Scientific session of the Division of General Physics and Astronomy of the Academy of Sciences of the USSR (24–25 February 1988)

Usp Fiz. Nauk **155**, 719–728 (August 1988)

A scientific session of the Division of General Physics and Astronomy of the USSR Academy of Sciences was held on February 24 and 25, 1988, at the S. I. Vavilov Institute of Physics Problems of the USSR Academy of Sciences. The following reports were presented at the session:

February 24

1. *A. M. Bonch-Bruevich, M. N. Libenson, and V. S. Makin.* Surface polaritons and intense laser radiation.
2. *V. I. Anisimov, V. P. Antropov, V. A. Gubanov, M. I. Katsnel'son, and A. I. Likhtenshtein.* Band theory of magnetism in metals and alloys.

February 25

3. *N. N. Chugaĭ.* Supernova in the Large Magellanic Cloud: first year of observations.
4. *G. S. Bisnovatyĭ-Kogan.* Gravitational collapse, neutrino radiation, and supernova light curves.

Brief summaries of the reports are presented below.

A. M. Bonch-Bruevich, M. N. Libenson, and V. S. Makin. *Surface polaritons and intense laser radiation.* Several years ago it was discovered that surface polaritons, that is optical frequency surface electromagnetic waves (SEW), play a significant role in the interaction of laser radiation with condensed matter. These waves are comprised of partially longitudinal TM-type waves that propagate along the interface between two media with permittivities (ε) of opposite sign; they exist in both media simultaneously.[1,2] Electric and magnetic fields of SEW are concentrated near the interface and fall off fairly quickly on both sides away from it. The concept of surface polaritons entered into the physics of laser radiation effects from spectroscopy, where methods of exciting SEW by laser radiation were proposed and realized by means of coupling prisms, diffraction elements, and diaphragms. Also, promising possibilities of employing SEW to study the optical properties, composition, profile, and other properties of surfaces were demonstrated (see, for example, Ref. 2). By applying the concept of surface polaritons (and other surface electromagnetic modes) excited on a rough surface by intense laser radiation it became possible to understand a number of previously unexplained experimental observations of such phenomena as the appearance of periodic surface structures (PSS), the orientation dependence of the absorptivity in materials, changes in the mean reaction rates of surface physicochemical processes, and so forth.[3] Currently these investigations have coalesced into a separate branch of the physics of laser interaction with matter. Results in this field have been summarized in review articles.[4]

The report discusses the main processes and dependences that are related to the excitation of surface polaritons in the interaction of intense laser radiation with materials with active surfaces (Re $\varepsilon < 0$). Materials that have active surfaces in the visible and IR spectral ranges, where the majority of lasers operate, include metals, melts of many semiconductors, and some dielectrics in which the anomalous dispersion of permittivity ε is due to the interaction of light with the lattice. One of the main manifestations of the excitation of surface polaritons upon laser irradiation of such media is the appearance of PSS with a period of the order of wavelength λ and wavefronts oriented perpendicularly to the surface projection of the electric field vector of the laser beam (given linearly polarized radiation). According to developed theories, the appearance of PSS is due to the partial transformation of laser radiation into SEW on "resonant" periodic lattices which are present, to some extent, in the spatial spectrum of random surface roughness (polariton mechanism). The period and orientation of the lattice correspond to the condition when diffracted waves of the first order ($+1$ or -1) propagate along the surface. Because of the interference between the incident radiation and the SEW, the total radiation intensity at the surface becomes spatially modulated with the same period as the resonant lattice. Given incident radiation of sufficient intensity, the resulting interference field causes inhomogenous heating of the material and consequent changes in the surface relief at the resonant spatial frequency due to the activation of various thermal processes on the surface. These last provide the positive feedback mechanism and lead to a growing resonant relief, whose height determines the efficiency of SEW excitation and the modulation amplitude of the interference field. When the laser radiation is removed the profile is preserved in the form of PSS. Actual thermal processes that produce PSS may include evaporation, partial surface melting and displacement of the melt by excess vapor pressure, thermocapillary and thermochemical mechanisms, thermal deformation, generation of surface acoustical waves, etc. This phenomenon is universal, as it occurs after laser irradiation over a wide range of wavelengths (from IR to UV) and pulse durations (from picosecond pulses to CW operation). We note that long before the actual observation of this phenomenon,[3] Kats and Maslov[5] applied the stimulated emission formalism to discuss an essentially similar problem of the growth of a resonant surface relief on an ideal metal as a

0038-5670/88/080772-07$01.80

result of ponderomotive forces. Real PSS, however, are produced by lower threshold thermal processes.

