SOVIET PHYSICS USPEKHI VOLUME 7, NUMBER 3 NOVEMBER-DECEMBER 1964

006.3:536.48

Meetings and Conferences

TENTH ALL-UNION CONFERENCE ON LOW TEMPERATURE PHYSICS

Yu. D. ANUFRIEV and A. Ya. PARSHIN

Usp. Fiz. Nauk 83, 361-369 (June, 1964)

THE regular, Tenth All-union Conference, convoked by the Scientific Council on the Problem of "Low Temperature Physics" was held in Moscow on 26—30 June 1963. Almost all organizations engaged in research in this field were represented. The total number of participants exceeded 500. Approximately 120 papers were delivered. The program of the conference covered a very wide range of questions: properties of liquid helium, superconductivity, electronic properties of metals and semiconductors, questions in cryogenic technique, and many others.

The introductory address at the first plenary session was made by Academician **P. L. Kapitza.** His lecture, touching upon general problems in the development of science in general and low-temperature physics in particular, was heard by the participants with great interest.

The present status of critical velocities in liquid helium and properties of quantum vortices were treated in a review paper by **V. P. Peshkov.** It is presently assumed that the most probable mechanism for the destruction of superfluidity is the formation of vortices. Although this assumption does not result in any rigorously defined value of the critical velocity, it is in qualitative agreement with many experimental results.

The explanation of the nature of critical velocities was the subject of a paper by **V. K. Tkachenko,** who investigated heat flow through a long capillary filled with He II. It has been found that regions of turbulent (vortical) and laminar flow can exist in the capillary for certain values of the heat flux. The turbulent region is generally speaking bounded on two sides—the side closest to the heat source (cold front) and the side closest to the cold end of the capillary (hot front). Both fronts move—the hot front moves with the heat flux and the cold front may move both with and against the heat flow. If the heat flux drops below a certain critical value, the velocity of the cold front reverses sign in such a way that the distance between fronts begins to decrease and the region of turbulent flow disappears. The velocity of the normal component corresponding to this critical flux is in good agreement with the values of the critical velocity obtained in other experiments. It has been found that at the same temperature and at the same excess over critical velocity, the front velocities are inversely proportional to the diameter of the capillary. This fact is in complete agreement with the vortical character of the turbulence. In addition, it has been observed that an appreciable influence on the occurrence of fronts is exerted by the smoothness of entry into the capillary.

The question of critical velocities was discussed also by **B. N. Esel'son, Yu. V. Kovdar', and B. G. Lazarev.** They made direct measurements of the linear flow velocity in a film of He II and found that the critical velocity in the film, at a temperature of 1.5°K, amounted to approximately 100 cm/sec. The authors presented a possible explanation for such a high value of the critical velocity. At the session on the properties of liquid helium, much attention was paid to a direct study of vortices in He II and to experiments with rotating helium. A communication by **G. A. Gamtsemlidze, Sh. A. Dzhaparidze, and Ts. M. Salukvadze** was devoted to an attempt of direct observation of coupling between vortex filaments and a solid surface. So far only preliminary results have been reported on experiments in which the angle of deflection of a torsion balance rotating together with the He II, with the balance additionally twisted by a clockwork mechanism, was measured. **E. L. Andronikashvili and L. A. Zamtaradze** have observed that the rate of flow of the helium over the film decreases with increasing rate of rotation, and reverses sign at a certain value of the angular velocity. Rotating helium is also the subject of a paper by Yu. G. Mamaladze and S. G. Matinyan. They have shown that owing to the stabilizing influence of vortex filaments the region of stability of superfluid helium is broader than that of a classical ideal liquid. This result is in quantitative agreement with the experimental data.

Two conference papers concerned the propagation of sound in helium. **A. F. Andreev and I. M. Khalatnikov** have shown that at very low temperatures, when the collisions between the thermal excitations become unimportant, the velocity of sound in He II increases with increasing temperature like $T^4 \ln(\mathrm{const}/T)$. If it is recognized that $\partial c/\partial T < 0$ at sufficiently high temperatures, this can explain the experimentally observed maximum on the velocity of sound vs. temperature curve. The absorption of sound under such conditions is proportional to $T^6\omega$, where ω is the frequency of the sound. **A. N. Shaanova** considered the reflection of zero sound from a solid wall, which turns out to be accompanied by energy dissipation due to the redistribution of the quasiparticle momenta (the reflection is assumed diffuse). The value of the reflection coefficient and its dependence on the angle of incidence of the sound wave are given.

