netic sound [4] and this should increase the lifetime. Indeed, the particle lifetime τ_n was increased by application of the HF.

The magnetosonic heating was produced under the conditions $\omega \gtrsim \omega_i$ (hydrogen) and $\omega \gtrsim 2\omega_i$ (deuterium), when no ion-cyclotron waves were excited. At $\omega < \omega_i$ we observed effective excitation of ion-cyclotron waves, in which case the HF power absorption was somewhat lower.

Consequently, the experiments have demonstrated the following:

1. Plasma can be heated by magnetosonic waves; the absolute increase of nT reaches 1.5 and $T_i + T_e$ is increased by 1.5 - 1.8 times in comparison with heating by current.

2. The heating took place mainly in the ionic component. T_i could become several times larger than the T_i obtained by Joule heating and could exceed T_e.

3. The lifetime τ_i was approximately double τ_E.

4. The energy absorption did not decrease when the plasma was heated, and the optimum corresponded to $(nT)_{max}$ in Joule heating.

5. The HF heating displaced the plasma filament, thus confirming the qualitative estimate of nT from the diamagnetic signal.

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DC VOLTAGES INDUCED BY MICROWAVE IRRADIATION IN SUPERCONDUCTING POINT JUNCTIONS

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One of the most pronounced manifestations of the nonstationary Josephson effect is the occurrence of current steps on the current-voltage characteristics (CVC) of Josephson junctions under the influence of electromagnetic radiation. Stepped CVC were observed many times in all types of weak superconducting junctions, such as tunnel, point-contact, and thin-film bridge junctions. Such characteristics result from the occurrence of an alternating Josephson current in the dc-biased junction, and its interaction with the external electromagnetic field.

The inverse effect, namely the appearance of dc voltage on the junction when high-frequency current is made to flow through it (at zero dc transport current) has been observed so far only in experiments with Josephson tunnel junctions [1 - 3]. In these experiments, the induced dc voltages V assumed either discretely-quantized values V_n connected with the irradiation frequency ν by the Josephson equation $V_n = n(h\nu/2e)$ (where n is an integer), or continuously varying values [2, 3]. Owing to the instability of V with time, no regular expressions were obtained for the induced dc voltage (at least the continuously varying one) as a function of the microwave radiation power and of the magnetic field.

We report here the observation, in the absence of transport current, of dc voltages induced by microwave radiation in clamped point junctions. We investigated point junctions produced by mechanical pressure of a needle point against the flat end surface of a wire. Nb-Nb and Nb-Sn junctions were investigated. The junction was placed in a standard 3-cm waveguide perpendicular to the broad wall of the waveguide in an antinode of the electric field, a quarter-wavelength away from the short-circuiting plunger. The experimental technique is described in detail in [4].

We have observed continuously-varying as well as quantized dc voltages V induced by the microwave radiation, in junctions having a monotonically-decreasing dependence of the critical current I_c on the magnetic field, typical of "singly-connected" junctions, as well as in junctions with an oscillating $I_c(H)$ dependence, typical of "multiply-connected" junctions (superconducting interferometers). Unlike the experiments with the tunnel junctions [1 - 3], spontaneous changes of V were observed extremely rarely in our experiments. We were therefore able to obtain regular relations between the induced dc voltage V and the microwave radiation power. A rigorous relation was observed between V and the spectrum of the steps on the CVC upon irradiation. One example of this relation is plotted in Fig. 1. As seen from Fig. 1, the continuously varying V goes over smoothly into a quantized level. We have observed quantized values of V equal to ~20 and 40 μV (irradiation frequency ~10 GHz), corresponding to the first and second quantum levels. In the presence of subharmonic steps on the CVC, we observed fractional quantum levels of V (~6.5, 10, 13 ...μV) connected with the radiation frequency ν by the relation $V = (n/m)(h\nu/2e)$. In all the investigated junctions (both singly- and multiply-connected) the maxima of V (beginning with the second) are rigorously connected with the minima of the zeroth step or the maxima of the first step on the CVC upon irradiation. In Fig. 1a, I_0 and I_1 are the heights of the zeroth and first steps. If the first maximum is quantized, then the height of the first step on the CVC always decreases monotonically to zero with increasing radiation power, when a constant value of V is maintained.

