REVIEW

on the project "Nanobiophotonics" for the years of 2024-2027 within the theme "Optical methods in condensed matter studies"

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The project "Nanobiophotonics" proposed for implementation is directed on fundamental and applied research in the field of 2D materials (2DM) and van der Waals heterostructures (vdWHs), as well as on solving a number of relevant and socially significant problems in the field of Life Sciences. It is proposed to use vibrational, predominantly Raman, spectroscopy as the main research method since at the present stage of development of optics and photonics it is one of the most sensitive and powerful tools for non-destructive analysis of the chemical structure of a material. In this regard, the issues identified in the project are adequately and succinctly described by its title, which includes the characteristics of objects ("nanobio" - nanomaterials and biological samples) and the features of the method ("photonics" - optical spectroscopy based on the interaction of matter with phonons) research.

Currently, layered materials are of great scientific interest since the physical properties of atomically thin monolayers often differ greatly from the properties of the original bulk materials. In the proposed project, it is planned to analyze the properties of various 2D materials and based on them van der Waals heterostructures (vdWHs) using spontaneous and enhanced Raman light scattering spectroscopy. Vivid examples of 2DM are graphene and MoS_2 monolayers since their unique electrodynamic properties and extremely thin thickness open up incredible prospects for the development of new electronics and optics devices. Atomically thin two-dimensional transition metal dichalcogenides such as MoS_2 and WSe_2 are model systems for layered semiconductors with band gaps in the visible region of the optical spectrum. These nanomaterials can be assembled into heterostructures that combine the properties of constituent monolayers. At the same time, they open access to new degrees of freedom of the electronic system or interactions between quasiparticles, such as excitons (Coulomb-coupled electron-hole pairs). Sensitive to various dispersion changes (frequency shift and band intensity to name a few), Raman spectroscopy is a well-suited method for studying and analyzing the physical and optical properties of such nanomaterials.

In the "Nanobiophotonics" project proposed to be open, research work with 2D materials and van der Waals heterostructures is planned in accordance with the following research activities:

- *investigate fundamental, resonant, interlayer and defect induced vibrational modes;*
- *investigate the dispersion dependence of individual peaks (e.g. G, D) of the Raman spectrum of 2D materials and vdWHs in the Stokes and/or anti-Stokes regions depending on the pump photon energy and excitation power;*
- *determine the number of layers in 2D materials and vdW heterostructures, including analysis by the method of low-frequency Raman spectroscopy;*
- *to investigate exciton-phonon interactions, transport properties of excitons;*
- *to study the characteristics of upconversion luminescence (UCL) for single- and multi-phonon absorption in various 2DM and vdWHs;*
- *to investigate the transport properties of UCL depending on the excitation wavelength (possible resonance effects);*
- *determine the characteristics of the UCL depending on the power of the exciting radiation.*

Such a program is extremely relevant at the present stage of development of nanotechnologies and optics, is interdisciplinary in nature, has a high scientific significance and is interesting in terms of both fundamental and practice-oriented research. Despite the fact that the authors do not plan to independently synthesize and fabricate samples of two-dimensional nanomaterials at the project implementation stage in the coming years, their commercial availability, which has been growing in recent years, will make it possible to successfully carry out all the studies mentioned above.

Another significant part of the research, which is planned in the project framework, is focused on the continuation of research activities in the field of Life Sciences. This concerns a very important direction associated with the identification of features of lipid-protein interactions and programmed cell death, such as netosis and apoptosis. Here I would like to note two important prerequisites that, in my opinion, should contribute to the implementation of this part of the project program at a high level. The first is related to the fact that Raman spectroscopy, and, in particular, the CARS microspectrometer (SOL Instruments, Minsk, Belarus), is undoubtedly an ideal instrumentation adapted to biomedical research in general, and, in particular, for solution of the tasks defined by the authors of the project. The second, no less important prerequisite, is the groundwork that the team of this project already has in this direction.

In this area, among the most important tasks of the project, I will note several:

- *study of conformational transformations in lipid-protein structures, including temperature dependencies;*
- *study and detailed analysis of the secondary and tertiary structure of proteins embedded in membrane mimetics;*
- *modeling of lipid-protein interactions by molecular dynamics (MD) and density functional theory (DFT) methods;*
- *identification of primary photoacceptors of light-induced netosis under the action of UV, visible and IR radiation;*
- *further search and identification of spectral markers of netosis.*

It is important to note that the research program regarding problems in the field of Life Sciences will be complementarily accompanied by measurements using neutron scattering, circular dichroism, atomic force and electron microscopy, photoelectron spectroscopy with angular resolution, etc.

An analysis of the applicants' publications indicates that they have not only a laboratory and experimental research base that meets the objectives of the project, but also the necessary experience in solving such problems.

In view of the foregoing, I support and recommend the "Nanobiophotonics" project for a period of 4 years (2024–2027) under the theme "Optical methods in condensed matter studies" for implementation and wish its successful implementation.

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