The question of the state diagram of mixtures of the isotopes He^3 and He^4 was considered in papers by **K. N. Zinov'eva** and **N. G. Bereznyak** and **I. V. Bogoyavlenskiĭ** and **B. N. Esel'son. K. N. Zinov'eva** obtained experimental data on the stratification and solidification of He^3–He^4 solutions and constructed from them state diagrams for 0–29 atm and 0–1.7°K. In the discussion, **I. M. Lifshitz** noted that in diagrams of this type it is difficult to extrapolate to 0°K. **N. G. Bereznyak** proposed diagrams constructed on the basis of results obtained at the Ukrainian Physico-technical Institute, and also on the basis of an analysis of all the available data on this question. Although such diagrams eliminate the difficulties connected with extrapolation to 0°K, turn out to be incapable of explaining the fact that a solution of He^3 and He^4 becomes stratified at pressures $p > 25$ atm, when pure He^4 is already solid. Thus, the question of the diagram of state of He^3–He^4 mixtures calls for further study.

A paper by **É. L. Andronikashvili, R. A. Bablidze, G. V. Gudzhabidze, L. A. Zamtaradze, Dzh. S. Tsakadze**, and **G. V. Chanishvili** dealt with the influence of rotation on the λ-transition temperature in helium. Some inertial nature was observed in the vortical structure of the motion, and the dependence of the corresponding delay times on the speed of rotation and on the temperature was investigated. This delay is of purely hydrodynamic origin and is not connected with the delay in the λ transition. The absence of a shift in the λ point during rotation is in good agreement with the experiments of Bablidze, Tsakadze, and Chanishvili. **Dzh. S. Tsakadze** talked of the kinetics of formation of the meniscus on the surface of rotating helium. He observed the rate of formation of the meniscus after abruptly setting the helium to rotate and noted that the time dependence of the logarithm of the depth of meniscus was different for He II and He I, the curve being smooth in the case of He II and kinked in the case of He I. Tsakadze also presented some new quantitative data on the properties of the Andronikashvili vortex produced in rotating boiling He I.

In spite of the fact that the phenomenon of superconductivity has been known for a long time, interest in it has not abated. The greatest number of investigations is devoted to the properties of superconducting alloys, compounds, and thin films having high critical fields and high transition temperatures. Different problems connected with superconducting alloys, their properties, preparation, and use for the production of extremely strong magnetic fields were reported in a review article by **N. E. Alekseevskiĭ. N. E. Alekseevskiĭ, N. N. Mikhaĭlov, M. N. Smirnova, A. N. Fedotov** and **S. A. Khromov**, and also **Yu. F. Bychkov, I. N. Goncharov, V. I. Kuz'min**, and **I. S. Khukhareva**, investigated the influence of heat treatment on the critical parameter of superconducting alloys based on Nb and Zr. In many cases the heat treatment makes it possible to increase the critical current density and temperature of the superconducting transition. **N. V. Volkenshteĭn** and **É. V. Galoshina** measured the transition temperature of V–Sc alloys. **N. E. Alekseevskiĭ** reported an investigation of the magnetic properties of Nb alloys, and also the observation of superconductivity in many alloys and compounds, particularly nitrides of gallium and aluminum.

A review paper by **A. A. Abrikosov** and **L. P. Gor'kov** was devoted to the theory of alloys belonging to the second group of superconductors. The properties of such alloys are brought about by the fact that the surface energy of the separation boundary between the superconducting and normal phases is negative. According to the Ginzburg-Landau-Abrikosov-Gor'kov (GLAG) theory, thin normal filaments begin to form in such a superconductor in some relatively small external magnetic field. A so-called mixed state sets in, in which the average magnetic induction in the sample differs from zero, and the dc resistance remains zero as before (this state has nothing in common with the ordinary intermediate state). The filaments form a lattice structure, the period of which decreases with increasing external field. Recently many workers have shown that such filaments have a quantized magnetic moment and have properties similar to those of the Onsager-Feynman vortices in He II. Finally, at a certain value of the external field, which may be very high, the sample again acquires resistivity. The phase transition is in this case of second order, and not first as for superconductors of the first group. The GLAG theory makes it possible to calculate the critical field from the electronic characteristics of the normal metal. This theory describes well the properties of "ideal" superconductors of the second group (i.e., those without hysteresis effect).

In rigid superconductors an important role is apparently played by dislocations and other structural defects. According to the recently advanced hypothesis, the dislocation lines may retain the superconducting state in external fields that are appreciably larger than the critical field of the bulk specimen, when most of the metal is already in the normal state.

V. V. Shmidt investigated a model of such a superconductor. He considered a dielectric slab threaded longitudinally by thin superconducting filaments (the radius of the filament is much smaller than the depth of penetration of the weak magnetic field). On the edges of the slab, the filaments were electrically interconnected. The total critical current of such a slab, and its distribution over the cross section as a function of the magnetic field for different orientations, were determined. The results are in qualitative agreement with experiment.

Ferromagnetic ordering, as is well known, hinders the onset of the superconducting state in pure ferromagnets. In alloys with paramagnetic impurities, however the coexistence of superconductivity and ferromagnetism, due to ordering of the ions by their indirect exchange interaction via the conduction electrons, turns out to be possible. At low impurity concentrations, the Curie temperature and the temperature of the superconducting transition are small and equal to each other in order of magnitude. **L. P. Gor'kov** and **A. I. Rusinov** investigated the picture of this phenomenon and constructed possible types of phase diagrams.

