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Meetings and Conferences

TWELFTH ALL-UNION CONFERENCE ON LOW-TEMPERATURE PHYSICS

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THE regular, twelfth All-union Conference on Low-temperature Physics, held from 25 to 29 June 1965 in Kazan', was devoted to investigations by means of resonance methods of condensed systems at low temperatures. Approximately 300 scientists attended, from Moscow, Leningrad, Khar'kov, Sverdlovsk, Kishinev, Tbilisi, and other cities of the country, and more than 100 papers were heard. The conference opened with an introductory address by Academician **P. L. Kapitza.** Then, **S. A. Al'tshuler** presented a review paper dealing with various phenomena due to spin-phonon interactions in paramagnets.

The agenda of the conference were dealt with in four sections.

ELECTRON SPECTRA IN NONCONDUCTING CRYSTALS

Particular attention was paid in this section to research on the microstructure of impurity crystals by methods of electron and nuclear paramagnetic resonance (EPR and NMR) and optical spectroscopy.

A large number of papers was devoted to the structure of the surroundings of rare-earth ions in crystals of the CaF_2 type. **N. E. Kask, L. S. Kornienko,** and **A. I. Rybaltovskiĭ** observed EPR spectra possessing rhombic symmetry in fluorite crystals doped with dysprosium and neodymium and grown in the presence of oxygen. By studying their variation under the influence of γ irradiation, they reached the conclusion that the environment of the Dy^{3+} and Nd^{3+} ions, which give the "rhombic spectra," contains two oxygen ions, and, in addition, a vacancy is produced at the location of the F^- ion. **Yu. S. Greznev, M. M. Zaripov, L. D. Livanova,** and **V. G. Stepanov** investigated the possible mechanisms of local compensation of excess charge in CaF_2, SrF_2, and BaF_2 crystals with interstitial triply-charged rare-earth ions by adding alkali-metal ions as impurities. **A. A. Antipin, I. N. Kurkin, L. D. Livanova, L. Z. Potvorova,** and **L. Ya. Shekun** investigated the EPR spectra of Sm^{3+} ions in CaF_2, SrF_2, and BaF_2, and of Tu^{2+} in BaF_2 and SrF_2. **L. Ya. Shekun** proposed a number of reasons why the EPR of trigonal centers in fluorite are rarely observed. **Yu. A. Bobrovnikov, G. M. Zverev,** and **A. I. Smirnov** used EPR data to interpret the optical absorption spectrum of the Er^{3+} ion in CaF_2. In particular, an additional line was observed, with an exponential dependence of the spin-lattice relaxation time on the temperature. The influence of the temperature on the optical spectrum of the Gd^{3+} ion in CaF_2 was investigated by **F. Z. Gil'fanov, Zh. S. Dobkina, L. D. Livanova,** and **A. L. Stolov.**

M. M. Zaripov, V. S. Kropotov, and **L. D. Livanova** observed the hyperfine structure, due to the fluorine nuclei, of the EPR spectrum of Mn^{2+} ions and of Co^{2+} in MgF_2.

The spin-Hamiltonian constants of the ions Tb^{4+} and Gd^{3+} in CeO_2 were obtained by **Yu. S. Greznev, M. M. Zaripov,** and **L. D. Livanova,** and by **G. L. Bir, I. V. Vinokurov,** and **V. A. Ioffe** respectively.

R. A. Zhitnikov, I. V. Kolesnikova, and **A. L. Orbeli** developed methods for stabilizing free atoms in media of molecular type, at liquid-nitrogen temperature. They studied by means of EPR and optical spectroscopy the interactions with matrices of different atoms of the first group of the periodic table. The matrices used were either purely molecular media (paraffins, alcohols, water, benzene) or frozen solutions of electrolytes, as well as ionic crystals (silver in KCl).

I. N. Kurkin determined the dependence of the g-factor of Nd^{3+} on the lattice constant in crystals of the homological series of scheelite. **L. Ya. Shekun** attempted to establish the form of the potential of the electric field acting on the rare-earth ion in crystals with scheelite structure.

L. V. Dmitrieva, V. A. Ioffe, and **I. B. Patrina** investigated by EPR and NMR methods the character of the bonds of the ions V^{4+} and Fe^{3+} in V_2O_5, and also established that there is no local compensation of the charge of these ions in the first coordination sphere.

A. S. Borovik-Romanov and **V. A. Tulin** observed mixed electron-nuclear resonance in antiferromagnetic $MnCO_3$. This phenomenon is due to the existence of a coupling between the electronic and nuclear magnetic sublattices.

