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Photonic Materials for THz Light Control: feature issue introduction

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Abstract: We introduce the *Optical Materials Express* feature issue on Photonic Materials for THz Light Control. This issue comprises a collection of eleven manuscripts and one Opinion on the recent advances in materials, including metamaterials, and the instrumentation to characterize them, for the development of TeraHertz science and engineering.

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1. Introduction

The frequency range between 0.1 and 10 THz, the so-called TeraHertz gap, on account of the experimental challenges that held the field back until recent years, holds promise for a myriad of applications such as high-speed communication, nondestructive testing, medical imaging and remote sensing [1]. Materials science and engineering plays a crucial role in the conquer of such THz gap [2]. For instance, new materials have been engineered to realize high-power solid-states THz sources like quantum cascade lasers (QCLs) [3] and to achieve ultrabroadband emission (e.g., spintronic emitters) [4]. Also, the advent of metasurfaces has provided an efficient and compact platform for the manipulation of THz light [5–8]. This progress in materials underpins today's high-performance spectroscopy and imaging systems [9, 10] that, as a vicious cycle, are enabling the characterization and optimization of new materials for the next generation of THz technology.

This feature issue serves as a platform to showcase state-of-the-art research on this fast-moving field of Photonic Materials for THz Light Control.

2. Feature issue summary

It encompasses one Opinion, two invited mini-review articles, four invited original research articles and five original research articles.

In [11], a unique opinion on the topic of THz near-field nanoscopy of quantum materials and how it may develop in the future is provided by Vitiello. The Opinion features the THz detectorless nanoscopy scheme based on QCLs whose underlying mechanism is self-mixing interferometry. Still in the field of THz near-field microscopy, Hale *et al.* review the recently developed THz near-field microscopy capabilities for research on metamaterials [12]; they argue that there is a need for standardization of the methodologies for quantitative extraction of complex near-field signals and sample-probe interaction.

The use of metamaterials and metasurfaces for THz light control is discussed in [13–15]. Lee *et al.* demonstrate how the combination of complementary metasurfaces with nanogaps and THz spectroscopy provides a highly sensitive scheme suitable for ultrafine dust particles [13]. Park *et al.* carry on with their pioneering work on graphene-enabled THz reconfigurable metasurfaces and demonstrate in [14] an electrically controlled THz beam splitting with near non-dispersive characteristics. Mavrona *et al.* extract the THz complex dielectric constant of two photoresists and showcase direct laser writing in combination with the studied photoresists for dielectric woodpile-type metamaterials [15].

Still in the context of additive manufacturing as [15], but not within the field of metamaterials, Lu *et al.* demonstrate the benefits of THz time-domain spectroscopy for rapidly inspecting 3D-printed alloys over large areas [16].

References [17–19] illustrate the efforts of the community in terms of design and modelling. Lee *et al.* put forward an inverse design underpinned by a double deep Q-learning model in conjunction with analytical solutions to speed up the prototyping of high Q-factor resonators [17]. With the same motivation of accuracy and speed, Yevtushenko *et al.* study the scattering and absorption of the E-polarized plane wave by on-substrate grating of graphene strips [18]; unlike commercial codes, their method of analytical regularization based on the inverse discrete fourier transform guarantees the convergence of numerical results to the true solution if the discretization order gets larger. Li *et al.* design a compact on-chip THz circular polarization detector based on quantum well detection material sandwiched by a chiral plasmonic antenna array and a ground plane [19].

In their review contribution, Mansourzadeh *et al.* discuss the unique properties of organic crystals to achieve high THz power at high repetition rates together with an ultra-broad THz spectrum [20].

In the framework of THz spectroscopy and focused on the needs of industries utilizing granular compacts such as pharmaceutical, food and chemical, Murphy *et al.* conduct a systematic investigation of THz scattering in granular compacts with varying particle sizes and concentrations [21]; they are then able to differentiate two regimes where photons travel predominantly ballistically separated by a regime where THz photons are predominantly scattered. Meanwhile, Kitagishi *et al.* explore the combination of THz time-domain spectroscopy and capillary electrophoresis for direct detection of separated substances in solutions [22].

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