The properties of superconducting films are not only of theoretical but of great practical interest in connection with their use in electronics (cryotrons). **N. E. Alekseevskiĭ** and **M. N. Mikheeva** investigated the temperature dependence of the critical current of thin films. At some temperature, which depends on the thickness of the film, the critical current has a maximum value. This result is made possible by the dependence of the width of the energy gap on the current density. As in earlier findings, beryllium films freshly condensed on a substrate cooled by liquid helium display superconductivity. The beryllium obtained under such conditions is in a different unstable modification and has a strongly disordered structure. Such films have very large critical fields that do not depend on the film thickness (**B. G. Lazarev, E. E. Semenenko, A. I. Sudovtsev**). Another group in Khar'khov (**I. G. Yanov, A. A. Maksakova**, and **O. N. Ovcharenko**) measured the critical fields of thin films of niobium, obtained by evaporation of the metal under high vacuum conditions, and obtained results which agreed with the theoretical calculations.

S. Ya. Berkovich and **R. A. Chentsov** attempted to account for the effect of the inhomogeneities, which are characteristic of real films, on the kinetics of the destruction of their superconductivity by means of current. They have considered films having randomly distributed sections with different critical currents and critical temperatures (the Monte Carlo method). Such a model apparently explains satisfactorily the laws governing the destruction of the superconductivity of thin films by means of current.

V. P. Galaĭko theoretically investigated electron paramagnetic resonance in a superconducting film. The intensity of the spin absorption is proportional to the static susceptibility of the electrons. The question of the influence of the film boundaries on the value of the spin moment of the electrons was also considered in connection with experiments on the Knight shift.

The properties of hollow superconductors in the magnetic field (with a wall thickness much smaller than the depth of penetration) were considered by **G. F. Zharkov** and **Hsu Lung-tao** within the framework of the Ginzburg-Landau macroscopic theory.

The tunnel effect, which makes it possible to measure directly the energy gap in superconductors, continues to attract the attention of experimenters. **N. V. Zavaritskiĭ** reported a detailed investigation, by means of this method, of the anisotropy of the gap in tin. The unique anisotropy picture (several narrow regions of strong variation of the gap) is related by the author to the band structure. The temperature dependence of the gap width was close to theoretical. No changes were observed of the relative gap anisotropy with the temperature. The energy gap in single-crystal tin was investigated also by the ultrasound absorption method (**A. G. Shepelev**). **I. M. Dmitrenko, I. K. Yanson**, and **V. M. Svistunov** investigated the properties of a three-layer superconducting film structure and the possibility of its use as a radiation detector in the near and middle infrared regions of the spectrum.

A transition to a new crystalline state, which may turn out to be superconducting, is possible in some metals under the influence of high pressure; conversely, a superconductor may turn into a normal metal. In an interesting paper, **N. B. Brandt** and **N. I. Ginzburg** indicated the possibility of the transition of Cd, under hydrostatic compression, into a non-superconducting state without a change in its crystal structure. The value of the pressure at which the energy gap in Cd is closed is calculated by the authors to be 57—70 thousand atm. An appreciable increase in the critical temperature of Zr under hydrostatic compression was observed. Two mechanisms by which pressure affects superconductivity have been considered. **B. G. Lazarev, L. S. Lazareva, T. A. Ignat'eva**, and **V. I. Makarov** investigated the influence of pressure and of non-magnetic impurities with different valencies on the temperature of the superconducting transition of Tl. **V. L. Ginzburg** made a general theoretical analysis of the influence of pressure on the width of the energy gap.

I. A. Privorotskiĭ undertook an interesting attempt to explain the nonzero Knight shift observed in some superconductors at zero temperature. It is customary to assume that the superconducting state is the result of interaction between the conduction electrons via exchange of virtual phonons. In antiferromagnets, however, a different mechanism is possible, due to electron interaction via spin waves, and this leads to the absence of an isotopic effect (ruthenium, osmium). The Cooper pairs then have a nonzero orbital angular momentum. Pair production with zero angular momentum is likewise possible in ordinary superconductors and in superfluid He^3. If the pair is produced in the triplet state, the spin paramagnetic susceptibility turns out to be independent of the temperature and equal to the susceptibility of the normal metal. The susceptibility is anisotropic in antiferromagnets. The deductions of the theory agree with the experimental data. Closely related to the work by **Privorotskiĭ** is a communication by **S. V. Vonsovskiĭ** and **M. S. Svirskiĭ**, who considered the influence of the singlet or triplet nature of the electron pairs on the state of superconductivity and who ascertained the conditions under which the formation of such pairs is energetically favored.

The external photoeffect on a superconductor was investigated theoretically by **V. V. Slezov**, who showed that the red edge of the photoeffect shifts by an amount equal to the energy gap, owing to the additional energy lost in breaking the pair. The frequency dependence of the photocurrent near this new boundary also differs from the case of a normal metal, owing to the interaction-induced redistribution of the electrons in momentum space.