L. I. Dzhordzhishvili, T. L. Kalabegschvili, N. G. Politov, and **S. V. Sobolevskaya** obtained the EPR spectra of F-centers in irradiated LiF.

Yu. A. Bratashevskiĭ, N. N. Dykhanov, V. A. Moiseev, V. N. Topchiĭ, and **V. R. Shilov** established with the aid of EPR that copper atoms in $(ClC_6H_2SO_2NH)_2CuNH_3$ are for the most part covalently coupled to the ligands.

S. A. Moskalenko and **N. I. Botoshan** calculated different characteristics of paramagnetic resonance of triplet excitons.

V. Ya. Zevin and **B. D. Shanina** determined the frequencies, the magnetic-dipole transition probabilities, and the EPR line shape at the levels of the hyperfine structure in zero and weak magnetic fields.

I. B. Bersuker, **S. A. Budnikov**, and **B. G. Vekhter** considered the influence of inversion splitting on the EPR spectra of complexes with spin S = 2 in crystals.

M. M. Zaripov and **G. K. Chirkin** observed the influence of low-temperature phase transitions of NH_4Cl crystals on the EPR spectra. On the basis of their analysis of the spin-Hamiltonian constants, they proposed a model for the nearest surrounding of the divalent paramagnetic ions in the ammonia lattice.

More accurate derivations of the spin-Hamiltonian of a paramagnetic ion in crystalline and external fields were reported by **N. I. Delyugin** and **A. B. Roĭtsin** and by **V. V. Druzhinin** and **A. A. Kazakov**.

S. A. Al'tshuler and **R. M. Valishev** observed an exchange coupling of ferromagnetic type between Ni^{2+} ions in zinc fluorosilicate. From analysis of the EPR spectra of the exchange pairs of different types they determined the magnitude of the exchange integral. A. E. Nikiforov and V. I. Cherepanov wrote out the spin-Hamiltonian for a pair of exchange-coupled ions of the iron group in an ionic crystal, and **A. E. Nikiforov**, **Yu. A. Sherstkov**, and **V. I. Nepsha** considered the influence of the electric field on the EPR spectrum of Cr^{3+} pairs in corundum.

DYNAMIC PHENOMENA IN NONCONDUCTING CRYSTALS

The establishment of equilibrium in a spin system was the subject of a most detailed discussion at the sessions of this section. In connection with the fact that recently many statements have been made in the literature concerning the role of exchange-coupled pairs of ions in spin-lattice relaxation, reports of two experimental investigations in this field were heard with interest. In studying the spin relaxation of Cr^{3+} impurities in different crystals, **V. A. Atsarkin** found that a two-step spin-lattice relaxation process takes place, in which the excess heat of the spin system is transferred to the thermal vibrations of the lattice via rapidly relaxing "exchange pairs." In another study, **S. A. Peskovatskiĭ** investigated the spin-lattice relaxation of chromium ions in ruby in the absence of an external magnetic field, and arrived at the opposite conclusion, that in a wide interval of chromium concentrations the "exchange pairs" make no essential contribution to the relaxation of the single ions. The ensuing sharp discussion led to no meeting of minds, and this question must apparently be regarded as open.

Interest was evinced again in the singularities of spin-lattice relaxation, connected with the non-ideal nature of the crystal lattices. In studying the model of a linear monatomic crystal, **A. B. Roĭtsin** established that the presence of a point defect leads only to an additional factor in the expression for the relaxation time, without changing its dependence on the temperature and the magnetic field. **I. V. Aleksandrov** found that in a one-dimensional crystal the spin-lattice relaxation is faster than in a three-dimensional crystal. Allowance for anharmonicity of the lattice vibrations leads to a new dependence on the magnetic field. Distortion of the form of the lattice wave by a defect such as a dislocation leads, as shown by **B. I. Kochilaev**, to an intensification of the spin-phonon interaction and to a change of its dependence on the oscillation frequency. It should be noted that although most relaxation measurements are presently made with impurity crystals, and many facts point to the appreciable role of the lattice defects in spin-lattice interaction, there have so far been no systematic experimental investigations in this direction.

Investigating the absorption of longitudinal and transverse hypersonic waves in single-crystal quartz and ruby, **E. M. Ganapol'skiĭ** and **A. N. Chernets** estimated the magnitude and the temperature dependence of the lifetime of thermal phonons. In the discussion, **M. I. Kaganov** emphasized the importance of continuing similar work, which would make it possible to verify details of our concepts concerning lattice dynamics. **Yu. V. Vladimirtsev**, **V. A. Golenishchev-Kutuzov**, and **U. Kh. Kopvillem** measured the absorption of sound due to relaxation processes in a spin system of ruby crystals and potassium-chrome alum. **A. K. Morocha** proposed a method of finding the exchange integral as a function of the distance by measuring the absorption of ultrasound by exchange pairs. **A. V. Mitin** considered the influence of ultrasound on the EPR line shape.

