frontiers | Frontiers in Physics

EDITORIAL
published: 14 July 2022
doi: 10.3389/fphy.2022.959847

Editorial: Application of Terahertz Frequency in Substance Detection and Recognition

Jianjun Ma[1,2]*, *Yuping Yang*[3], *Bin Li*[4] and *Hichem Guerboukha*[5]

[1]School of Integrated Circuit and Electronics, Beijing Institute of Technology, Beijing, China, [2]Beijing Key Laboratory of Millimeter Wave and Terahertz Technology, Beijing, China, [3]School of Science, Minzu University of China, Beijing, China, [4]Intelligent Equipment Research Center, Beijing Academy of Agriculture and Forestry Sciences, Beijing, China, [5]School of Engineering, Brown University, Providence, RI, United States

Keywords: terahertz frequency, substance detection and recognition, terahertz time-domain spectroscopy (THz-TDS), High-voltage cable, protein, sedimentary rocks, cattle feed, metamaterial (MM)

Editorial on the Research Topic

Application of Terahertz Frequency in Substance Detection and Recognition

Frequencies in the terahertz range, from 100 GHz (GHz) to 10 THz (THz), are endowed with many uniquely attractive features and assumed to be widely used in various fields, such as wireless communication [1], aerospace, security and biomedicine [2]. In laboratory demonstrations, terahertz frequency can transfer large amounts of data quickly [3], obtain high-resolution images [4, 5], identify explosives and reveal hidden weapons without ionizing atoms and molecules in human tissue [6–8]. Indeed, located between microwaves and infrared, the THz band has a number of relevant benefits when applied to sensing and imaging [9]. Like microwaves, THz waves can penetrate most dielectric materials with different attenuation levels, revealing inner structures with meaningful contrast. Like infrared, THz wavelengths are sufficiently small to provide high-resolution images applicable in many day-to-day practical scenarios. Moreover, many molecules have unique spectral fingerprints in the THz range, which can lead to accurate spectroscopic identification. Finally, due to their low photon energies, THz wave are harmless for biological tissues. But the path from laboratory achievements to real-world applications is filled with serious challenges [10], such as limited resolution and sensitivity of detectors, lack of efficient sources, investigations on potential application scenarios, and so on. This issue presents novel research exploring important developments and applications of the THz frequency band, by collecting one review and seven contributed articles as explained below.

Fu et al. provide a comprehensive review on application of terahertz spectroscopy, which not only presents the working principle of terahertz time-domain spectroscopy (THz-TDS) systems with/without metamaterial-enhancement, but also provides an overview of its application in biomedicine, agriculture and food production, and security inspection as shown in **Figure 1**. Terahertz frequency has been showing more and more significant potential for application in the detection and recognition of substances.

Additionally, there are four papers involving the substance detection and recognition for SARS-CoV-2 S1 protein, high-voltage cable, sedimentary rocks, and cattle feed. Niu et al. experimentally demonstrate that terahertz spectroscopy integrated with a metamaterial-based biosensor and biological modification technology can be used to detect SARS-CoV-2 S1 protein with high sensitivity and label-free detection. Zhang et al. show noteworthy applications of a THz frequency-modulated-continuous-wave non-destructive testing imaging system for non-destructive detecting internal structure of a high-voltage cable. Feature defect signals are automatically classified and recognized by combining the principal component analysis (PCA)

OPEN ACCESS

Edited and reviewed by:
Nicholas X. Fang, Massachusetts Institute of Technology, United States

***Correspondence:**
Jianjun Ma
jianjun_ma@bit.edu.cn

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

Received: *02 June 2022*
Accepted: *17 June 2022*
Published: *14 July 2022*

Citation:
Ma J, Yang Y, Li B and Guerboukha H (2022) Editorial: Application of Terahertz Frequency in Substance Detection and Recognition. Front. Phys. 10:959847. doi: 10.3389/fphy.2022.959847

