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Editorial

Special Issue on New Trends in Nonlinear Optics in Nanostructures and Plasmonics

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1. Introduction

Nonlinear optics, which emerged in the early 60s of the 20th century, immediately after the invention of powerful lasers, had a significant influence on the formation of modern photonics. Studies in the field of nonlinear optics led to such discoveries as the generation of second and higher harmonics of laser radiation, parametric scattering, stimulated Raman scattering, wavefront reversal, self-focusing and self-defocusing of light beams, and multiphoton absorption. The development of nonlinear optics, in turn, had a significant impact on the development of lasers and laser technologies. This resulted in the emergence of lasers based on stimulated light scattering, tunable lasers with a wide range of wavelengths, pico- and femtosecond lasers, and terahertz radiation generators, which significantly expanded the instrumental capabilities for research in the field of nonlinear optics. Fantastic results obtained in the field of nanotechnology over the last two decades have provided scientists with new, unique materials, the study of nonlinear optical properties of which was crowned with the discovery of new natural phenomena. Thus, at present, nonlinear optics is still a burgeoning branch of physics.

2. Summary of the Articles of the Issue

This Special Issue presents the results of studies conducted in various fields of nonlinear optics. These studies range from experimentally investigating the generation of higher harmonics of laser radiation in laser-induced plasma to theoretically examining the generation of edge currents in graphene caused by second-order nonlinearity. In [1], the peculiarities of the generation of the 17th and 18th harmonics of the femtosecond laser radiation (at a wavelength of 806 nm) in the laser plasma were studied. The plasma was excited in bulk Sn and Sn nanoparticles glued onto a glass substrate by powerful, focused radiation of picosecond and nanosecond lasers. Additionally, plasma probing was performed using bi-harmonic radiation at wavelengths of 806 and 403 nm (the second harmonic of a femtosecond laser) as well as the radiation of a femtosecond parametric light generator (1280–1440 nm) and its second harmonic in the single-frequency and double-frequency modes. It is shown that the use of a two-frequency mode allows achieving a 12-fold increase in the intensity of even harmonics. It was found that for the effective generation of higher harmonics pulses, it is necessary to provide an optimal delay (130–180 ns) between the plasma excitation laser pulses and pulses of probing radiation. The results of a study on the generation of higher harmonics in the wavelength range of 30–100 nm by a femtosecond laser at 806 nm in a laser-induced plasma from six carbon-containing materials (graphite, fullerenes, carbon nanotubes, carbon nanofibers, diamond nanoparticles, and graphene) are presented in [2]. It was demonstrated that the presence of nanoparticles (C_{60}, carbon nanofibers, and multi-walled carbon nanotubes) and their fragments in the laser plasma leads to an increase in the efficiency of 9–17th harmonic generation at wavelengths of 50–95 nm. The generation of laser radiation harmonics can be utilized to develop unique tools for studying the surfaces of materials. In [3], magnetization-induced second and third harmonic generation of a femtosecond laser radiation of an optical parametric oscillator at

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Citation: Mikheev, G.M. Special Issue on New Trends in Nonlinear Optics in Nanostructures and Plasmonics. *Appl. Sci.* **2023**, *13*, 11601. https://doi.org/10.3390/app132011601

Received: 18 October 2023
Accepted: 21 October 2023
Published: 23 October 2023

740–1800 nm has been applied for the visualization of the interface magnetic domains of 10 μm thick $(LuBi)_3Fe_5O_{12}$ garnet film. It has been shown that the technique of nonlinear optical microscopy based on third harmonic generation provides better spatial resolution compared to microscopy based on second harmonic generation.

In the paper [4], comparative studies of the nonlinear optical properties of aqueous suspensions of high pressure-high temperature (HP-HT) nanodiamonds and detonation nanodiamonds under femtosecond laser excitation are performed. It was shown that at the same parameters of femtosecond laser pumping and experimental conditions, saturable absorption occurred in an aqueous suspension of detonation nanodiamonds accompanied by short-term nonlinear bleaching, while in an aqueous suspension of HP-HT nanodiamonds, two-photon absorption appeared, leading to optical limiting. In study [5], the nonlinear up-conversion luminescence in the aqueous suspensions of carbon dots with polyfunctional and carboxylated surfaces synthesized by a hydrothermal method was observed. It was shown that the discovered nonlinear up-conversion luminescence in these carbon dots was caused by two-photon absorption. The optimal laser excitation wavelength at which nonlinear up-conversion luminescence manifests itself most strongly was found. The results obtained can be used to determine the pH of liquid media in a wide range of pH values.

A 40 nm thick film of topological insulator ($Bi_{1.9}Sb_{0.1}Te_2Se$) was used for efficient generation of terahertz radiation under femtosecond laser radiation at 1560 nm excitation in [6]. It was shown that the generation of terahertz radiation in this film occurred due to photo-excited bulk carriers and their relaxation through the surface states in the presence of the constant electric field. Thus, it has been demonstrated that low-cost $Bi_{1.9}Sb_{0.1}Te_2Se$ ultrathin topological insulators, which can be easily integrated into various nanophotonic devices, enable the conversion of femtosecond infrared radiation to terahertz radiation. The research presented in [7] focuses on the development and investigation of a new type of robust photonic topological insulators for laser array applications. It was constructed from identical prism resonators connected to each other. The author experimentally demonstrated a topologically protected propagating state due to the disconnected faces of the edge resonators.

A new and accurate, fully explicit finite-difference time-domain method for modeling a nonlinear electromagnetic medium has been proposed in theoretical work [8]. The developed algorithms describe the interaction of the laser pulse with metals and interfaces of nonlinear dielectric media well, where Kerr and Raman effects, as well as multiphoton ionization and metal dispersion, occur simultaneously. The author also modeled the nonlinear propagation of an ultrafast laser pulse through a dielectric medium using this method.

In [9], the generation of nanosecond photocurrent pulses due to the surface photogalvanic effect (the second-order nonlinear optical phenomenon) was studied in thin semitransparent CuSe/Se films as a function of the angle of incidence and polarization of exciting femtosecond laser pulses at 795 nm. It was found that the evolution of the temporal profile of the helicity-sensitive transverse photocurrent with a change in incident angle strongly depends on polarization. In particular, at circular polarization, the generation of unipolar and bipolar pulses is possible, with the waveforms strongly depending both on the angle of incidence and the sign of circular polarization. A kinetic theory of the edge photogalvanic effect for the intraband electron transport in two-dimensional materials was developed in [10]. It should be noted that a photogalvanic effect in 2D structures can be considered as a low-dimensional analog of the surface photogalvanic effect. The authors obtained an analytical expression for the edge current valid for arbitrary dispersion law and scattering mechanism and analyzed the result for single-layer and bilayer graphene for electron scattering by short-range defects and Coulomb impurities. The authors believe that the edge photogalvanic effect will find applications in fast terahertz radiation and terahertz radiation polarization sensors.

Funding: This work was supported by the Ministry of Education and Science of the Russian Federation (state registration number 1021032422167-7-1.3.2.).

Acknowledgments: I consider it my duty to express my gratitude to all the authors of the articles who sent their insightful papers to this Special Issue. Special thanks to all the reviewers who provided substantive comments and suggestions to improve the quality of the submitted articles. I am grateful to the entire editorial team of *Applied Sciences* for the high editorial quality. I would also like to thank A.E. Fateev for discussing the articles published in this Special Issue.

Conflicts of Interest: The author declares no conflict of interest.

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