and N – is the total number of registered neutrons. The numbering of points corresponds to the labeling in Fig. 2. In the table are also given the probable statistical errors. In the last column of the table is given the smallest displacement of the neutron beam which could be detected in this experiment.

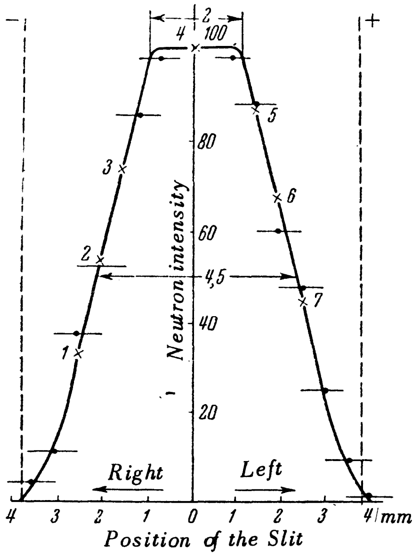

FIG. 2. Dependence of the intensity of neutrons on the position of the exit slit on the axis perpendicular to the neutron beam and parallel to the electric field intensity.

As is seen from the table, the effect does not exceed the experimental errors. In other words,

Number of the point	Relative effect $\Delta N/N$ in %	The smallest detectable displacement of the beam in mm
1	+0.3±1,0	0,03
2	–0,2±0,5	0,02
3	–0,8±0,8	0,05
4	–0,8±0,7	1,00
5	–0,6±0,5	0,05
6	–0.8±0,7	0,05
7	–0,55±0,4	0,02

the displacement of the beam under the influence of the electric field was not detected. This means that the displacment of the neutron beam was less than 0,02 mm. Considering this fact and Eq. (2), we obtain the following value for the upper bound of the neutron charge.

$$q < 6\times 10^{-12}.$$

In conclusion we express our thanks to I. M. Frank for the discussion of the present work and to V. P. Kudriashov who helped us during the conduction of the experiment.

*Based on the angular anisotropy of the scattering of thermal neutrons from venom atoms, Feld[3] gives, without deduction, the estimate $q < 10^{-18}$ e. It is not completely clear, however, how this number was obtained.

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Transformation of the λ-Transition in Helium to a Special Transition of the First Kind in the Presence of a Heat Flow

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IT is known that the λ-transition in liquid helium, as well as the transition to a superconducting state in the absence of a field, are typical examples of transitions of the second kind, that is, occurrences without release of heat and without change in volume. However, the superconducting transition in the presence of a magnetic field, and, consequently, of superconducting surface currents, changes from a transition of the second kind to a transition of the first kind, that is, it takes place with absorption or release of heat. Although the temperature of the transition from a superfluid to a normal state in liquid helium is lowered at increased pressure, the λ-transition remains a transition of the second kind, and it was assumed in the past that it is impossible by any changes in parameters to convert it to a transition of the first kind. We succeeded in observing a transformation, by means of a heat flow, of the λ-transition in helium to a transition of the first kind. The observation was made on an apparatus (which will be later described in more detail), consisting of a chamber of bow-shaped glass 3 mm thick and two plane parallel glasses, closed by platinum foil. A heater was located in the base of the bow, which produced a heat flow in the direction of the foil. Helium was introduced inside the chamber through a capillary, sealed to the base of the bow. Interference bands of equal width were observed in light from a low pressure Hg. lamp. The space in the chamber was shaped as a small wedge: 13 bands could be put within 12 mm. The chamber was placed in a Dewar flask with liquid helium, held at a temperature below the λ-point: inside it, however, there was no liquid helium at atmospheric pressure. When some noticeable power was released in the heater, the temperature inside the chamber increased, because some temperature jumps were produced at the boundary line between the foil and the liquid He II. When the temperature corresponding to the λ-transition was reached inside the chamber, a visible boundary line appeared in it, which moved from the heater to the cold end with increasing power or with an increase in the temperature of the outer bath. Fig. 1 shows a series of

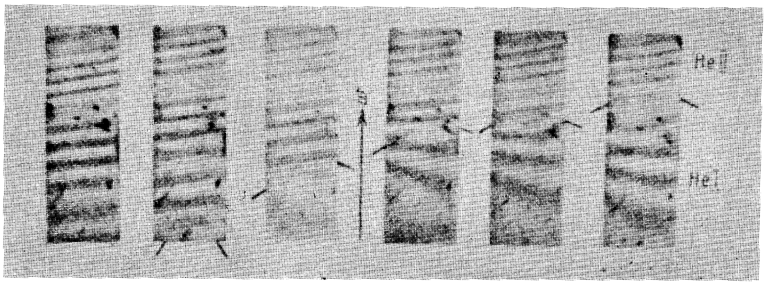

FIG. 1. The displacement of the boundary line between He I and He II with the increase of heat flow density

photographs, in the first of which the boundary line has not yet appeared, and in the following, the boundary, marked by a small line, is found in places progressively closer to the platinum foil. A visible boundary line signifies that in the presence of a heat flow between He I and He II in a λ-transition there is a jump in density, that is the transition under those circumstances is found to be a transition of the first kind. With a decrease in the magnitude of the heat flow the jump in density decreases, the boundary line becomes less and less discernable and finally it becomes invisible. One can determine from the gradual displacement of interference bands the dependence of the magnitude of the density jump on the value of heat flow.

