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Editorial: Low-dimensional structures, nanoparticles, and optical measurements

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Editorial on the Research Topic
Low-dimensional structures, nanoparticles, and optical measurements

Nanotechnology unites creation and studies of very small objects in order to use them in different fields—from biology and physics to nanoengineering and nanomaterial fabrication. Modern science is looking for new ways and approaches aimed at creation of materials with predictable nanoscale structure, formation and manipulation of nanoscale objects with different properties, addressing to solve the vital problems of physical, chemical and biological technologies. A separate branch of research addresses the low-dimensional material structures (material "sheets" and "threads") that have at least one nanoscale dimension, along which the physical properties are intermediate between those of the bulk material and of individual atoms.

Among the most efficient and promising ways to deal with such objects, optical methods and instruments are especially useful and sometimes unique. Here, the main prospects are associated with the recent concepts of "structured light" [1] employing the special properties of light fields with purposely formed spatial, polarization and spectral inhomogeneities. On the other hand, nanoscale materials, including nanoparticles, offer exceptional possibilities both for studying and controllable generation of structured optical fields with necessary properties.

The structured light fields are usually characterized by the rich and non-trivial patterns of the internal energy flows and 3D polarization distribution. These patterns include optical singularities–isolated points, lines or surfaces where some of the optical-filed parameters are indeterminate [1]. Each singularity is topologically stable and associated with certain peculiar behavior of the field characteristics in its vicinity. In complex, the field singularities form a coherent and interrelated set ("singular skeleton") that represents the field "in a whole" and can be controlled using the coherent-optics and statistical approaches. Thus, combining the correlation-optics and singular-optics methods offers fruitful ways for meaningful description and purposeful formation of scalar and vector optical fields, as well as extension of their practical applications, which is the topic of papers [2–4].

The main idea of the review by Angelsky et al. is to reveal and emphasize interconnections between the methods of correlation (interference) optics and singular optics. Their interpenetration is demonstrated both theoretically and by discussion of corresponding experimental results. In particular, the structured-light employment for the controllable generation of gas microbubbles in liquids and their potential applications are discussed. Particular attention is paid to polychromatic optical singularities and their connection with the optical-field coherence.

The original paper Structured Light Control and Diagnostics Using Optical Crystals demonstrates the use of anisotropic and birefringent optical crystals as a means for purposeful creation of controllable structured optical fields. Additionally, the diagnostics of structured optical fields with extraordinary and singular properties are described, which employ the special features of birefringent crystals and crystal-like structures. Especially, specific distributions of the internal energy flows and optical angular momentum are studied in the evanescent wave formed due to the total reflection at the crystal surface. In this regard, the authors discuss the possibilities to design and control the multifunctional optical traps, the prospects for the creation of polychromatic optical tweezers and spanners, in particular, for studying and manipulating the biological objects, e.g., erythrocytes. The results presented open up attractive prospects for pharmacology, microbiology, nanophysics, and nanotechnology.

The next paper, presented by Plutenko and Vasnetsov, describes the photonic nanojet formation behind a spherical metallic particle illuminated by a focused laser beam with polarization singularity. A nanojet represents the 3D structured light field with a longitudinal series of dark and bright spots concentrated along the incident beam axis in the particle-shadow region; the metal scatterers of different sizes, varying from subwavelength particles to microbeads, were used. The generated photonic nanojets possess the essential longitudinal electric field component, zero magnetic field component and subwavelength transverse sizes. The numerical analysis of the nanojet generation is based on the Lorentz—Mie theory and involves the incident radially-polarized beam representation as a superposition of orthogonally polarized Laguerre—Gaussian beams. The results will be perspective for nanophysics, plasmonics, and non-linear structured-light physics, e.g. for the purposeful on-surface second-harmonic generation.

The paper "Fluorescence Record Diagnostics of 3D Rough-Surface Landscapes With Nano-Scale Inhomogeneities" describes the application of the carbon nanoparticles for the diagnostics of surface inhomogeneities. The specially designed nanoparticles show luminescence in the yellow-green range, which is excited by light of the wavelength 405 nm. A single such particle can be used as a sensitive probe in the manner similar to the atomic-force microscope. It is located at a desirable point of the surface by means of the optical tweezer employing the He-Ne laser radiation, whereas its vertical position (indicating the local surface height) is detected *via* the luminescence signal excited by the strongly focused Gaussian beam whose waist plane is strictly fixed. After scanning the whole surface area, the surface 3D landscape can be reconstructed with a high degree of accuracy and the lateral resolution of 50–70 nm.

The work presented by Li et al. illustrates the structured-light applications in the thin-film technologies. A series of amorphous carbon films were deposited on a-plane sapphire substrates by magnetron sputtering with different deposition times, and their optical properties were monitored continuously in a non-destructive manner. This is realized due to combined application of Mueller matrix spectroscopic ellipsometry, topography profilometry, Raman spectroscopy and transmission electron-microscope techniques. The films' parameters (thickness and optical constants) in the spectral range 210 nm–800 nm are recovered based on the Bruggeman effective-medium-approximation model and the single Cody-Lorentz oscillator model. The results show the abilities and limitations of different techniques depending on the film thickness and the deposition time. Main results of the research testify the validity of optical methods for permanent control of the film growth, and confirm the conclusion that amorphous carbon films and devices based on them are promising objects of the optoelectronic industry.

The authors of the brief research report Saldaña-Heredia et al. describe a non-invasive optical procedure for studying the mechanical deformations of a structure caused by the influence of an external impact. The system "fuselage + wing" was modelled by a metal box with embedded steel bar. The optical techniques including the coherent-light reflection, speckle-pattern analysis and the digital image correlation, were employed to measure relative deformations of the structure elements in different points far from the impact application. The experimental results are compared to the analytical data obtained through the modified Gauss—Newton approach.

And finally, the paper by Dubolazov et al. illustrates the rich and vibrant research activity concerning the optical methods and instruments in biology and medicine. The authors describe the singular-optics and polarization-optics approaches based on the analysis of the Mueller-matrix images. These techniques enable experimental measuring the polarization properties of biological tissues, which are helpful for the sensitive, specific, accurate, and express diagnostic methods. The rapid, suitable and reliable means for distinguishing pathological elements in a human body open up new horizons in evidence-based medical applications.

We hope that the present Research Topic collection, with demonstration of applications in nano-optoelectronics, nanophysics, biology and medicine, will be useful for deeper understanding the ideas and contents of the structured-light paradigm, as well as for further elucidation of the specific features of low-dimensional structures, nanoparticles and optical means for their characterization.

Author contributions

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

Conflict of interest

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