T. I. Sanadze and **B. G. Berulava** investigated experimentally the establishment of equilibrium both inside the spin system of U^{3+} ions in CaF_2, BaF_2, and SrF_2 crystals as well as in the lattice.

Ya. L. Shamfarov measured the spin-lattice relaxation time of F-centers in quartz as a function of the external magnetic field.

V. S. Grechishkin, **A. D. Gordeev**, and **N. E. Aĭnbinder** observed a sharp decrease in the transverse relaxation time of the isotopes Sb^{121}, Sb^{123}, and Cl^{35} during formation of complexes.

V. V. Mank, **I. V. Matyash**, and **M. A. Piontkovskaya** investigated the influence of temperature on proton relaxation in molecules adsorbed by zeolites.

A. V. Shevchenko proposed a method of measuring spin-lattice relaxation in strong magnetic fields.

R. M. Mineeva calculated the spin-lattice relaxation time for ions with singlet electron levels.

B. I. Kochilaev has shown that in the spectrum of a bound spin-phonon system there are produced branches of mixed spin-lattice vibrations, separated by a gap on the order of the spin-phonon interaction. This result leads, in particular, to the appearance of a hyperfine structure of the Rayleigh scattering line of light in paramagnets. **S. A. Al'tshuler** and **B. I. Kochelaev** calculated earlier the shifts and the broadening of the components of the fine structure in the case when the hyperfine structure is not resolved.

Yu. E. Perlin and **V. S. Tsukerblat** calculated in the adiabatic approximation the probabilities of multiphonon nonradiative transitions of the Cr^{3+} ions in ruby, leading to population inversion at the working levels of a laser. **D. N. Vylegzhanin** found the coefficient of inversion of the populations of a four-level system. **M. P. Zhelifonov** and **A. R. Kessel'** calculated the susceptibility of a three-level system without assuming that the external electromagnetic field is small.

I. V. Aleksandrov formulated the condition for applicability of the Bloch equations for the case of EPR in a solid, in the form $\tau/\tau_1 \ll 1$, where τ is the phonon free-path time, determined from the thermal conductivity of the sample, and τ_1 is the spin-lattice relaxation time.

U. Kh. Kopvillem and **V. R. Nagibarov** proposed to use quantum-electronics methods in neutron spectroscopy, investigating the response of a beam of polarized neutrons to interaction with external fields and with matter. They discussed also the possibility of amplifying the nuclear-resonance signal in ferro- and antiferroelastic states of matter. **V. R. Nagibarov** estimated the interaction between impurity centers via exchange of quanta of optical oscillations of the lattice.

N. G. Koloskova investigated the variation of the specific heat of a paramagnet when defects such as dislocations appear in the crystal.

V. Ya. Zevin found the EPR line shape due to contact hyperfine interaction with the magnetic moments of randomly arranged nuclei.

MÖSSBAUER EFFECT

N. E. Aleksandrov, A. P. Kip'yanov, V. I. Nizhakovskiĭ, and **Yu. A. Samarskiĭ** investigated, in a wide range of temperatures, the anisotropy of the Mössbauer effect in single crystals of white tin, and observed inversion of the anisotropy effect. The authors indicated possible causes of this phenomenon.

V. P. Romanov, V. V. Chekin, B. I. Verkin, and **V. A. Bokov** investigated the change in the phonon spectrum and types of coupling for ferroelectric phase transitions in solid solutions based on barium titanate.

B. I. Verkin, V. V. Chekin, and **A. P. Vinnikov** measured the change in the isomer shift in a white-tin matrix alloyed with different impurities.

Sh. Sh. Bashkirov, R. A. Manapov, V. A. Chistyakov, and **G. D. Kurbatov** investigated the dependence of the quadrupole splitting and chemical shift on the temperature and on the content of the crystallization water in the compounds $FeCl_2 \cdot nH_2O$, $FeBr_2 \cdot nH_2O$, and $FeI_2 \cdot nH_2O$.

