MORNING SESSION

Th16A 09:00-11:10

Nanostructures – Hall A
09:00-11:10 Chairman: V. Temnov

09:00-09:30 **Th16A(A)-1** (invited)

Local fields mapping and microrefractometry by fluorescence nanoscopy of single molecules and quantum dots

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We show how the nanoscopy techniques based on registration of single fluorescent molecules (SM) and semi- conductor quantum dots (QD) have been extended to perform advanced characterization of dielectric materials. In our studies SMs and QDs have been used as both the point light sources and sensitive multi-parameter local probes which reveal light-matter interactions at the nanoscale. Measuring sufficient numbers of the probes simultaneously gives us an opportunity for mapping dielectric parameters of some materials. The mapping procedure, if performed with the use of a convincing mathematical model, may be accurate down to nanometers and give reliable averages at micro- and macro-scales.

Our successful probing was based on optical imaging and spectroscopy of single chromophore molecules at cryogenic temperatures [1,2]. We used the fact that the fluorescence (excitation) lifetime of a single emitter embedded in a matrix is a function of the parameters which describe the surrounding medium at different spatial scales (see, e.g., [3,4]). The key factors that change the excitation lifetime in the matrix are known to be related to existence of the local density of the photon states and the local response of the medium to incident light. Both factors may be attributed to the local effective values of the dielectric function describing the continuous surroundings of each chromophore light emitter. Thus, measuring the radiative lifetime distribution may help revealing the spatial variation of material's permittivity, and, if handled accurately, spatial fluctuations and distribution of the effective refractive indices. It may as well be a method for restoring the patterns of the local fields. In our experiment the spatial mapping of the local values is accomplished by localizing terrylene molecules with nanometer accuracy in a polycrystalline film. Certain algorithms were applied to make a selection of single chromophores to be the proper probes, i.e., be convincingly free of additional undesired broadening. The mapping showed unexpectedly large fluctuations of the local-field effects and the effective index values. At the same time the macroscopic averages derived from the measured distributions are shown to be in agreement with conventional characterization of the material. Finally, we show the further development of our approach by using single colloidal semiconductor quantum dots CdSe/ZnS as nanoprobes for local field sensing by nanoscopy with direct measurements of QD luminescence kinetics.

The experiments on laser selective nanoscopy was performed within State Contract of the Institute of Spectroscopy RAS. The financial Support from RFBR (17-02-00652) is acknowleged.

[1] A. V. Naumov, A. A. Gorshelev, M. G. Gladush, T. A. Anikushina, A. V. Golovanova, J. Ko¨hler, and L. Kador, "Micro-Refractometry and Local-Field Mapping with Single Molecules," Nano Lett. 18(10), 6129 (2018).

[2] T. A. Anikushina, M. G. Gladush, A. A. Gorshelev, and A. V. Naumov, "Single-molecule Spectromicroscopy: a Route towards Sub- wavelength Refractometry," Faraday Discussions 184, 263 (2015).

[3] R. A. L. Vallé, N. Tomczak, L. Kuipers, G. J. Vancso, and N. F. van Hulst, "Single Molecule Lifetime Fluctuations Reveal Segmental Dynamics in Polymers," Phys. Rev. Lett. 91, 038301 (2003).

[4] A. Aubret, M. Orrit, F. Kulzer, "Understanding Local-Field Correction Factors in the Framework of the Onsager-Böttcher Model," ChemPhysChem https://doi.org/10.1002/cphc.201800923 (2018).

09:30-10:00 **Th16A(A)-2** (invited)

Optical Microscopy and Spectroscopy of Single Nanoparticles

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Light visualization of single nanoparticles is one of the key challenges of the modern optical microscopy. Ultra small sizes and extremely low level of optical signals in such cases makes this task very difficult. It is especially difficult to observe the so-called "invisible" nanoparticles, which weakly absorb a visible light and are characterized by the refraction index close to its value in nearby environment. Such particles are typical in biology studies and are often used in modern technologies (for example, suspension of transparent polymer nanoparticles in aquatic environment). Another difficult task is a measurement of individual optical spectra of single nanoparticles.

We present two novel experimental far-field optical microscopy techniques for high sensitive imaging of small single nanoparticles including nearly invisible nanoparticles. Our setups are based on two different schemes: the modified surface plasmon-assisted microscope and the optical light sheet microscope.