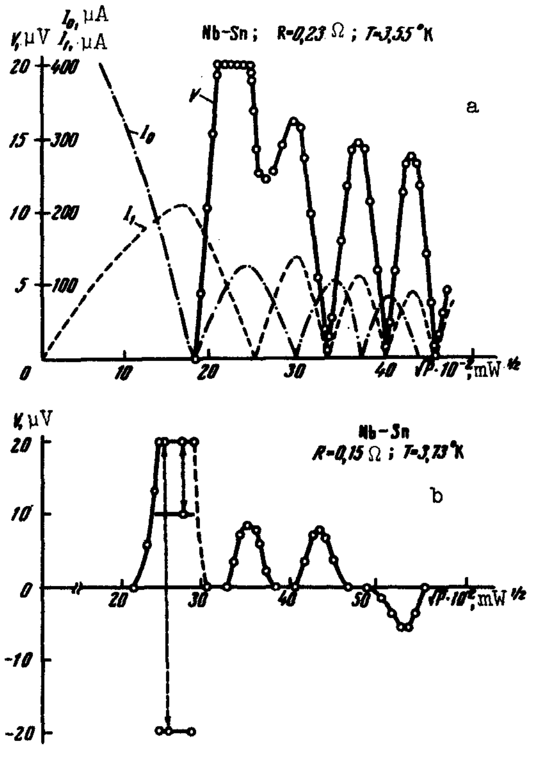

Fig. 1

As indicated above, the induced dc voltages V observed by us were sufficiently stable in time, although spontaneous changes of the magnitude and sign of V always occur in junctions with a monotonic $I_c(H)$ dependence. Figure 1b shows the spontaneous transitions from the quantum level + 20 μV to the levels 10 μV and -20 μV. The dashed curve in the same figure shows the region in which V is not stable in time.

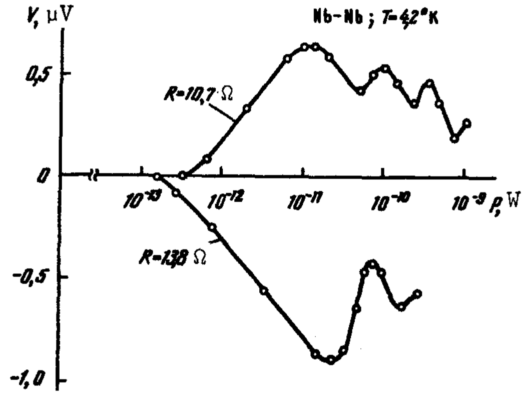

Fig. 2

Just as in [1 - 3], for most of our junctions the value of V depended strongly on the pulsed noise (switching of various devices). Such switching could reverse the sign of the observed induced voltages, both quantized and continuous. Junctions with an oscillatory $I_c(H)$ dependence were more stable against such switching.

The dependence of V on the microwave power was always oscillatory (Figs. 1 and 2). It should be noted that dc voltages were observed, just as in [5], when a low-frequency current (∿10 kHz) was made to flow through junctions with an oscillatory $I_c(H)$ dependence. But the plots of these voltages against the amplitude of the alternating current always had only one maximum, and the threshold power at which the constant voltage appeared was larger by not less than two orders of magnitude than the threshold power for the case of microwave irradiation.

The concrete form of the dependence of V on the microwave power P is determined mainly by the normal resistance R of the junction. Thus, for high-resistance junctions (∿0.3 Ω and higher), the minima of V(P) usually did not reach a zero value. The power at which dc voltages appear decreases with increasing R; in the case of high-resistance junctions, the sensitivity to the microwave power becomes thus very high. It is seen from Fig. 2 that in a junction with R = 13.8 Ω the power at which a noticeable (∿0.1 μV) dc voltage V is observed is of the order of 10^{-13} W. The voltage-power sensitivity of such a junction is $\sim 4 \times 10^5$ V/W. We know of no microwave detector having such a high voltage-power sensitivity.

While the appearance of quantized voltages can be understood at least qualitatively [2], the mechanism whereby continuous voltages are produced is quite unclear.

We believe that further research will show whether this is a consequence of an already known detection mechanism (Josephson [2] or interference [5]), the consequence of the existence of asymmetry of the CVC near the current zero, or caused by some third still unknown mechanism.

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