The American theoretician **P. Hohenberg**, who has been working for sometime in the Soviet Union as part of the cultural exchange program between the USSR and the USA, reported on his investigation of the influence of nonmagnetic impurities on the properties of anisotropic superconductors. The impurities lead to isotropization of the electron-state density at relatively low concentrations, at which the mean free path of the electrons is of the order of the correlation radius in the superconductor. The dependence of the critical temperature, of the energy gap, and of the nuclear spin relaxation time on the impurity concentration was determined.

The behavior of very pure metals in a constant magnetic field continues to attract the interest of both theoreticians and experimenters. Recently many new interesting effects were observed in this field. **É. A. Kaner** and **V. F. Gantmakher** have investigated theoretically and experimentally two effects connected with electrons drifting deep into the surface of a metal. They have shown that a system of periodic slowly decreasing peaks of currents and field can arise in the presence of open trajectories inside the metal. Their distances to the surface are determined by the period of the reciprocal lattice and by the magnitude of the magnetic field parallel to the specimen surface. Analogous bursts occur also in a magnetic field inclined to the surface of the metal, due to the electrons situated near the elliptic limiting points on the Fermi surface. The periodicity is then determined not only by the magnitude of the magnetic field but also by the ratio of the Fermi velocity to the Larmor velocity in the vicinity of the limiting point. In the case of a plane-parallel plate, the anomalous penetration of the field inside the metal makes the surface impedance a function of the magnetic field. This phenomenon was observed experimentally with single crystals of tin.

M. Ya. Azbel' has shown theoretically that in a sufficiently strong magnetic field direct current flows in conductors essentially near the surface, in a layer of thickness on the order of the Larmor radius in a magnetic field parallel to the surface, and on the order of the electron mean free path in a perpendicular field. This leads to a linear dependence of the resistance on the magnetic field in single crystals and polycrystals, regardless of the ratio between the number of "holes" and electrons and regardless of the sharp anisotropy of the resistance. In the general case, the dependence of the resistance of thin wires and plates on the magnetic field and the anisotropy of the resistance were investigated. Comparison between experiment and theory would make it possible to estimate the quality of the sample surface, the Larmor radius, and the mean free path, to ascertain the degree to which it is meaningful to introduce the corresponding characteristic quantities, and to measure the Fermi-surface diameters. In another paper, **M. Ya. Azbel'** and **V. G. Peschanskiĭ** have established that in the case of the presence of open plane Fermi-surface sections, a linear dependence of the resistance of metallic single crystals is possible only in a field parallel to the sample surface, and is absent in the case of an inclined magnetic field. This circumstance can be used to investigate the topology of the Fermi surface.

Whereas in a weak magnetic field the electromagnetic oscillations do not penetrate deep into the metal, **É. A. Kaner** and **V. G. Skobov** have shown that in a strong magnetic field, when the cyclotron frequency is large compared with the collision frequency, weakly damped electromagnetic excitations of different types exist in metals. In metals with unequal densities of electrons and holes there are helical waves with a square spectrum. In metals with identical concentrations of carriers there are magnetohydrodynamic waves with a line spectrum. The wavelength is large compared with the Larmor radius and small compared with the carrier mean free path. In metals having one group of carriers there exist quasiparticles with a discrete spectrum, the wavelength of which is small compared with the Larmor radius. Kaner and Skobov predicted the existence of a new resonance effect in metals, connected with the excitation of quasiparticles with a discrete spectrum. When the frequencies of the external field coincide with one of the natural frequencies, a circularly-polarized weakly damped wave is produced in the metal; the surface impedance has a resonance maximum. The existence of weakly damped electromagnetic waves in metals leads to many new resonance effects in the propagation of ultrasound (**V. G. Skobov** and **É. A. Kaner**). Resonance occurs when the phase velocities of the sound and electromagnetic waves coincide. Owing to the induction interaction between the conduction electrons and the alternating fields, coupled waves are produced in the resonance region. The spectrum, attenuation, and the polarization of the coupled waves were investigated. Their excitation by an external electromagnetic field or by ultrasound was considered. The effective value of the coupling between the waves depends on the magnetic field. The attenuation and the dispersion of the ultrasound wave velocity in the region of resonance have a maximum at relatively low coupling. The damping of the ultrasound is small in this case compared with the damping of the electromagnetic wave. In stronger magnetic fields the coupling is so strong that both waves have identical damping and the distinction between acoustic and electromagnetic becomes meaningless.

F. G. Bass, A. Ya. Blank and **M. I. Kaganov** investigated theoretically the propagation of low frequency electromagnetic waves in a conducting gyrotropic medium under the conditions of normal skin effect. For a metal with closed carrier trajectories on the Fermi surface with unequal electron and hole densities it has been shown that the waves are weakly damped in a strong magnetic field. The resonance excitation of weakly damped waves in a plate was considered.

