi: 10.1002/lpor.201300205
2. Cong L, Singh R. Symmetry-Protected dual bound states in the continuum in metamaterials. *Adv Opt Mater.* (2019) 7:1900383. doi: 10.1002/adom.201900383
3. Cong L, Pitchappa P, Wu Y, Ke L, Lee C, Singh N, et al. Active multifunctional microelectromechanical system metadevices: applications in polarization control, wavefront deflection, and holograms. *Adv Opt Mater.* (2017) 5:1600716. doi: 10.1002/adom.201600716
4. Cong L, Srivastava YK, Zhang H, Zhang X, Han J, Singh R. All-optical active THz metasurfaces for ultrafast polarization switching and dynamic beam splitting. *Light Sci Appl.* (2018) 7:28. doi: 10.1038/s41377-018-0024-y
5. Cong L, Singh R. Spatiotemporal dielectric metasurfaces for unidirectional propagation and reconfigurable steering of terahertz beams. *Adv Mater.* (2020) 32:2001418. doi: 10.1002/adma.202001418
6. Tonouchi M. Cutting-edge terahertz technology. *Nat Photon.* (2007) 1:97–105. doi: 10.1038/nphoton.2007.3

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.