I. I. Lukashevich, V. V. Sklyarevskiĭ, K. P. Aleshin, B. N. Samoĭlov, E. P. Stepanov, and **N. I. Fillipov** investigated the Mössbauer spectra of γ rays of Dy^{161} of 26-keV energy. The source was metallic Gd^{160} irradiated in a reactor. It was found that the emission spectra consist of two systems of hyperfine splittings, having different temperature dependences.

U. Kh. Kopvillem considered phenomena occurring in the case when the Mössbauer effect is observed in the presence of additional perturbation by means of an electromagnetic or sound field.

A. E. Balabanov, N. N. Delyagin, and **Hussein el Said el Sais** investigated the Mössbauer effect on Gd^{155} nuclei.

V. I. Gol'danskiĭ, V. A. Trukhtanov, M. I. Devisheva, and **V. F. Belov** investigated the connection between the values of the magnetic fields on nuclei of both magnetic (Fe) and nonmagnetic atoms (Sn) and exchange interactions of sublattices in a number of ferrites such as garnets and spinels.

RESONANT PHENOMENA IN METALS AND SEMICONDUCTORS

A report by **Yu. V. Sharvin** and **L. M. Fisher** of an experiment aimed at producing and observing focused electron beams in a metal, was heard with interest. The idea of the experiment, advanced by Yu. V. Sharvin in 1964, consists in the fact that the electric current in a metal, between two point contacts, in a longitudinal magnetic field H will increase rapidly at certain values of the magnetic field. The reason is that the electrons which emerge from some point inside the metal are again gathered together, owing to the magnetic field, at a point lying on the same flux lines and located at a distance $L \sim H^{-1}$. At those values of the magnetic field when the distance between contacts is a multiple of L (the focusing conditions), the resistance of the contact decreases, i.e., periodic minima should appear on the plot of the resistance against the magnetic field. From the values of these periods it is possible to reconstruct the Gaussian curvature at the limiting point of the Fermi surface. To observe this effect it is necessary that the mean free path of the conduction electrons exceed the distance between the current contacts. The experiment was carried out with very pure tin.

An appreciable number of the reports was devoted to an experimental investigation of the measured spectrum of conduction electrons with the aid of resonance methods.

R. T. Mina and **M. S. Khaĭkin** measured, by the cyclotron resonance method, the effective masses of carriers in indium, and determined by the method of cutting off the cyclotron orbits, certain extremal dimensions of the hole Fermi surface. The Fermi surface of the same indium was investigated by **V. F. Gantmakher** and **I. P. Krylov** with the aid of the radio frequency size effect. The gist of this method was described in a paper by **V. F. Gantmakher** and **É. A. Kaner,** and consists in the fact that in a magnetic field which is inclined to the surface of a thin sample, the impedance oscillates with the magnetic field.

The oscillating part of the impedance is connected with the number of revolutions executed by the electron on the path from one surface to the other.

V. P. Nabereshnykh, A. A. Mar'yakhin, and **V. P. Mel'nik** investigated the Fermi surface of cadmium by the cyclotron-resonance method and the radio frequency size-effect method. In the case of cyclotron resonance, they succeeded in observing electron orbits passing through several reciprocal-lattice cells. This means either that the Fermi surface of the cadmium is open or that "magnetic breakdown" takes place.

A. P. Korolyuk and **L. Ya. Matsakov** investigated the Fermi surface of antimony by a magnetoacoustic method. They succeeded in observing, in an inclined magnetic field, for the first time magnetoacoustic resonance which is much less sharp than resonance on open electron orbits in a magnetic field perpendicular to the direction of sound propagation.

In the papers listed above, the experimental data on the Fermi surface are compared with the model of almost free electrons and are found to be in good agreement with this model. This surprising fact is more likely to be connected only with the possibility of interpreting the far from complete set of experimental data with the aid of the model of almost free electrons. For example, the Fermi surface of bismuth, which has been investigated in detail by numerous experimental methods, does not recall in any manner the Harrison model, and is in satisfactory (but not complete) agreement with the model of Shoenberg and with the model of A. A. Abrikosov and L. A. Fal'kovskiĭ. **V. S. Édel'man** and **M. S. Khaĭkin** observed, using the cyclotron-resonance method, an appreciable difference between the effective masses of electrons in the central sections and at the limiting points of the Fermi surface of bismuth.

Investigating theoretically the energy spectrum of the carriers in bismuth in a magnetic field, **L. A. Fal'kovskiĭ** has shown that for an arbitrarily directed magnetic field, the spin splitting of the energy levels in bismuth greatly exceeds the spin splitting of the levels of the free electrons.