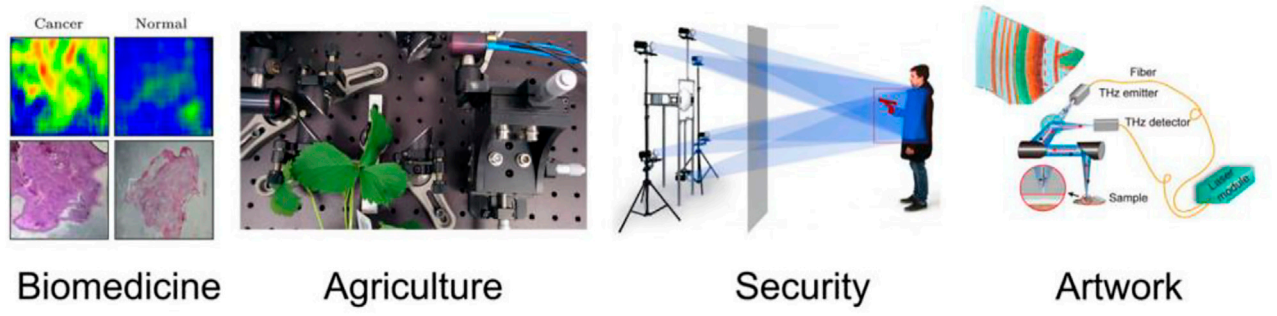

FIGURE 1 | Terahertz spectroscopy and some typical applications by Fu et al.

method and the support vector machine classification method. Meng et al. propose to exploit a THz dating method by combining THz-TDS and PCA method, for characterizing the geological age of sedimentary rocks. Huang et al. demonstrate how a THz-TDS system can be utilized to evaluate cattle feed equality by detecting moisture content inside.

This issue also contains three articles where enhanced THz generation and detection is achieved using structured material devices. Tu et al. develop an enhanced THz source by fabricating metasurfaces on an x-cut LNOI ($LiNbO_3$ on an insulator) film residing on SiO_2, where the enhancement is contributed by the resonance-induced electric field enhancement on the metasurface. In the article by Jiang et al., the mechanism of the resonance coupling is revealed and can be used for further enhancement in THz sensing devices. Shi et al. report on a polarization detector for THz electric field, by employing photoconductive antenna array to eliminate the reverse current between adjacent antenna elements and improve signal-to-noise ratio. The detector can measure amplitude, phase and polarization of THz electric field simultaneously.

In conclusion, this special issue is created to present the latest advances and trends concerning the application of terahertz frequency in the field of detection and recognition substances. Our special thanks to the Frontiers in Physics team for the technical assistance with publishing.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

REFERENCES

1. Kurner T, Mittleman DM, Nagatsuma T, editors. *THz Communications: Paving the Way towards Wireless Tbps*. Springer (2022).
2. Mittleman DM. Twenty Years of Terahertz Imaging [Invited]. *Opt Express* (2018) 26(8):9417–31. doi:10.1364/oe.26.009417
3. Ma J, Karl NJ, Bretin S, Ducournau G, Mittleman DM. Frequency-division Multiplexer and Demultiplexer for Terahertz Wireless Links. *Nat Commun* (2017) 8(1):729. doi:10.1038/s41467-017-00877-x
4. Dworak V, Mahns B, Selbeck J, Gebbers R, Weltzien C. Hyperspectral Imaging Tera Hertz System for Soil Analysis: Initial Results. *Sensors (Basel)* (2020) 20(19). doi:10.3390/s20195660
5. Guerboukha H, Cao Y, Nallappan K, Skorobogatiy M. Super-resolution Orthogonal Deterministic Imaging Technique for Terahertz Subwavelength Microscopy. *ACS Photon* (2020) 7(7):1866–75. doi:10.1021/acsphotonics.0c00711
6. Kidavu AV, Nagaraju N, Damarala G, Chaudhary AK. Scattering Analysis of Explosive Materials Mixed in Teflon Matrix in THz Regime. In: *Presented at the 2019 Workshop on Recent Advances in Photonics*. Guwahati, India: WRAP (2019). doi:10.1109/wrap47485.2019.9013700
7. Federici JF, Schulkin B, Huang F, Gary D, Barat R, Oliveira F, et al. THz Imaging and Sensing for Security Applications-Explosives, Weapons and Drugs. *Semicond Sci Technol* (2005) 20(7):S266–S280. doi:10.1088/0268-1242/20/7/018
8. Borovkova M, Khodzitsky M, Demchenko P, Cherkasova O, Popov A, Meglinski I. Terahertz Time-Domain Spectroscopy for Non-invasive Assessment of Water Content in Biological Samples. *Biomed Opt Express* (2018) 9(5):2266–76. doi:10.1364/boe.9.002266
9. Saeedkia D. *Handbook of Terahertz Technology for Imaging and Sensing*. Cambridge: Woodhead Publishing (2013).
10. Guerboukha H, Nallappan K, Skorobogatiy M. Toward Real-Time Terahertz Imaging. *Adv Opt Photon* (2018) 10(4):843–938. doi:10.1364/aop.10.000843

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.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.