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* The results of an investigation of Bi-Sb alloys at concentrations from 0 to 5 at.% Sb will be published in the very near future.

INFLUENCE OF MAGNETIC FIELD ON THE THRESHOLD ABSORPTION OF JOSEPHSON RADIATION IN Sn-Pb TUNNEL JUNCTIONS *

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An investigation of the behavior of the maxima of the dV/dI characteristics of Josephson tunnel junctions [1-3] as a function of the magnetic field provides an answer to the question whether the observed structure of the dV/dI characteristics is due to Josephson electromagnetic radiation [1,3] or whether it is connected with many-particle tunneling processes [4]. In the former case a strong field dependence is expected, whereas the many-particle tunnel current is practically independent of the field. It was observed in [1] that in magnetic fields ~100 Oe the fine structure of the dV/dI characteristics of Sn-Pb junctions vanishes gradually, and Rochlin [3] observed no field dependence for Pb-Pb junctions.

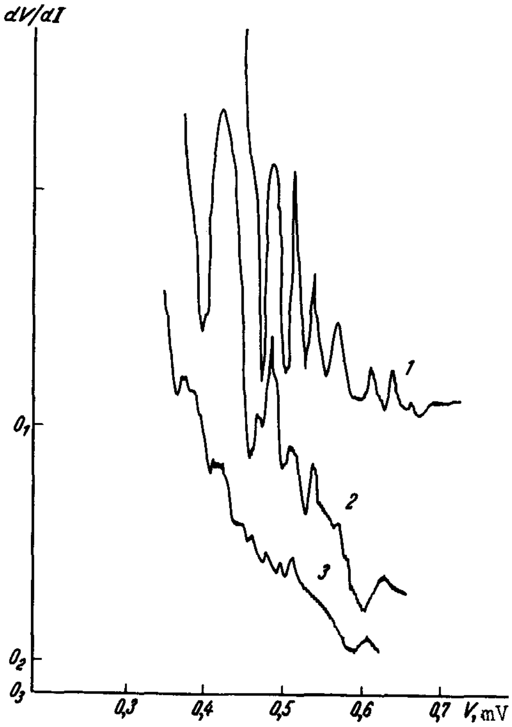

Fig. 1. dV/dI characteristics of Sn-Pb tunnel junctions at T = 1.7°K. 1) H = 21 Oe, 2) H = 52.5 Oe, 3) H = 84 Oe. The null point of the abscissa axis is shifted to the left. The null point of the ordinate axis is different for the different curves and is tagged with an appropriate number. The amplitude of the alternating modulating voltage V across the junction does not exceed 3 μV.

We present in this communication the results of a detailed investigation of the dependence of the **intensity of the minima of the group** Δ_{Sn} (see [1]) on a constant magnetic field parallel to the plane of the junction for two different Sn-Pb tunnel junctions. Figure 1 shows dV/dI characteristics plotted at different values of the magnetic field. It is clearly seen that the fine structure of the dV/dI characteristics near $\overline{\Delta}_{Sn} = 0.6$ meV vanishes gradually with increasing magnetic field, whereas the positions of the maxima on the V axis are practically independent of the field. It should be noted that the investigated junctions had very low resistivity ($\rho < 10^{-4}$ ohm-mm^2) and had a sufficiently homogeneous dielectric layer. The homogeneity of the oxide is apparently a necessary condition for the observation of a strong interaction between the electromagnetic wave of the Josephson radiation and the paired electrons in superconductors. Inhomogeneity of the oxide layer leads to the occurrence of generation in individual spots of the junction, which act like point contacts in this case [5]. In the case of a homogeneous dielectric layer between the superconductors comprising the tunnel junction, the dependence of the Josephson current density on the coordinates and on the time is given by

$$j_s = j_0 \sin(\omega t - qz), \text{where } \omega = 2eV/\hbar, \quad q = 4e\lambda_L H_0/\hbar c \ .$$

It is reasonable to assume that in sufficiently strong fields H_0 the electromagnetic-field wave excited by the Josephson current moves in the same direction and at the same velocity as the current-density wave. By the same token, we are afforded an opportunity to vary independently the energy, magnitude, and wave-vector direction of the photons of the Josephson radiation by varying the dc voltage and the magnitude and direction of the constant magnetic field applied to the junction.