Great interest was aroused by a communication by **M. S. Khaĭkin, L. A. Fal'kovskiĭ, V. S. Édel'man,** and **R. T. Mina** concerning an investigation of recently discovered magnetoplasma waves. The existence of two types of magnetoplasma waves, which have different dispersion laws, was established. The velocity of these waves in bismuth lies in the range $(2-50) \times 10^7$ cm/sec, and their length is 0.02–0.5 mm at 9.5 Gc. The quantitative characteristics of magnetoplasma waves are related to the energy spectrum of the carriers in the bismuth.

An investigation of quantum oscillations of different thermodynamic and kinetic quantities is a powerful method of reconstituting the shape of the Fermi surface in metals. **E. P. Vol'skiĭ** investigated conductivity quantum oscillations of single-crystal bismuth and aluminum. The anisotropy of the extremal sections of the Fermi surface was thoroughly investigated by plotting the periods of the oscillations against the reciprocal of the magnetic field. **Kh. I. Amirkhanov, R. I. Bashirov, Yu. É. Zakiev, A. Yu. Mollaev,** and **Z. A. Ismailov** measured the quantum oscillations of the transverse magnetic resistivity in degenerate electronic samples of antimonides and arsenides of indium and gallium (in pulsed fields up to 400 kOe).

N. B. Brandt reported an investigation of the deHaas-van Alphen effect in Bi–Se and Bi–Te alloys. The concentration of the electrons increases and the concentration of the holes decreases with increasing concentration of Se and Te. The form of the electronic energy surface remains unchanged in first approximation as the electron density increases by 2–3 times. The anisotropy of the hole surface decreases somewhat when the hole density is analogously decreased. It is shown that the law of dispersion for the electrons and holes is not quadratic. This is manifest, in particular, in the dependence of the effective mass on the carrier concentration. The effective mass of the electrons increases with increasing electron concentration, while that of the holes decreases. The electron and hole state density, the total electron and hole density in bismuth, and the "efficiencies" of the Se and Te impurities were determined.

The anisotropy of magnetoacoustic oscillations in single-crystal specimens of gallium was investigated by **P. A. Bezuglyĭ, A. A. Galkin, A. I. Pushkin, S. G. Zhevago,** and **A. P. Korolyuk,** who observed "giant" oscillations of the absorption coefficient of sound in bismuth. The form of the oscillation curve duplicates well that theoretically predicted by Gurevich, Skobov, and Firsov. The dependence of the oscillation periods on the angle between the wave vector and the direction of the magnetic field was studied. The periods of oscillations in different crystallographic planes were measured. A comparison was made of the experimental results with the three-ellipsoid Fermi-surface model proposed by Shoenberg.

Interesting features of "poor" metals of the bismuth type were treated in a few other papers. The high "electron" and "hole" energy levels correspond in such metals to open Fermi surfaces. This governs many of their distinguishing properties (**A. A. Abrikosov**). For example, at temperatures of several hundred degrees, the expression for the number of free carriers contains a term $n_0 \exp(-U/T)$, where n_0 is approximately 100 times larger than the number of carriers at $T = 0$, while $U \sim 0.01-0.1$ eV. This fact does not influence the conductivity, since such carriers are strongly scattered by phonons, but greatly influences the dependence of the dielectric constant ϵ on the temperature in the infrared region. The large value of ϵ leads to smallness of the interaction of the electrons with each other and with phonons, making it possible to use the gas model and, in addition, explains the absence of superconductivity in metals of the bismuth type.

E. V. Potapov investigated experimentally the optical properties of crystalline bismuth and antimony, and also of Bi + 0.05% Te in the infrared region of the spectrum $(1-15\,\mu)$ at $T = 2°K$. He showed that for bismuth $\mathrm{Re}\,\epsilon = 0$ (ϵ —complex dielectric constant) at $\lambda_1 = 12.5\,\mu$, and for antimony $\mathrm{Re}\,\epsilon' = 0$ at $\lambda_1 = 3.5\,\mu$ and $\lambda_2 = 9.6\,\mu$. Comparison of the results with the Abrikosov theory of the dielectric constant of metals of the bismuth type shows that for bismuth and antimony there probably exist at λ_1 interband transitions with open Fermi surfaces. For antimony λ_2 apparently corresponds to intraband electronic transitions. The addition of 0.05% Te to the bismuth gives two wavelengths: $\lambda_1 = 8.7\,\mu$ and $\lambda_2 = 12\,\mu$, at which $\mathrm{Re}\,\epsilon' = 0$. It is assumed that λ_1 corresponds to interband and λ_2 to intraband transitions.

