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A scientific session of the Division of General Physics and Astronomy of the U.S.S.R. Academy of Sciences was held on 29 and 30 October 1969 in the Conference Hall of the P. N. Lebedev Physics Institute. The following papers were delivered:

1. E. B. Aleksandrov, O. V. Konstantinov, and V. I. Perel', Interference of Atomic States.
2. L. V. Keldysh, Electron-hole Drops in Semiconductors.
3. V. N. Lugovoĭ and A. M. Prokhorov, Self-focusing of Intense Light Beams.
4. G. A. Askar'yan, V. B. Studenov, and I. L. Chistyĭ, Thermal Self-focusing in a Beam with Decreasing Intensity Near the Axis ("Banana" Self-focusing).
5. Yu. N. Barabanenkov, Yu. A. Kravtsov, S. M. Rytov, and V. I. Tatarskiĭ, Status of the Theory of Wave Propagation in Randomly-inhomogeneous Media.
6. Yu. A. Kravtsov, Geometrical-optics Method and Its Generalizations.
7. L. L. Goryshnik and Yu. A. Kravtsov, Correlation Theory of Radio Wave Scattering in a Polar Ionosphere.
8. Z. I. Feĭzulin, Propagation of Bounded Wave Beams in Media with Random Inhomogeneities.

We publish below a brief content of the papers.

E. B. Aleksandrov, O. V. Konstantinov, and V. I. Perel'. Interference of Atomic States.

THE wave function ψ of an atom optically excited in an arbitrary manner is in general case not an eigenfunction of the energy operator, and is described by a superposition of states of definite energy. The probability of radiative transition of the atom from the state ψ to any new eigenstate, experiences in the course of time beats with frequencies corresponding to the energy intervals between the levels covered by the superposition. Experimental interest attaches to beats connected with the interference of close sublevels and falling in the radio band. Elementary beats of radiative-transition probability can lead under definite conditions to observable effects in the optical properties of an ensemble of atoms.

1. Coherent phenomena of interference of states (collective beats). This type of phenomenona in the interference of states includes a group of optical effects, the most characteristic of which is resonant microscopic modulation of the spontaneous emission or absorption of the system of atoms. The condition for the formation of collective effects of interference of states is that the elementary beats be in phase, or, what is the same, that the non-diagonal elements of the density matrix of the initial state differ from zero. To ensure this condition in interference, say, of excited magnetic sublevels, it is necessary to use anisotropic excitation with one of three conditions: a) with pulsed or harmonic modulation of the excitation intensity; b) with modulation of the energy gap between the interfering sublevels; c) with modulation of the parameter of the anisotropy of the excitation (e.g., periodic change of the plane of polarization of light or of the direction of the beam of exciting particles).

All these methods of ensuring phasing of the beats lead to essentially different optical phenomena. For example, in the case of harmonic modulation of the excitation one observes a resonant increase of the depth of modulation of the spontaneous emission (or absorption) when the excitation-modulation frequency coincides with the frequency of the transition between the interfering states, no matter how large the latter may be. In the other variant, in modulation of the energy interval between the levels at a frequency Ω, one observes modulation of the luminescence at frequencies equal to and multiples of the frequency Ω, when this frequency is close to or is smaller by an integer factor than the average frequency of the transition between the interfering states. All these phenomena allow us to determine from the position and width of the resonance the fine energy structure of the atoms, including the cases when it is spectroscopically masked by the Doppler broadening.

Experimentally, the phenomena of collective beats were obtained in 3261 Å luminescence of cadmium—we investigated the interference of the magnetic and electric sublevels of the state 5^3P_1. Phenomena of interference of states in absorption were observed in cesium vapor under conditions of optical orientation.

2. Incoherent beats. In the case of random excitation, the phases of the elementary beats are random if there are no supplementary phasing actions. Under these conditions, no macroscopic modulation of the total radiation can occur, but the statistics of the fluctuation of the field contains information concerning the superposition states of the source atoms. This information can be extracted by analyzing the spectrum of the receiver photocurrent. Such a procedure makes it possible to draw conclusions concerning the spectral-polarization characteristics of the radiation inherent in elementary radiators, in spite of the arbitrarily large inhomogeneous broadening of the resultant spectral line. The corresponding experiment could be realized at the xenon 3.508 μ line.

