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Scientific session of the Division of General Physics and Astronomy of the Russian Academy of Sciences (25 November 1998)

A scientific session of the Division of General Physics and Astronomy of the Russian Academy of Sciences (RAS) was held at the Institute of Spectroscopy, RAS on 25 November 1998. Eight papers were presented at this session:

(1) **Letokhov V S** (Institute of Spectroscopy, RAS, Troitsk, Moscow region) "Problems of nanooptics";

(2) **Vinogradov E A, Dobryakov A L, Kovalenko S A, Lozovik Yu E, Matveets Yu A, Farztdinov V M** (Institute of Spectroscopy, RAS, Troitsk, Moscow region) "Spectroscopy of polaritons in a semiconductor microcavity";

(3) **Agranovich V M** (Institute of Spectroscopy, RAS, Troitsk, Moscow region) "Excitons and optical nonlinearities in hybrid organic-inorganic nanostructures";

(4) **Lozovik Yu E, Merkulova S P** (Institute of Spectroscopy, RAS, Troitsk, Moscow region) "The outlook for nanolocal femtosecond spectroscopy and nanolithography";

(5) **Ryabtsev A N** (Institute of Spectroscopy, RAS, Troitsk, Moscow region) "Spectroscopy of ions with the 5d electrons in the ground state";

(6) **Dumesh B S** (Institute of Spectroscopy, RAS, Troitsk, Moscow region) "Microwave spectroscopy of molecular Van der Waals complexes in astrophysical studies";

(7) **Popova M N** (Institute of Spectroscopy, RAS, Troitsk, Moscow region) "Infrared spectroscopy of new spin-Peierls compounds";

(8) **Kompanets O N** (Institute of Spectroscopy, RAS, Troitsk, Moscow region) "New developments of optical spectral instruments in the Institute of Spectroscopy, RAS".

Abridged versions of the papers are given below.

PACS numbers: 42.30. Yc, 42.50.Dv, **42.87.–d**, **85.42. + m**

Problems of nanooptics

V S Letokhov

Nanooptics is a new line of investigation in *nanoscience* and *nanotechnology*, which uses light localized in space at a scale $a \leqslant \lambda$ (λ is the wavelength of light) or within a volume $V \ll \lambda^3$. It uses new or modified known effects of the linear or nonlinear, classical or quantum-mechanical interaction of laser light with atoms, molecules, clusters, and nanostructures. The practical development of this field is based on the advent of lasers and technology for fabrication of submicron structures (nanoapertures, nanoslits, nanotips, etc.) for localization of light at the nanometer scale.

The fundamental features of nanooptics are as follows: (i) the possibility of localizing laser light for studying the structure of matter with nanometer spatial resolution, retaining the spectral selectivity inherent in optics; and (ii) a substantial change in the response of matter (atoms, molecules, etc.) to the localized light near nanostructures as compared to the case of free space.

In this report, both these features are considered and also some possible applications are mentioned.

The first serious achievement of nanooptics is the development over the last fifteen years of near-field scanning optical microscopy (NSOM) [1] based on the ideas of E Synge and A Einstein proposed seventy years ago [2] (see reviews [3 – 5]). The spatial resolution of NSOM is limited to 30 nm due to problems associated with the propagation of light through such small apertures. We suggested modifying NSOM in such a way [6] that instead of funneling light through a small aperture, the resonance dipole – dipole excitation transfer from donor to acceptor in a sample would occur with consequent fluorescence (Fig. 1). (In this case, the spatial resolution is determined by the Förster radius of about 0.5 – 5 nm rather than by the aperture size.) For this purpose, we fabricated a 'nanotip' containing absorbing centers at low concentration (F_2-centers in LiF), with a single resonantly excited center under the nanotip [7]. The observation was performed with a laser resonance photoelectron microscope we developed with a standard spatial resolution of 30 nm [8], which represents an ideal instrument for the selection of such nanotips. In addition, it was also necessary to develop a technique of vertical scanning of the nanotip with an accuracy better than 1 nm. This was achieved

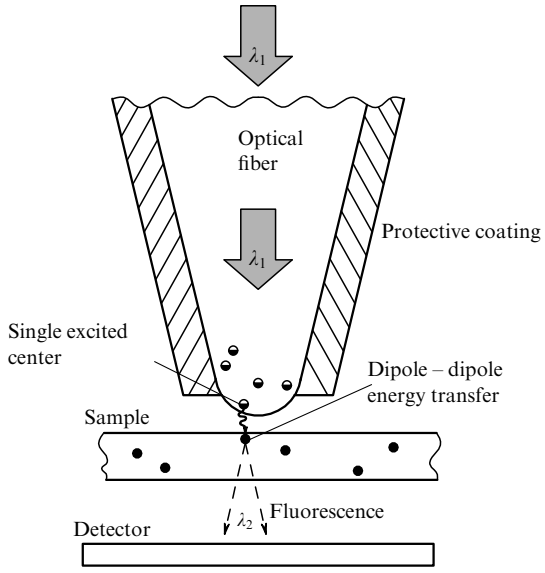

Figure 1. Scanning optical microscope with a nanometer spatial resolution based on resonance energy transfer from a donor on the tip surface to a fluorescing acceptor on the sample surface [6].