The original scheme of optical signal detection, used in the case of the surface plasmon resonance microscope, sensitive to distortion of scattered light, allows to increase noticeably signal to noise ratio of this device. The important advantage of this microscope is the possibility to detect the same nanoparticles simultaneously by two different methods. It can be realized

by collecting light signals from two different sides of the sample. This way allows to raise the reliability of nanoparticle detection with the assumption that the origin of the experimental errors in two methods is different.

In contrast to conventional light sheet microscopes, which are based on the fluorescence detection, our device is based on elastic scattering detection. It allows to increase markedly the sensitivity of nanoparticles detection. We will present the schemes of the developed microscopes and demonstrate theirs possibilities on example of nanoparticles of different origins (polystyrene nanoparticles, gold nanoparticles, exosomes, liposomes etc). We will present also the scheme of the developed by us special microscope for ultrahigh sensitive detection of individual optical spectra of single nanoparticles. The examples of measured spectra will be presented.

10:00-10:30 **Th16A(A)-3** (invited)

FRET in Single Donor-Acceptor Pair Attached to a Macromolecule Can Serve As a Tool for Studying Conformational Dynamics of the Macromolecule

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Proteins, DNA-molecules and other macromolecules, being in natural media, are able to change their shape (conformation) in time scale of minutes or milliseconds. Investigation of such conformational dynamics of macromolecules is important task. Luminescence of donor-acceptor (D-A) pairs attached to these macromolecules can be effective tool for investigation of conformational dynamics of the macromolecule. The most important feature of D-A pair is energy transfer of electronic energy of the donor molecule to the acceptor molecule. Efficiency of energy transfer is described by simple equation $E(R_{DA}) = I_A(R_{DA})/[I_A(R_{DA}) + I_D(R_{DA})]$ where I_D and I_A are intensities of D- and A-molecules. Since energy transfer depends on the distance R_{DA} between D- and A-molecule we can find information concerning R_{DA} by measuring efficiency $E(R_{DA})$.

Luminescence of D- and A- molecules separated by few nanometers and excited via absorption band of D-molecule is described by the Förster theory proposed more than seventy years ago for mixture of D- and A-molecules. However, application of the Förster theory (Förster Resonance Energy Transfer or FRET) for single D-A pair creates a number of new questions. These questions could not emerge when we deal with mixture of D- and A-molecules. In particular role of triplet states existing in D- and A-molecules can be reconsidered if we deal with single D-A pair. New aspects that emerge in FRET of single D-A pair are discussed in this talk. RFBR grant #17-02-00652 is acknowledged

10:30-11:00 **Th16A(A)-4** (invited)

Entanglement of a Nanowire System Interacting with Laser Field

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We discuss the entanglement in a ballistic quantum wire with Rashba spin-orbit interaction in the presence of both strong and weak magnetic fields and for different initial states of the system. Our results show that there is a strong relationship between the spin-orbit interaction and the entanglement sudden death and sudden birth. This allows new knobs to control the strength and the component of entanglement in the nanowire system.

[1] R. I. Mohamed, Ahmed Farouk, A. H. Homid, O. H. El-Kalaawy, Abdel-Haleem Abdel-Aty, M. Abdel-Aty and S. Ghose, Scientific Reports (2018) 8:10484 | DOI:10.1038/s41598-018-28607-3

11:00-11:10 **Th16A(A)-5** (sponsor)

Confocal Raman microspectrometers from SOL instruments for quantum dot analysis

Sergei Shashkov

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A sponsored talk.

Fundamentals of quantum measurements – Hall B
09:00-11:10 Chairman: L. Mista

09:00-09:30 **Th16A(B)-1** (invited)

Fundamental limitations for measurements in quantum many-body systems

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Dynamical measurement schemes are an important tool for the investigation of quantum many-body systems, especially in the age of quantum simulation. Here, we address the question whether generic measurements can be implemented efficiently if we have access to a certain set of experimentally realizable measurements and can extend it through time evolution. For the latter, two scenarios are considered (a) evolution according to unitary circuits and (b) evolution due to Hamiltonians that we can control in a time-dependent fashion. We find that the time needed to realize a certain measurement to a predefined accuracy scales in general exponentially with the system size – posing a fundamental limitation. The argument is based on the construction of ϵ-packings for manifolds of observables with identical spectra and a comparison of their cardinalities to those of ϵ-coverings for quantum circuits and unitary time-evolution operators. The former is related to the study of Grassmann manifolds. The results show that it is a question of clever design to allow for the measurement of observables of interest through efficient dynamical schemes and a suitable encoding of models in quantum simulation protocols.

[1] T. Barthel and J. Lu, Phys. Rev. Lett. 121, 080406 (2018)