Experimental observation of paramagnetic resonance in bismuth and antimony discloses a strong deviation of the g-factor from 2 (by 10–100 times) and its great anisotropy. This signifies that the g-factor in metals of the bismuth type depends considerably on the quasimomentum. **L. A. Fal'kovskiĭ** has shown that this dependence is due to the spin-orbit coupling, which plays an important role in the analysis of the spectrum in the absence of a magnetic field. **M. Ya. Azbel'** and **E. K. Skrotskaya** calculated the diamagnetic susceptibility of an electron gas in very strong magnetic fields (the distance between the Landau levels is much larger than the limiting Fermi energy in the absence of a magnetic field, but, of course, is considerably smaller than the band width). The susceptibility turns out to be inversely proportional to the fourth power of the magnetic field. Such a case can be realized in semiconductors and "poor" metals of the bismuth type. The possibility of the existence of a new type of quantum oscillations in metals was reported by **M. Ya. Azbel'**. He showed that for a charged quasiparticle with periodic dispersion law the distance between the Landau level has an added term which is periodic in the reciprocal magnetic field. The transition is universal for all the conduction electrons and depends only on the direction of the magnetic field and on the parameters of the crystal lattice. This results in quantum oscillations with a period that is unrelated to the period of the ordinary deHaas–van Alphen oscillations. In another report, **M. Ya. Azbel'** indicated the possibility of observing ordinary quantum oscillations (the deHaas–van Alphen effect, the Shubnikov–deHaas effect) at temperatures that are high compared with the distances between the Landau levels, but such that the Larmor radius is of the order of or smaller than the mean free path of the electrons responsible for the oscillations. At some directions of the magnetic field, the quantum oscillations are not exponentially small, as is usually the case at such temperatures. In a magnetic field of the order of 10—100 kOe, such oscillations can apparently be observed even at room temperatures. The deHaas–van Alphen method can be used in principle to obtain low temperatures (**M. Ya. Azbel'**). Adiabatic variation of the magnetic field by an amount on the order of the period of the deHaas–van Alphen oscillations leads to a decrease in the temperature of the metal (in real conditions, by an amount on the order of several per cent). By using multiple cyclic remagnetization, it is apparently possible to attain an appreciable decrease in temperature.

Still another theoretical paper (**G. A. Gogadze**, **F. Yu. Itskovich**, and **I. O. Kulik**) was devoted to quantum oscillations of the cold-emission current of metals in a magnetic field. The existence is shown, first, of oscillations of the deHaas-van Alphen type and, second, of oscillations connected with oscillations of the chemical potential. The amplitude of the oscillations of the second type is sufficiently high, whereas the oscillations of the first type can be observed only for electron groups with low Fermi energy. Oscillations of the current of tunnel emission between two metals on the contact surface were also investigated.

Two papers reported investigations of the Fermi surface by the cyclotron resonance method. The anisotropy of the effective masses of electrons in zinc (**V. P. Naberezhnykh** and **V. L. Mel'nik**) and in aluminum (**V. P. Naberezhnykh**, **V. L. Mel'nik**, **I. M. Glazman**, **A. I. Kononenko**) was investigated. The experimental results are in good qualitative agreement with the model of the Fermi surface of almost free electrons. **V. G. Peschanskiĭ** and **D. S. Lekhtsier** investigated theoretically the possibility of observing cyclotron resonance in a metal in an inclined magnetic field. They have found that for selected magnetic field directions, at which the Fermi surface has open periodic sections, the amplitude of the resonant variations of the impedance has the same order of magnitude as the amplitude of the resonance in a field parallel to the surface for electrons with non-quadratic dispersion.

As before, much attention is paid to studies of galvanomagnetic properties of metals. The galvanomagnetic properties of Re and Be are discussed in the paper by **N. E. Alekseevskiĭ** and **V. S. Egorov**. It was observed that new open directions appear in such metals in sufficiently strong fields (20 kOe for Re and 50 kOe for Be). This phenomenon is related to the possibility of "magnetic breakdown." The galvanomagnetic properties of Pd were investigated by **N. E. Alekseevskiĭ**, **G. É. Karstens**, and **V. V. Mozhaev**. They have demonstrated on the basis of stereographic projection, data on the Hall emf, and the current diagram that the hole part of the Fermi surface of Pd has open directions parallel to the fourfold axes. Some details of the construction of the Fermi surface are presented. It was noted that, unlike pure Pd samples ($R_{300°K}/R_{4.2°K} = 2000$), a break is observed on the curve of the Hall emf vs. magnetic field for samples having $R_{300°K}/R_{4.2°K} = 300$. A maximum of the $(\Delta\rho/\rho)(H)$ dependence was observed, and also a maximum of the magnetic susceptibility as a function of the temperature at 80°K.

The effect of pressure on the galvanomagnetic properties of Zn and Cd was investigated by **Yu. P. Gaĭdukov** and **E. S. Itskevich**. Results were reported of investigations of the electric resistivity of Zn and Cd in a magnetic field of 8700 Oe at pressures up to 8000 kg/cm^2. The results are used to estimate the changes induced by hydrostatic compression in the Fermi surface of zinc. It is assumed that at 30,000 kg/cm^2 the open cross sections in the (0001) plane disappear from the Fermi surface of zinc.

