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FIFTH ALL UNION SEMINAR ON "EXCITONS IN CRYSTALS"

(Leningrad, 31 May–2 June 1969)

S. A. PERMOGOROV

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THE Fifth All-union seminary "Excitons in Crystals" was held in Leningrad on 31 May–2 June 1969. Twenty nine papers were delivered (Leningrad-11, Moscow-6, Kiev-4, Kishinev-3, Tartu-3, Riga-1, Drogobych-1). Approximately 150 persons took part.

Greeting the participants of the seminar, Corresponding Member of the USSR Academy of Sciences, E. F. Gross said in his opening address:

"I am very glad that we have gathered at a conference on excitons in Leningrad. I recall the time, almost two decades ago, when the exciton was first observed in Leningrad in the semiconducting cuprous oxide crystal (Cu_2O). I am very glad that I am not the only one, that there are now many of you—those who believe in excitons and have no doubt that these quasiparticles play an important role in crystal physics.

At that time, however, in the spring of 1951, when I reported observation of the optical spectrum of the exciton in the Cu_2O crystal to the Science Council of the Physico-technical Institute of the USSR Academy of Sciences and described the phenomenon in the then traditional semi-annual report, nobody believed me. My communication was greeted with such unbelief, that the director of the Physico-technical Institute refused to authorize the publication of this work.

This lack of belief, which was expressed also by certain prominent scientists in Leningrad and in Kiev, caused much damage to work on excitons and to the author. The same lack of belief also caused a considerable delay in work on excitons in the Soviet Union. I am happy that this disbelief has come to an end and that excitons, which were discovered both theoretically and experimentally by Soviet physicists, now migrate and have propagated over the entire globe."

The largest number of seminar papers (six) was devoted to the investigation of the properties of crystals at large exciton-excitation densities.

Intensive experimental investigations, closely connected with the problems of condensation of excitons and of obtaining stimulated emission of excitons, have led to observation of new lines in the spectra of radiative recombination of many crystals. The intensities of these lines increase linearly with increasing excitation intensity. In a paper by Ya. K. Pokrovskiĭ and K. I. Svistunova, this new radiation in crystals of Ge is explained by using the concept of formation of the condensed phase of excitons—metal-like drops—at large excitation levels. B. M. Ashkenadze, I. P. Krets, S. M. Ryvkin, and I. D. Yaroshetskiĭ used a similar model to explain the spectrum of the exciton emission of Si crystals excited by ruby-laser pulses. V. M. Asnin and A. A. Rogachev describe briefly results of earlier investigations devoted to the study of the properties of metal-like drops of exciton condensates by using the spectra of direct exciton absorption of Ge crystals.

A somewhat different point of view on the nature of the new emission lines produced at large exciton densities was advanced in the paper by E. F. Gross, L. N. Kurbatov, V. E. Mashchenko, B. S. Razbirin, and F. I. Kreĭngol'd, who propose that these lines arise in radiative recombination of biexcitons or during the course of Auger recombination in collisions of two excitons.

A theoretical paper by S. A. Moskalenko and P. I. Khadzhi was devoted to the hydrodynamic properties of a Bose condensate of excitons at non-zero temperature. The possibility of formation of an exciton molecule (biexciton) and of an exciton ion at different ratios of the effective masses of the electron and the hole was discussed in a paper by A. I. Bobrysheva, M. F. Migleĭ, and S. A. Moskalenko.

Problems of the interaction of free excitons with phonons were the subject of five papers. M. V. Kurik reported extensive experimental material favoring the applicability of the Urbakh rule for the description of the spectral dependence of the absorption coefficient near the intrinsic absorption edge. In a theoretical paper, V. G. Fedoseev considered the singularities in the spectral density of exciton absorption, existing on the edges of the "steps" of indirect exciton absorption. Unfortunately, the presented calculations were performed using a one-dimensional model, making a comparison with the available experimental data difficult. A paper by D. S. Bulyanitsa was devoted to the calculation of the spectral form of lines produced upon annihilation of higher quantum states of excitons with simultaneous creation of optical phonons. A paper by E. F. Gross, S. A. Permogorov, and V. V. Travnikov deals with an investigation of the luminescence excitation spectra of free excitons in CdS crystals. These spectra have a clearly pronounced oscillatory structure with the same period as the energy of the longitudinal optical phonon; the structure is the result of incomplete establishment of thermal equilibrium in the exciton bands during the lifetime of the free exciton. An analysis of the excitation spectra has permitted the authors to conclude that an important role is played by processes of indirect exciton absorption in the excitation of the exciton luminescence and that "hot" excitons, with a kinetic energy exceeding the ionization energy by several times, can exist. V. V. Khizhnyakov considered the problem of exciton-phonon interaction with allowance for spatial dispersion.