Raising the temperature of the outer bath and simultaneously decreasing the heat flow, so as to make the boundary remain in the same place, no displacement (within an error of a 1/4 band) is observed in the He II region in the interval of heat flow density change from 0.16 W/cm^2 to 0. This indicates that the density of He II is changed by less than 0.1 %; consequently the displacement of the λ-transition in presence of a heat flow of 0.16 W/cm^2 is smaller than 0.03°. But in the He I region, as the heat flow was decreased, there was a gradual shift of interference bands in the direction of the boundary and a decrease in their separation, which corresponded to an increase in density and a decrease in the temperature gradient. With a change in the density of flow of 0.16 to 0.04 W/cm^2, the picture at the boundary line was displaced by 2.5 bands. The dependence of the magnitude of the density jump on the value of heat flow can be determined from the displacement of interference bands.

The results of the experiment are shown in Fig. 2. It can be seen that the jump in density is proportional to the square of the heat flow, and that for 0.16 W/cm^2 the density of He I is smaller at the boundary than the density of He II by 1.3×10^{-3} gr/cm^3 or approximately by 1%, which corresponds to a rise in temperature of 0.3°. The lower curve in Fig. 2 corresponds to the jump in temperature calculated from the density. Therefore, in presence of a heat flow through the boundary line, the equilibrium between He I and He II is established

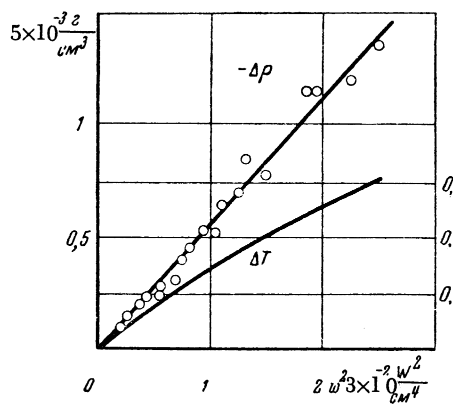

FIG. 2. The dependence of the density jump (upper curve, left scale) at the boundary between He I and He II, and the temperature (lower curve, right scale) on the square of the heat flow density.

with a jump in density and temperature. To estimate the jump in temperature more precisely, the dependence of the density change of He^4 on temperature was taken at a pressure of 1 atm. (fig. 3). The density was determined from the passage of interference bands in the same apparatus. On the X-axis is shown, instead of temperature, the helium vapor movement in the bath, because in this presentation

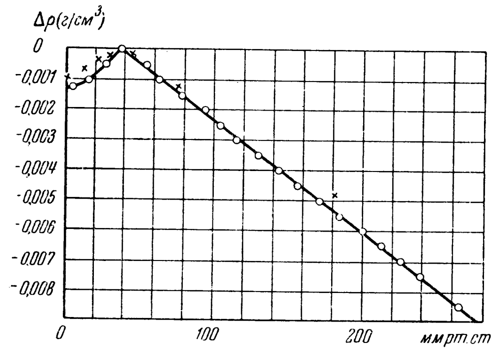

FIG. 3. The change in the density of liquid helium under 1 atm. pressure as a function of temperature, expressed in helium vapor pressures in the bath. o — present measurement data, × — data by Keesom [Physica 1 128 (1933)]

the density of He I changes linearly in a large interval. Inasmuch as, for transitions of the second kind, the equality at the boundary line of temperatures and pressures, and also entropies and densities is characteristic, whereas in a transition of the first kind, the temperatures and pressures are equal and jumps occur in the entropy and the density, the transition of He I to He II and back, in presence of a heat flow, should be called either a special transition of the first kind, or a transition of zero order, since here at the boundary line not only the values of entropies and volumes, but also those of temperatures and probably pressures suffer a break. The presence of a temperature jump between two phases of liquid helium does not have direct analogy and it can be explained by a change in the mechanism of heat transfer at the boundary. If in He I one can speak of a thermal movement of strongly bonded but still separate helium atoms, the heat flow in He II is effected by a quantum movement of thermal excitations of photons and rotons. It is obvious that the interaction between these types of heat transfer is accomplished with difficulty, which causes the jump in temperature.

The experiments to study the described phenomena are continuing.

In conclusion I express my gratitude to N. I. Kondrat'ev, who built the apparatus, and also to A. I. Filimonov and I. A. Uriutov, who helped with the measurements.

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Relativistically Invariant Formulation of Electrodynamics without Longitudinal and Scalar Fields

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IT was shown [1] that the generalized Coulomb field of charges can already be excluded in a relativistically invariant way in classical electrodynamics, a fact which facilitates the transition to the quantum theory. However, the problem of formulation of quantum electrodynamics in the Heisenberg representation and the transition to the interaction representation has only been superficially raised and needs a more exact treatment. In the present note, it will be shown that the formulation of quantum electrodynamics in the Heisenberg representation can be obtained from the variational principle

$$\delta \int L d\omega = 0, \qquad (1)$$