B. S. Borisov, **N. V. Volkenshteĭn**, **P. S. Zyryanov**, and **G. G. Taluts** investigated the current-voltage characteristics of bismuth in a magnetic field at helium temperatures. The paper presents a possible interpretation of the obtained results. **I. O. Kulik** investigated the dependence of the velocity of sound in a metal on the magnetic field and on the frequency of the sound. The free-electron model was used in the calculations. **K. B. Vlasov** and **B. N. Filippov** considered the possible rotation of the plane of polarization of ultrasound in magnetically-polarized metals. The magnetic field is assumed to be sufficiently strong, so that the radius of the cyclotron orbit is smaller than the mean free path of the electron or the length of the ultrasound wave. It turns out that in one region of frequency and magnetic-field variation the rotation of the plane of polarization of ultrasound is expressed in terms of the Hall constant, while in another region it is expressed in terms of the deformation potential.

A paper by **I. M. Lifshitz** was devoted to an explanation of the structure of the energy spectrum of impurity bands in unordered solid solutions. In condensed structures without spatial periodicity the energy spectrum of the impurity bands differs greatly from the corresponding spectrum in a periodic system. The paper reports on the behavior of the spectral density near the singular points and on a determination of the exact form of the concentration broadening of the levels in limiting cases. Another paper by **I. M. Lifshitz**, with **M. I. Kaganov**, considers the absorption of the electromagnetic field by a metal (it is assumed that $\omega\tau \gg 1$, where τ —electron relaxation time). The authors show that thresholdless absorption should be observed if the band is overlapped. At sufficiently low frequencies, the absorption coefficient is $\Gamma \sim \omega^3$. For graphite this law goes over with increasing frequency into a quadratic dependence ($\Gamma \sim \omega^2$).

V. G. Lazarev, **A. I. Sudovtsev**, and **F. Yu. Aliev** have determined by direct measurements the electronic component of the thermal expansion coefficient for iron and nickel. It turned out to be $(3.2 \pm 0.3) \times 10^{-9}$ T for iron and $(5 \pm 1) \times 10^{-9}$ T deg^{-1} for nickel. No ferromagnetic part was observed in the coefficient of expansion of iron and nickel, within the accuracy of measurement (10^{-9}).

R. N. Gurzhi has shown that, at sufficiently low temperatures, interelectron collisions that are not accompanied by umklapp (as well as collisions with phonons and spin waves) can greatly change the electric conductivity; in particular, they can lead to a temperature minimum of resistivity.

B. I. Verkin, **L. B. Kuzmicheva**, and **I. V. Svechkarev** investigated some electronic properties of indium alloys. A tentative estimate of the effective masses of the filled states suggests that they are responsible for the anomalous diamagnetism of certain alloys. When the contribution of these states is taken into account, the susceptibility of the alloys is in qualitative agreement with the form of the spectrum obtained with the free electron model.

A. I. Belyaeva, **V. V. Eremenko**, and **A. I. Zvyagin** investigated the absorption spectra of antiferromagnets. They investigated optical ($0.3-1\,\mu$) and infrared ($1-20\,\mu$) absorption spectra of the crystals MnF_2, $MnCO_3$ and CoF_2 in a wide range of temperatures, from 4.2 to 290°K. It is interesting that a sharp narrowing of the absorption band is observed after cooling below the Néel point. **L. S. Lukoshkin** described a method for determining some characteristics of the lattice and of the local center in a nonmetallic crystal from the forms of the light-absorption bands. Inasmuch as phonon processes of all orders are taken into account, the coupling between the optical electrons of the centers with the lattice can be arbitrary. By using this method one can calculate the phonon spectrum from the shape of the Mössbauer-line wings. A paper by **B. L. Timan** dealt with the question of absorption of the high frequency transverse sound in dielectrics at low temperatures. He calculated the probability of absorption of ultrasound in a wide range of temperatures under the condition that $\omega\tau \gg 1$.

