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CONCERNING CERTAIN FEATURES OF THE STATIONARY JOSEPHSON EFFECT

A. A. Galkin, B. U. Borodai, V. M. Svistunov, and V. N. Tarasenko
Donets Physico-technical Institute, Ukrainian Academy of Sciences
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In discussions of the effect of superconductivity, Anderson [1] and Josephson [2] pointed out the role of fluctuations in superconducting tunneling. A distinct observation of the Josephson effects [3] is possible only in the case when the binding energy of the system is sufficiently large compared with the energies of thermal and other fluctuations. Vant-Hull and Mercereau [4] presented proof for the induced phase coherence. As shown by Larkin and Ovchinnikov [5], dissipative fluctuations introduced from an external circuit lead to the appearance of a finite band of frequencies radiated in the Josephson manner. Recently Ivanchenko and Zil'berman [6] considered the influence of thermal fluctuations on the Josephson direct current and have shown that a finite voltage appears on the barrier even in the region of currents where a superconducting tunnel current would be observed at $V = 0$ in the absence of fluctuations.

We report in this paper preliminary experimental results on the investigation of the stationary Josephson effect, which apparently offer evidence of the influence of fluctuations on the superconducting tunneling.

The object of the investigations were high-resistance (0.05 - 0.1 ohm-mm^2) Pb-I-Pb tunnel junctions with film thickness $\sim$ 1300 Å. For all the samples, the width of the junction was small compared with the double the Josephson depth of penetration ($2\lambda_j > W$), i.e., the distribution of the magnetic field and of the current over the sample was homogeneous. The maximum value of the observed superconducting current was 6 - 20% of theoretical. We investigated the behavior of the critical Josephson current in magnetic fields. Unlike the low-resistance samples ($\sim$ 0.01 ohm-mm^2), two types of dependences were clearly observed.

1. In certain fields, the superconducting "direct" current flows at a finite voltage across the barrier, retaining the periodic dependence on the field (Fig. 1).

2. The Josephson current exhibits no oscillatory dependence on the magnetic field (Fig. 2).

The first phenomenon is observed in all the investigated samples, and the second one is observed less frequently, with a greater probability in junctions that have higher resistance and are broad, but not larger than $2\lambda_j$.

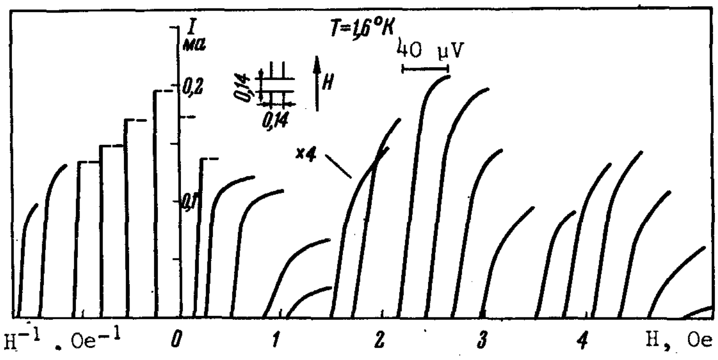

Fig. 1. Initial sections of I-V characteristics as functions of the magnetic field. The current scale is magnified four times for all curves starting with 1.5 Oe.

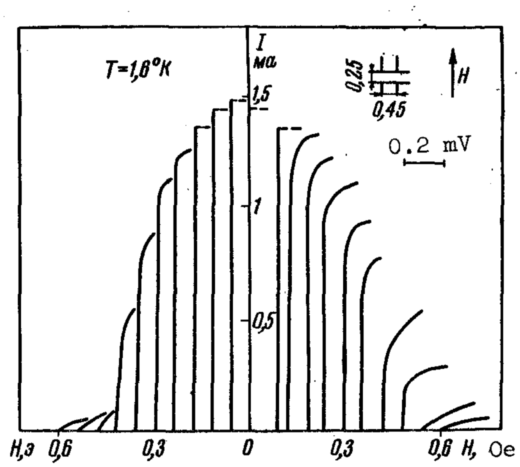

Fig. 2. Magnetic dependence of initial sections of I-V characteristics, demonstrating the behavior of the Josephson current.