Uspekhi Fizicheskikh Nauk **169** (3) 345 – 356 (1999)
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with the help of a so-called near-field microscope [9]. Thus, having all the required elements, we started to realize near-field microscopy using resonance energy transfer.

However, the parameters of the resonance energy transfer can substantially change near nanostructures, in particular, near the nanotip. This is a typical problem of nanooptics, which was theoretically studied in Ref. [10] to gain a deeper understanding of the microscope being developed. We modeled the nanotip as a dielectric sphere of radius $a \ll \lambda$ and, indeed, found a noticeable difference between the resonance energy transfer in the case of the surface curvature at the nanometer scale and the cases of free space and plane surface. This difference is mainly caused by a different mismatch between the frequencies of the donor and acceptors located in different regions of a nanomedium (Fig. 2).

Another interesting effect in nanooptics is a change in the probability of forbidden (in particular, quadrupole) transitions near a dielectric nanotip. This problem was theoretically studied in Ref. [11]. Figure 3 shows that a nanosphere of radius $r \ll \lambda$ enhances the ratio of the probability of the quadrupole transition to that of the dipole transition by a factor of $(\lambda/r)^2$.

Of course, many other optical effects are also modified near nanostructures.

Finally, note that a laser photoelectron microscope can be used for parallel and sequential reading of information in systems of ultrahigh-density optical memory (10^{11} bit cm^{-2}) [12].

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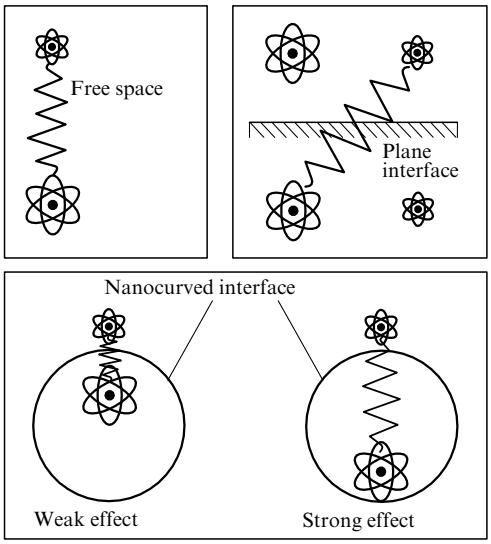

Figure 2. Qualitative explanation of the change in the rate of resonance energy transfer between dipoles separated by a 'nanointerface' compared to the cases of free space and a plane surface. The effect is caused by a change in the matching between frequencies of the donor inside a nanosphere and an acceptor [10].

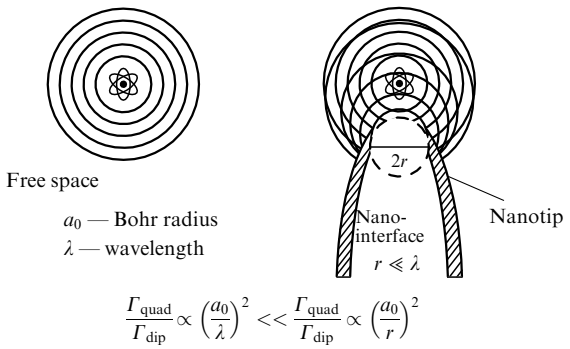

Figure 3. Qualitative explanation of the change in probability of the quadrupole transition compared to that of the dipole transition near a nanosphere [11].

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PACS numbers: **71.36.+c**, **78.66.–w**

Spectroscopy of polaritons in a semiconductor microcavity

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1. Introduction

At present, the optical properties of thin dielectric and semiconductor films on metal surfaces, the excitation of polaritons in these structures (see, for example, Refs [1, 2]), and the nonlinear optics of thin-film microcavity structures of Fabry – Perot resonator type [3] are attracting much attention. These systems represent a pithy model of nonlinear optics: planar microcavity structures are a simple physical model, which permits a sequential account of boundaries when a resonance medium of finite thickness is used. In addition, these systems are promising for the study of the nonstationary Kasimir effect and other phenomena of quantum electrodynamics in a cavity (see Ref. [4] and references therein).