As a measure of the intensity of the minimum we can choose the quantity $I = (V_2 - V_1)(1 - \tilde{V}_{min}/\tilde{V}_0)$, which is proportional to the area S of the rectangle whose construction is clear from Fig. 2. The proportionality coefficient ensures that I is independent of the modulating current signal. The main error lies in the determination of $\tilde{V}_0$ (the value of the derivative in the absence of the given minimum), which is frequently quite difficult to determine from the characteristics. This is precisely why a large scatter of the points is observed and it is impossible to draw any smooth curves through them.

Figure 3 shows the measured intensities of the fine-structure minima of the dV/dI characteristics near Δ_{Sn} as the magnetic field is varied from 10 to 100 Oe. The intensities of of all the minima decrease with increasing field. The only exceptions are the minima at V = 0.6 mV for the first junction and V = 0.63 mV for the second, whose intensities are practically independent of the field. These minima apparently represent an average gap in the tin films and are due to the usual two-particle tunnel current, which does not depend on the field. What is surprising is the different value of the average gap for the investigated films, although both have almost the same T_c (4.06 and 4.08°K, respectively). Greatest interest attaches to the following peculiarities that are seen from Fig. 3: 1. The field dependence of the intensities of the minima obviously does not satisfy the $1/H^2$ law, as is the case for the dc component of the Josephson current, and the same holds consequently for the electromagnetic power generated in the junction [1]. 2. The minima at large threshold voltages vanish in weaker magnetic fields, whereas the minima at V = 0.51 and 0.465 mV retain a noticeable magnitude in the entire field interval. 3. It can apparently be assumed that each V has its own characteristic H_{max}, above which the absorption of the radiation at a given frequency decreases.

This unexpected effect can apparently be related to the existence of one unique threshold in anisotropic superconductors - a threshold dependent on the magnitude of the photon wave vector q [6]. If the cosine of the angle θ_0 between the direction of the wave vector and the direction to the minimum of the energy gap corresponding to the given threshold exceeds $\sqrt{\eta/a}$, where a is a coefficient characterizing the shape of the surface $\Delta(p)$

near the minimum and $\eta = (\omega - \omega_0)/\omega_0$ is the relative frequency deviation from the threshold value ω_0, then, in accordance with [6], the photons whose wave vector is larger than

$$q_{max} = \frac{1}{\xi_0} \sqrt{a\eta/(a\cos^2\theta_0 - \eta)}$$

will not be absorbed. For a polycrystalline film this means that some of the crystallites will not take part in the absorption of the radiation when the magnetic field is increased, and with it the wave vector of the electromagnetic wave. Since q_{max} is comparable in order of magnitude with $1/\xi_0$, this effect will occur whenever the phase velocity of the electromagnetic wave becomes comparable with the Fermi electron velocity, as is indeed observed in the experiment.

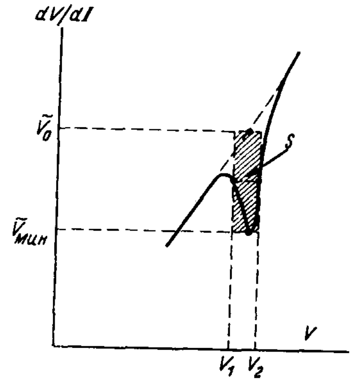

Fig. 2. Construction of the area S proportional to the intensity of the minimum. Base of triangle is the width of the minimum at the level $(\tilde{V}_0 + \tilde{V}_{min})/2$.

