EDITORIAL
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Editorial: Light-Nanomaterial Interactions for Energy Efficient Nanophotonic Devices

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Editorial on the Research Topic

Light-Nanomaterial Interactions for Energy Efficient Nanophotonic Devices

Light-matter interaction is the fundamental principle of optical/photonic devices, which includes absorption, transmission, and reflection at the fundamental level and can be further used to control emission, detection and amplification, as well as optical magnetization. Therefore, controlling the light-matter interaction holds the key in designing advanced functional optical/photonic devices. In the last few decades, the advancement in development of nanomaterials and nanofabrication techniques allows achieving light-matter interaction at nanoscale beyond the diffraction limit, which enable advanced manipulation of electromagnetic waves. Recent advancement in developing two-dimensional (2D) materials, such as graphene (Lin et al., 2019; Yang et al., 2019; Lin et al., 2020a; Lin et al., 2021), transition-metal dichalcogenides (TMDCs) (Lin et al., 2020b), perovskites (Wen et al., 2018; Wang et al., 2020) and hexagonal boron nitride (hBN) Wu et al., further pushed the light-matter interaction down to deep subwavelength scale, even to a single atomic layer, which is fascinating and extraordinary due to the 2D confinement of electrons. Therefore, light-nanomaterial interaction offers a broad range of applications in various areas including sensing, imaging, renewable energy harvesting, optical data storage, and optical communication, which is the technology revolution in the 21st century affecting our lives in medical, health, energy consumption, and communication.

This research topic has 9 research papers, focusing on the cutting-edge advances in research of light-matter interaction with different types of nanostructures and nanomaterials, including dielectric materials (silicon, Sb_2Se_3, β-Ga_2O_3 and diamond), 2D materials (graphene and MoS_2) and magnetic nanomaterials ($Ca_2Nb_2O_7$ PLD Film), covering different interactions, such as linear and non-linear optical responses, and magnetic response. In addition, there are several applications based on the fundamental light-matter interaction are demonstrated, such as silicon ring waveguides, hologram, nano-thermometers.

Optical non-linearity (Tan et al., 2017; Yang et al., 2018; Yang et al., 2020) is an important characteristic of materials for the applications of optical modulators, switches, high harmonic generation. There are four studies on the optical non-linearity of different nanomaterials in this research topic. Sun et al. experimentally demonstrated tuning the optical non-linearity of graphene/MoS_2/Ag thin films by controlling the DC power of magnetron sputtering power, which manipulate the local surface plasmon resonance effect of the Ag thin films. Such an enhanced surface plasmon resonance effect can enhance the non-linearity of the entire system. It is an interesting tuning method, with which the non-linearity is enhanced by the unique surface plasmonic effect. the magnetron sputtering technology has also been applied to tune the doping level of the Co-doped

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Sb2Se3, which exhibits ultrafast carrier absorption (<1 ps) and a stronger transient absorption intensity of ΔOD >6.3, thus, it may find applications in broadband non-linear photonic devices. Meanwhile, Xiao et al. found that with the introduction of nitrogen defects, the diamond can have the non-linear absorption in addition to the intrinsic non-linear refraction. In this way, the fundamental light-matter interaction in diamonds has been significantly modified, which can open up more applications of diamond materials. Sun et al. investigated the different non-linear optical mechanisms and defect-related carrier dynamics in Sn-doped β-Ga2O3 crystal and found that by choosing a proper probe wavelength that matches the defect state to the valence band, the non-linear absorption and refraction of the carriers can be greatly enhanced. This method provides an important reference for the design of gallium oxide-based waveguide materials and all-optical switching materials in the future.

In addition to fundamental optical property studies, there are three applications of light-matter interaction published in this topic. Liu et al. propose a holographic near-eye 3D display method based on large-size computer-generated holograms (CGHs), which are generated and they record the information of the 3D object from different angles. The unique feature of this method is the large viewing angle, which currently is one of the limiting factors. Wang et al. theoretically demonstrated a silicon ring waveguide, in order to tune the frequency of the phonon field of stimulated Brillouin scattering (SBS) laser based on the silicon substrate of the ring cavity. This silicon waveguide based on ring cavity provides a new technical scheme for designing tunable SBS lasers by tuning the ring widths. Li et al. investigated the up-conversion luminescence and optical temperature sensing properties of Ho^{3+}/Tm^{3+}/Yb^{3+}-co-doped $NaLuF_4$ phosphors, which could be potentially applied in far infrared temperature sensing in biological tissue for their high sensing sensitivity.

Finally, as the emerging field, magnetic property of materials has attracted broad applications, which enables unique interaction between light and nanomaterials, by introducing non-unity permeability of materials to modulate the magnetic part of the electromagnetic waves. Here Wu et al. study the introduction of magnetism in ferroelectric $Ca_2Nb_2O_7$ by the intrinsic complex vacancy of V_{Nb+O}. This method might be applicable to other $A_2Nb_2O_7$-type niobate ferroelectric films as well.

In addition to the collected papers, the light-matter interaction can also be applied to modify material to directly fabricate functional photonic devices, such as light reduction of graphene oxide materials (Zheng et al., 2015; Zheng et al., 2017), laser introduced phase change (Cho et al., 2015; Tan et al., 2018; Chaste et al., 2020), laser ablation (Cao et al., 2019; Li et al., 2020a; Wei et al., 2021), laser introduction of defects (Li et al., 2020b), laser introduced doping (Guo et al., 2014), and opto-magnetization (Nie et al., 2017). By using tightly focused laser beam, those light-matter interaction can be localized to achieve nanoscale modification to produce nanostructure. In turn those fabricated nanostructures with well-designed spatial distribution can further enhance the light-matter interaction to achieve advanced functionality. Furthermore, the laser fabrication technique can generally achieve high flexibility, low-cost and large area fabrication. As a result, by considering both material modulation of light and light modification of material, it is possible to not only improve the energy efficiency of the functional optical/photonic devices, but also the energy efficiency of the fabrication process. In this way, highly energy efficient nanophotonic devices can be achieved.

AUTHOR CONTRIBUTIONS

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

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