Yu. G. Litvinenko, **V. V. Eremenko**, and **Yu. A. Popkov**, cooling MnF_2 crystals below the Néel point, investigated the influence of strong magnetic fields (up to 200 kOe) on the absorption structure in the region of the $^6S_{5/2} \rightarrow {}^4G_{3/2}$ transition for different field orientations. Another paper by the same authors dealt with the Zeeman effect of cadmium sulfide crystals. The effect of pulsed fields up to 200 kOe on the first exciton absorption band, which has a doublet structure, was investigated. The temperature at which the experiments were made was 20°K. A paper by **Yu. A. Bratshevskiĭ**, **A. A. Galkin**, and **Yu. G. Litvinenko**, dealing with resonant absorption in InSb by band carriers, was heard with interest. At temperatures of liquid oxygen, the authors observed four new absorption lines at 7600 Mc. They observed in addition at liquid-nitrogen temperature a fifth line, apparently connected with spin transitions. The temperature dependence of the width of this line was determined. The study of the acousto-electric effect in semiconductors was the subject of a paper by **S. V. Gantsevich** and **V. L. Gurevich**. A traveling sound wave propagating in a semiconductor produces in it a constant emf. This effect turns out to be relatively large in semiconductors with many energy minima, such as n-type germanium and silicon. At not too high frequencies, the resultant emf is proportional to the relaxation time τ for the electronic transitions between different energy minima. It is shown in the paper that τ, together with the value of the acousto-electric effect, can greatly depend on the external magnetic field. It is noted that a study of this effect makes it possible to investigate different mechanisms of scattering in semiconductors with many energy minima. Two papers by **R. N. Gurzhi** concerned transport phenomena in solids. In the first paper "On the Influence of Anharmonisms of Higher Order on Transport Processes in Solids" it is shown that at sufficiently low temperatures the transport process can be determined by anharmonisms of arbitrarily high order. To this end it is necessary that the energy of the quasiparticles have a faster-than-linear variation with the quasimomentum. A specific calculation is given for the ferrite thermal conductivity connected with the spin waves. In the second paper it is shown that although collisions unaccompanied by umklapp between quasiparticles (phonons, spin waves) do not in themselves lead to an additional thermal resistance, they hinder greatly the momentum transfer from the quasiparticle gas to the boundaries in sufficiently large and pure specimens. Therefore at low temperatures, when collisions with umklapp have a low probability, a noticeable change takes place in the coefficient of thermal conductivity and in its dependence on the temperature and on the specimen dimensions.

A. V. Voronel', V. A. Popov, V. G. Simkin, Yu. R. Chashkin, and **V. G. Snigirev** measured the specific heat of oxygen and argon near the critical point. It follows from the results that the thermodynamic potential has a logarithmic singularity near the critical point. This makes necessary a review of the earlier theory. **M. Ya. Azbel', A. V. Voronel',** and **M. Sh. Giterman** proposed for the critical point a theory in which the initial premises are the experimental data of the preceding work.

K. K. Rebane, V. V. Khizhnyakov, and **E. D. Trifonov** reported a theoretical investigation of the vibrational structure of electron-vibrational bands. Many interesting results were obtained. The authors have shown, for example, that the electron-vibrational spectrum has at the energy of the purely electronic transition a δ-like singularity—the analog of the Mössbauer line. The temperature behavior of the electron-vibrational spectra of impurity molecules in a molecular crystal (the Shpol'skiĭ effect) was investigated. In addition, the authors established a very deep analogy between the Shpol'skiĭ effect and the Mössbauer effect: the formulas of the Mössbauer effect can be obtained from the corresponding formulas of the theory of electron-vibrational spectra, if one replaces in the latter the "Stokes losses" by the recoil energy. Therefore the Mössbauer effect can be regarded as a problem involving "Stokes losses" in momentum space.

A. V. Leont'eva, A. I. Prokhvatilov, and **V. V. Pustovalov** made a study of the temperature dependence of the hardness of polycrystalline methane and ammonia. The region in which the hardness does not depend on the temperature was determined. Neutron diffraction patterns of solid oxygen were discussed by **R. A. Alikhanov.** He compared the nuclear structure of the oxygen modifications with the structures previously proposed. In addition, some assumptions were made concerning the magnetic structure of oxygen.

A special session was devoted to cryogenic techniques. Great interest was aroused by the paper of **B. I. Danilov** on the possibility of gas lubrication of a helium compressor piston. Under some conditions the piston can move in the cylinder without touching the walls, since the hydrodynamic force exerted by the gas in the gap prevents the contact. The paper gives the results of an experimental determination of this force. Several papers were devoted to hydrogen liquifiers, compressors and vacuum installations, and also devices used in bubble chambers. A paper by **M. P. Orlova, D. N. Astrov,** and **L. A. Medvedeva** dealt with the establishment of a thermodynamic temperature scale in the 4.2—10°K range. The primary instrument used was a gas helium thermometer without dead space. The accuracy with which the temperature was measured with it was 0.01°C. The secondary instruments are resistance thermometers made of single-crystal antimony-doped germanium, which were developed by VNIIFTRI (All-union Research Inst. of Physico-technical and Radio Instruments) in conjunction with GIREDMET (State Rare Metals Institute). The sensitivity of these thermometers is 0.0001°K, and the stability over a half year is not worse than 0.001°K. An international comparison of temperature scales was dealt with in a paper by **D. I. Sharevskaya, D. N. Astrov,** and **M. P. Orlova.** The comparison was made at the National Physics Laboratory (England) and at VNIIFTRI. It was established that the discrepancy in electrical measurements made in different laboratories does not exceed 0.002°K in temperature equivalent. The discrepancy between the thermodynamic temperatures, according to data from different laboratories, does not exceed 0.01°K in the 20—90°K range.

In the concluding plenary session, representatives of individual sections presented reviews of the most interesting communications. The chairman of the Scientific Council of the Problem of "Low Temperature Physics," Corresponding member of the USSR Academy of Sciences **N. E. Alekseevskiĭ,** summarized the result of the conference in his concluding address.

Translated by J. G. Adashko