Spatial dispersion was also the subject of a paper by V. M. Agranovich, who developed the theory of gyrotropy in the vicinity of the exciton absorption line.

B. P. Zakharchenya and R. P. Sisyan investigated experimentally the structure of the spectrum of direct exciton absorption in Ge crystals in a strong magnetic field. An investigation of this structure makes it possible to determine certain parameters of the electron

bands. A strong magnetic field leads to deformation of the trajectory of the motion of electrons and holes on exciton orbits, and in the limiting case electrons in a strong field can be regarded as one-dimensional formations. A decrease of the dimensions of the exciton in a strong field makes it insensitive to the screening action of free carriers, and this makes it possible to reveal distinct magnetooptical absorption spectra in strongly doped crystals.

New methods of investigating exciton excitations were proposed in papers by I. I. Zheru, S. A. Moskalenko, and M. I. Shmiglyuk "Paraelectric Resonance on Excitons in Semiconductors" and of L. A. Blyumenfel'd, V. A. Benderskiĭ, E. A. Sokolov, and P. A. Stunzhas "Electron-electron Double Resonance." The absorption of hypersound by excitons in a strong magnetic field was considered by M. A. Ruvinskiĭ.

Two papers, one by V. M. Agranovich, Yu. V. Konobeev, and N. E. Kamenogradskiĭ and the other by M. V. Belousov, were devoted to the calculation of the energy of intermolecular interaction in molecular crystals.

The role of excitons in the processes producing photoconductivity in crystals was the subject of a paper by B. V. Novikov. Attentive investigations of the excitation spectra of the photoconductivity show that the diffusion of the excitons plays an important role in the processes of the internal photoeffect. These investigations show also the large influence of the surface properties of the crystal on its photosensitivity.

The experimental investigation of energy-transfer processes by excitons in alkali-halide crystals were the subject of papers by Ch. B. Lushchik, G. I. Lid'ya, and B. Ya. Berzin'. Migration of exciton energy in crystals of aromatic compounds was experimentally investigated by E. L. Frankevich and by V. R. Priĭmagen and A. N. Faĭdysh.

Kinetic recombination of excitons in semiconducting crystals was considered by V. V. Evstropov and B. V. Tsarenkov and investigated experimentally by É. L. Nolle. The lifetimes of exciton-impurity complexes were measured by E. F. Gross and F. I. Kreĭngol'd, using the spectra of luminescence quenching of Cu_2O crystals. In this case, a prolonged (10^{-2} sec) afterglow of the localized excitons was observed, whereas the recombination of free excitons occurred within times shorter than 10^{-5} sec.

A. I. Ryskin, L. G. Suslina, E. B. Shadrin, and G. I. Khil'ko used the spectra of the free excitons for the investigation of the structure of cubic ZnS crystals with stacking faults constituting an admixture of the hexagonal phase. An investigation of the concentration dependence of the shift of the spectrum has made it possible to determine the value of the trigonal field and the character of the location of the defect regions in the crystal. The manifestation of defects in the absorption spectra of exciton-impurity complexes in SiC crystals was investigated by I. S. Gorban. The work by N. L. Kramarenko, V. K. Miloslavskiĭ, and Yu. V. Naboĭkov was devoted to the measurement of the line shape of the direct exciton absorption in $PbCl_2$ crystal.

In spite of the highly crowded program of the seminar (29 papers in four sessions), most papers were followed by lively discussions. Actively participating in the discussion were Academician A. S. Davydov of the Ukrainian Academy of Sciences, V. M. Agranovich, E. F. Sheka, V. L. Broude, and others. The next, Sixth, All Union Seminar on "Excitons in Crystals" will be held in May 1970 at the Institute of Solid State Physics of the USSR Academy of Sciences in Chernogolovka (Moscow Oblast).

Translated by J. G. Adashko