Results of investigations of the electron structure of molybdenum were the subject of a paper by **P. A. Bezuglyĭ, S. E. Zhevago,** and **V. I. Denisenko.** From data on the anisotropy of the oscillation periods of the acoustic geometrical resonance (ν = 20 MHz) the authors determined the shape and dimensions of the small hole bands, and obtained much information on the fundamental electronic band, showing that Lomer's new model (1964) agrees better with experiment than the earlier model (1962).

An interesting communication was presented by **P. A. Bezuglyĭ, V. D. Fil',** and **O. A. Shevchenko,** who observed nonlinear effects in the absorption of ultrasound at frequencies 115, 160, and 210 MHz in superconducting indium. Thus, following lead (Love and Shaw, 1963), indium turns out to be the second superconductor in which an amplitude-dependent mechanism of ultrasound absorption by dislocations was observed.

A. G. Shepelev and **G. D. Filimonov,** investing the absorption of ultrasound in superconducting tin at low temperatures, observed large anisotropy of the energy gap. **I. O. Kulik** delivered a paper by I. M. Dmitrenko and I. K. Yanson, who observed "steps" on the voltage-current characteristic of the Josephson tunnel junctions in structures of the Sn-I-Sn type. **O. I. Kulik** presented his own theoretical calculation, confirming the hypothesis advanced by I. M. Dmitrenko and I. K. Yanson, according to which the cause of the steps is the interaction of the "traveling wave" with resonant type of electronic oscillations in the form of the dielectric gap between the superconductors.

A very interesting communication was delivered by **I. E. Dzyaloshinskiĭ,** who constructed a theory of magnetic structures in antiferromagnetic metals. The occurrence of these structures is connected with the exchange interaction of the conduction electrons with the spins of the magnetic ions, and their period is determined by the extremal dimensions of the Fermi surface. Resonance occurs here because the wavelengths agree, and not the frequencies as is usually the case. The realignment of the magnetic structure of the system caused in turn a change in the structure of the Fermi surface of the conduction electrons.

R. N. Gurzhi considered undamped second sound in a system of quasiparticles with arbitrary dispersion (in particular, in a system of phonons in a dielectric and a system of spin waves in a ferrite). For spin waves in ferrites, the propagation of second sound is connected with oscillations of the magnetic moment. In this connection, two waves of different nature arise. One recalls ordinary second sound; the second wave can be called thermomagnetic, since the energy of the thermomagnetic oscillations is of the same order in this wave.

R. N. Gurzhi and **M. I. Kaganov,** using the model of ideal Fermi gas with arbitrary dispersion, investigated the absorption of an electromagnetic wave, due to the interelectronic interaction. **Z. Uritskiĭ** and **G. Shuster** investigated resonant effects in dispersion and absorption of electromagnetic radiation in crystals.

V. I. Skidanenko and **V. A. Popov** investigated theoretically high-frequency properties of antiferromagnets.

A. Ya. Blank and **M. I. Kaganov** calculated the surface impedance of a ferromagnetic metal at frequencies close to the frequency of ferromagnetic resonance, when allowance for the spatial dispersion of the magnetic permeability is fundamental. At resonance, the field inside the metal is a standing wave.

Z. Uritskiĭ and **D. Sirota,** in calculating the magnetic susceptibility of an electron gas, took into account the interaction of the carriers with the phonons. In addition to the natural de Haas–van Alphen oscillation damping, the authors obtained resonant oscillation of the magnetic susceptibility, connected with the resonance scattering of the carriers by optical phonons. This effect is similar to the magnetophonon resonance obtained by V. A. Gurevich and Yu. Firsov.

Spin-acoustic resonance in metals at low temperatures was considered by **V. M. Kantorovich** and **I. M. Oleĭnik**. The interaction of the spin of the electron with the sound wave was either by modulation of the g-factor of the electron or by induction (alternating magnetic field, due to sound, acts on the spin). The resonance line width is determined by the frequency of the electron collisions.

M. I. Kaganov and **A. I. Semenenko** considered the influence of anisotropy of the Fermi surface on the character of the Kohn singularity in the dispersion of the phonons in a crystal. The authors have shown that the geometric locus of the singular points is, as it were, a unique "image" of the Fermi surface, and that the type of the singularity is determined by the tangency of the Fermi surface and its analog, shifted by an amount $-q_0$. Thus, still another new method is proposed for experimentally investigating the Fermi surface of conduction electrons.

At the concluding session, **N. E. Alekseevskiĭ** summarized the results of the conference. It was resolved that the 1967 All-union Conference on Physics and Technology of Low-temperatures be held in Khar'kov.

Translated by J. G. Adashko