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L. V. Keldysh. Electron-hole Drops in Semiconductors.

At sufficiently low temperatures, the non-equilibrium electrons and holes introduced into a pure semiconductor are bound together into excitons—systems similar to positronium, but differing from it in having macroscopically large Bohr radii ($a_0 \sim 10^{-6}$ cm) and very low binding energies ($\epsilon_0 \sim 10^{-2}$ eV).

Such a change in the length and energy scales in a system coupled by Coulomb forces is due to the decrease of the Coulomb interaction as a result of the large dielectric constants of the semiconductors, $\kappa \geq 10$, and the small effective masses of the electrons and holes, $m \sim 0.1\, m_0$ (m_0—mass of free electron). Substitution of these values into the known Bohr formulas for the binding energy and the radius of the hydrogenlike atom

$$\varepsilon_0 = e^4 m/2\varkappa^2\hbar^2, \qquad a_0 = \varkappa\hbar^2/me^2$$

leads to the estimates indicated above. An increase of the length scale by two orders of magnitude and a decrease of the energy scale by three orders of magnitude compared with the length and energy scales in ordinary substances is characteristic also of all the phenomena considered below which occur in a system of electrons and holes in a semiconductor. In particular, the criterion of high exciton density, wherein an important role is assumed by the interaction between them, corresponds obviously to concentrations $n_0 \sim a_0^{-3} \sim 10^{18}$ cm^{-3}, and the region of temperatures at which all these phenomena should be observed is $kT \lesssim 0.1\epsilon_0$, i.e., $T \lesssim 10°$ K.

If the electron concentration is large enough, the interaction between them can lead to a "liquefaction" of the exciton gas,[1] i.e., to the formation of a relatively dense electron-hole phase, in which all the particles are coupled by mutual attraction forces and the average distance between them is of the order of a_0, while their concentration is $n_0 \sim a_0^{-3} \sim 10^{17}$–$10^{18}$ cm^{-3}. This phase differs from the usual electron-hole plasma in semiconductors in the same manner as liquid metals (e.g., mercury) differ from an electron-ion plasma: it is contained by internal forces and has a perfectly well defined equilibrium density n_0. It does not diffuse over the entire sample, and occupies only that part of the sample volume which can be uniformly filled with a density n_0 at a specified total number of electrons and holes introduced into the sample. The transition from the gas of free excitons to the electron-hole "liquid" should have many characteristic features of a first-order phase transition. In particular, when the average exciton concentration in the sample reaches a certain value $n_c(T)$ that depends on the temperature T ($n_c(T) \ll n_0$ at sufficiently low temperatures), the system should become laminated into two phases: regions filled with the liquid phase—"drops"—with density n_0, and regions filled with an exciton gas having a much lower density. With further increase of the number of electrons and holes introduced into the sample, the volume of the liquid phase increases, but its density n_0 does not change so long as it does not fill the entire sample. A rigorous theoretical investigation of the properties of the liquid phase entails considerable difficulties, but its main properties can be predicted from general considerations. The absence of heavy ions from the sample makes it impossible to produce in such a phase any spatial ordering such as crystallization at arbitrary temperatures, since the amplitudes of the zero-point oscillations of the particles should be of the order of a_0, i.e., of the average distance between the particles. For the same reason, it is not very likely that such a liquid phase can consist of exciton molecules—biexcitons. The large zero-point oscillations and the low coupling energy of the biexciton should lead to an intense interaction of each particle with all the nearest neighbors, to a strong electron exchange, and as a consequence to a collectivization of all the electrons and holes. Therefore the phase under consideration is more likely to be similar to a liquid metal.

The electron-hole drops in pure semiconductors should have quite high mobility, since the scattering of the electrons and of the holes by the phonons, which is sufficiently small at low temperatures to start with, is suppressed even more by the presence of Fermi degeneracy in the drop, and the density of the effective mass in the drop is very small. Therefore such external actions as inhomogeneous deformations or inhomogeneous magnetic fields can relatively easily accelerate the drops to velocities of the order of the velocity of sound. It is not very likely that the drop can exceed this velocity, owing to the coherent emission of phonons. How-