According to the theoretical model [6], the finite slopes of the characteristics of the "direct" Josephson current are a result of the transition of the system from one metastable state to another under the influence of thermal fluctuations, leading to a time dependence of the phase, and consequently to a voltage. Qualitatively, the experimental results agree with the theoretical analysis. However, a quantitative comparison is still difficult. First, we do not know the value of θ, which is a certain effective temperature of the sample, and second, a finite slope is observed for all samples only in the presence of the magnetic field (this complicates the calculation). We note that in the case of low-resistance junctions in stronger magnetic fields (~10 Oe) a smooth transition to a step, connected with the occurrence of the high-frequency current, is also observed [7].

The second effect has not yet been explained theoretically, although the first report of an anomalous dependence of the tunnel superconducting current dates back to 1965 [1)] [8]. The behavior of the Josephson current is governed by the relative quantum phase. If the binding energy is sufficient to stabilize the phase difference, then superconducting current will flow through the barrier. It is reasonable to assume that the anomalous behavior of the Josephson current in a magnetic field reflects a violation of the phase coherence in weakly-bound superconducting systems. By introducing a controlled noise source (besides the magnetic field) it is apparently possible to observe both types of magnetic dependence of the current in one sample.

In conclusion, we thank A. P. Komar for an interesting discussion of the problem, Yu. M. Ivanchenko and L. A. Zil'berman for the opportunity to read their paper prior to publication and useful discussions, and E. M. Malinenko for help with the experiments.

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1) A non-oscillating dependence of the Josephson current in Sn-I-Sn samples with film thickness 500 Å was reported by A. A. Galkin, Yu. M. Ivanchenko, and V. M. Svistunov at the first session of the Donets Scientific Center, in December 1966.

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MEASUREMENT OF NATURAL LINE WIDTH OF THE EMISSION OF A GAS LASER WITH COUPLED MODES

Yu. P. Egorov
Siberian Physico-technical Research Institute, Tomsk
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Many recent investigations are devoted to theoretical and experimental studies of fluctuations in gas lasers. Investigation of the frequency fluctuations makes it possible to determine the natural laser line width due to spontaneous emission.

The natural emission line width is usually measured by obtaining beats from two independent lasers, after which one measures the spectral density S_ν of the beat-frequency fluctuations. A typical plot of $S_\nu(f)$ for this case is shown in Fig. 1 (curve 1). The value of S_ν connected with the natural emission line width does not depend on the observation frequency [1], and the rise at low frequencies is due to the line broadening resulting from technical causes: instability of the cavity dimensions, fluctuations of the pressure and temperature of the air, etc. By measuring S_ν in a region where it is no longer dependent on the frequency, it is possible to determine the natural laser-emission line width, which is π times larger than S_ν. This method, which is used in [2], has made it possible to measure the natural radiation line width, the minimum value of which turns out to be 0.06 Hz in this experiment. Measurement of the line width by this method leads to difficulties connected with the need for obtaining a single-frequency regime, exact alignment of the wave fronts of the emissions of both lasers at the photodetector, and stabilization of the frequency difference between the two lasers; all this calls for the use of a complicated automatic-tuning system.

A method free of the foregoing shortcomings is one based on measurement of the line width of the intermode beats of one laser. However, its use in [3] did not lead to measurement of the natural line width of the radiation, owing to the beat instability caused by various external and internal factors. To eliminate this shortcoming, we used in the present investigation synchronization between longitudinal

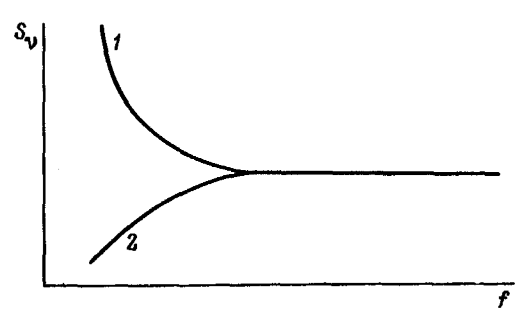

Fig. 1