The appearance of PSS is an interesting example of self-ordering in a system which originally possesses no definite structure or orientation. The growth of PSS is accompanied by a specific optical process—a significant redistribution (and enhancement) of the radiation field on and near the surface. In this case light is not only reflected and refracted at the interface, but also partially transformed into surface polaritons. It is estimated that the electric field intensities in the SEW and the incident, linearly polarized beam become comparable when the height of the resonant profile $h \sim 10^{-3} \lambda$, and that this transformation plays an important role in the energy balance at the surface. Radiation-excited surface polaritons are usually absorbed as they propagate along the surface. The absorptivity of the surface-active medium consequently changes. Not only can the absorptivity increase strongly (up to ~ 1), but it acquires a definite orientation dependence determined by the direction and mean free path of SEW when the free path comes to exceed the size of the irradiated region. This mechanism makes it possible to control the extent of thermal effects of laser radiation by changing the orientation of the light electric field vector with respect to some preferred direction, for example the direction in which the light beam is scanned along the surface. The redistribution and enhancement of the resulting field due to the generation of surface polaritons contributes to the intensification of various physicochemical processes on the surface: photo- and thermal emission; adsorption and desorption; chemical reactions; etc. It is also conceivable that surface polaritons participate in the basic steps of some catalytic reactions. The field enhancement can be local, due to the excitation of localized surface plasmons and cylindrical SEW, and lead to the lowering of the surface optical breakdown threshold. Various drag effects involving surface polaritons are also of interest, for example their drag of free electrons in thin metal films.

In addition to surface polaritons, under certain conditions surface structures and changes in the effective absorptivity can appear in dielectrics due to radiation-excited waveguide modes, resonant for materials with spatial inhomogeneities or several flat interfaces. Also, a radiative mode can be nonresonantly excited on a rippled dielectric interface. The field structure of such a mode is similar to SEW, albeit with a different physical origin and different generation efficiency.

---

[1] V. M. Agranovich and V. L. Ginzburg, *Crystal Optics with Spatial Dispersion and Excitons*, Springer-Verlag, N.Y., 1984 [Russ. original, Nauka, M., 1979].

[2] V. M. Agranovich and D. L. Mills (editors), *Surface Polaritons*, North-Holland, N. Y., 1982 [Russ. transl., Nauka, 1985].

[3] M. K. Kochengina, M. N. Libenson, V. S. Makin, and S. D. Pudkov, Proceedings of the Fifth All-Union Symposium on Nonresonant Interaction of Optical Radiation and Matter (In Russian), Leningrad, 1981, p. 381. A. M. Bonch-Bruevich, M. K. Kochengina, M. N. Libenson, V. S. Makin, S. D. Pudkov, and V. V. Trubaev, Izv. Akad. Nauk SSSR, Ser. Fiz. **46**, 1186 (1982) [Bull. Acad. Sci. USSR, Phys. Ser. **46**, No. 6, 152 (1982)]. V. P. Aksenov and B. G. Zhurkin, Dokl. Akad. Nauk SSSR **265**, 1365 (1982) [Sov. Phys. Dokl. **27**, 630 (1982)]. F. Keilman and Y. H. Bai, Appl. Phys. Ser. **A29**, 9 (1982). C. R. J. Brueck and D. J. Ehrlich, Phys. Rev. Lett. **48**, 1678 (1982). A. M. Prokhorov, V. A. Sychugov, A. V. Tishchenko, A. A. Khakimov, Pis'ma Zh. Tekh. Fiz. **8**, 961 (1982) [Sov. Tech. Phys. Lett. **8**, 415 (1982)]. Zhong Guosheng, P. M. Fauchet, and A. E. Siegman, Phys. Rev. **B26**, 5366 (1982). V. N. Anisimov, V. Yu. Baranov, L. A. Bol'shov, A. M. Dykhne, D. D. Malyuta, V. D. Pis'mennyi, A. Yu. Sebrant, and M. A. Stepanova, Poverkhnost' No. 7, 138 (1983) [Phys. Chem. Mech. Surf. **2**, 2138 (1983)].

[4] S. A. Akhmanov, V. I. Emel'yanov, N. I. Koroteev, and V. N. Seminogov, Usp. Fiz. Nauk **147**, 675 (1985) [Sov. Phys. Usp. **28**, 1084 (1985)]. A. E. Siegman and P. M. Fauchet, IEEE J. Quantum Electron. **QE-22**, 1384 (1986).

[5] A. V. Kats and V. V. Maslov, Zh. Eksp. Teor. Fiz. **62**, 496 (1972) [Sov. Phys. JETP **35**, 264 (1972)].