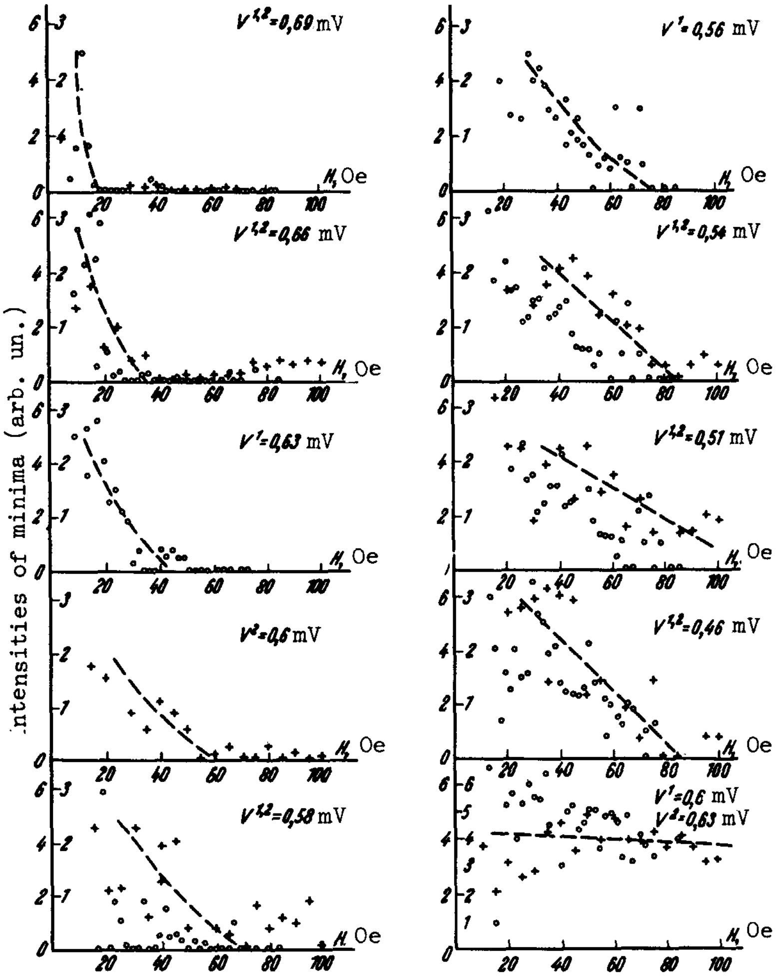

Fig. 3. Intensity of the minima vs. magnetic field for two Sn-Pb junctions. The circles, the voltage minima denoted V^1, and the left-side ordinate scale pertain to the first junction. The remaining data pertain to the second junction. The voltage minima $V^{1,2}$ pertain to both junctions. T = 1.7°K.

It is obvious that investigations with single crystals are essential for a final confirmation of the advanced hypotheses. We can state even now, however, that a new method exists for the investigation of anisotropic superconductors, namely the method of the Josephson tunnel effect. Of greatest interest is the possibility of independently controlling the frequency and the wave vector of the photons, as indicated by the observed unique dependence of the intensities of the minima on the magnetic field.

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GAS LASER FREQUENCY FLUCTUATIONS

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Equations for the spectral densities of the natural intensity and frequency fluctuations of the emission of a continuously-operating single-mode laser were derived in [1]. An experimental verification of the intensity fluctuation was performed earlier [2]. We report here the result of an experimental investigation of the frequency fluctuations of a helium-neon laser at wavelength 0.62 μ and the determination of the natural width of its spectral emission line.

According to the theory [1], the fluctuations of the frequency ν of a laser whose cavity is tuned to the center of the active-medium transition has an approximate spectral density

$$w_\nu = \frac{(\Delta\nu)^2 h\nu}{P} \alpha\tilde{\beta}\frac{\kappa^\circ{}_2}{\kappa^\circ{}_2} \ (\mathrm{Hz}^2/\mathrm{Hz}) \qquad (1)$$

where $\Delta\nu$ is the resonator bandwidth and P the power generated by the active medium. It follows from the earlier experiments [2] that for our purpose we can assume $\alpha\tilde{\beta}\kappa_2^0/\kappa_2 \simeq 2$.

If we put by way of an example in (1) P = 1 mW and $\Delta\nu$ = 6 MHz, we get $w_\nu \simeq 0.02$ Hz^2/Hz. The natural emission line width is π times larger, i.e., ≃ 0.06 Hz in our example. It is well known that the real (technical) instability of a laser frequency is larger than this quantity by many orders of magnitude. This discrepancy is due to a number of different technical factors, that lead to variations of the laser parameters, and hence to considerable spreading of the emission frequency. The possibility of separating the natural fluctuations is based on the fact that the value of w_ν does not depend theoretically on the observation frequency F, and the spectrum of the frequency fluctuations due to technical factors decreases rapidly with increasing values of F. A similar problem was encountered also in investigations of the frequency fluctuations of radio oscillators, and was also solved by stu-