EXPERIMENTAL OBSERVATION OF THE EFFECT OF "INDUCED TRANSPARENCY" OF THE BARRIER TO ELECTRONIC PLASMA WAVES IN AN INHOMOGENEOUS PLASMA

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The passage of waves with frequency below the plasma frequency through a density barrier in an inhomogeneous plasma was observed experimentally. The observed "induced transparency" of the wave barrier is attributed to transport of the perturbation through the barrier by the particles trapped by the wave.

The effect of "induced transparency" of wave barriers for plasma waves was predicted theoretically in [1][1]. The gist of this effect is that the electrons trapped in a potential well of such a wave (of frequency ω), which moves in the direction of the concentration barrier, where the plasma frequency $\omega_{pe} >> \omega$, are spilled out, as it were, from the potential wells when the wave field is attenuated and pass through the barrier, producing in the plasma a modulated particle current behind the barrier. Under certain conditions, this current can resonantly excite a wave of finite amplitude in the plasma behind the barrier. The effective coefficient of wave transmission through the barrier is no longer exponentially small in this case.

The experiments aimed at observing the "induced transparency" of the wave barriers to electronic plasma waves in an inhomogeneous plasma were performed with the setup shown schematically in Fig. 1a. To produce a concentration barrier, plasma was made to flow into the vacuum regions I and III from a Penning discharge with incandescent cathode, produced in the discharge gap II [2].

The entire system was placed in a homogeneous magnetic field which did not exceed 70 Oe in the present experiments, so that no intense low-frequency oscillations due to the rotational instability [3] were produced in the discharge plasma.

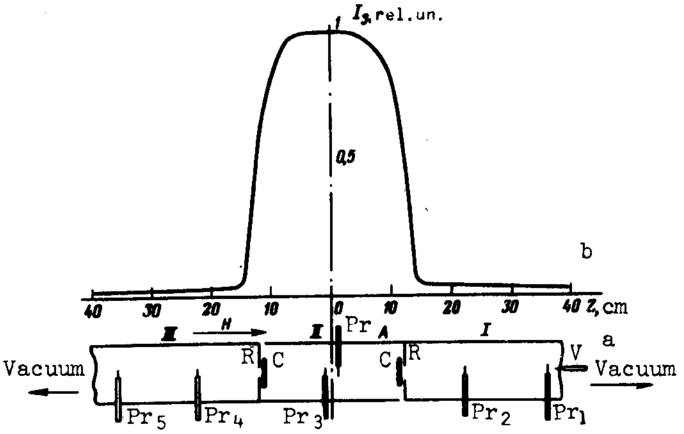

Fig. 1. a) Experimental setup, A - anode, C - cathodes, R - reflectors. b) Axial profile of the saturation current, I_a = 1 A; V_a = 100 V; argon.

The working gas (argon or helium) was fed to the central part of region II and its pressure was usually 1×10^{-3} mm Hg for the discharge in helium and 2×10^{-4} mm Hg for the discharge in argon; the pressures in regions II and III were lower by approximately one order of magnitude.

Figure 1b shows a typical axial profile of the ion saturation current to a probe moving along the system axis, and represents the corresponding density profile. The absolute values of the density at the maximum of the axial distribution at I = 1 A were 1×10^{11} cm^{-3} for argon and 5×10^{10} cm^{-3} for helium. In the region of the penetrating plasma, the concentration

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[1] As shown in [1], a similar effect exists also for extraordinary electromagnetic waves.

was of the order of 10^8 cm^{-3} and decreased monotonically with increasing distance from the exit opening of the reflector.

The plasma waves were excited in region I with a vibrating probe V, to which a signal with amplitude 0.5 V was fed from a G4-7A high-frequency generator at frequencies f = 20 - 50 MHz corresponding to ω_{p_e} in the penetrating plasma. The oscillations in the plasma were registered by a system of insulated high-frequency probes Pr_1 - Pr_5. The signal from the high-frequency probe was amplified by a U3-5 broadband amplifier and fed through a IP-26 receiver to a PDS-021 automatic x-y recorder to obtain the plots of the amplitudes (u_1 - u_5) of the oscillations received by the probe against the discharge current.

Experiment has shown that oscillations at the excitation frequency are observed in region III under definite conditions. The amplitudes of these oscillations depend in the resonant fashion on the discharge current (see curve 1 of Fig. 2a). If the physical mechanism whereby the oscillations are produced in region III is indeed described by the theory of "induced transparency" of the wave barriers [1] then, if we make it impossible for the electrons bunched by the wave in region I to enter region III, we should expect oscillations in region III to vanish. Indeed, when a thin dielectric screen Sc was introduced into the discharge plasma and was rotated into a position that excludes the possibility of direct flight of the electrons from region I into region III, no oscillations were observed in region III in the entire range of variation of the discharge current (see curve 2 of Fig. 2a). At the same time, the amplitude of the oscillations in region I remained practically unchanged. Rotation of the screen had little influence on the stationary parameters of the plasma in the system. The amplitude of the oscillations in the chain of probes 3, 4, and 5, due to the investigated effect, was subsequently defined as the difference of the signals obtained by setting the screen parallel and perpendicular to the geometrical axis of the system.

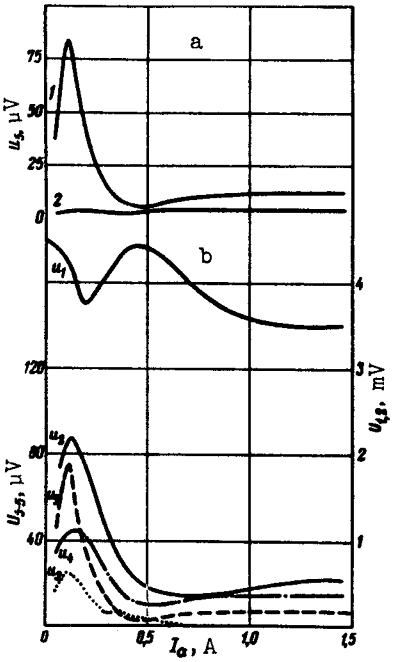

Fig. 2

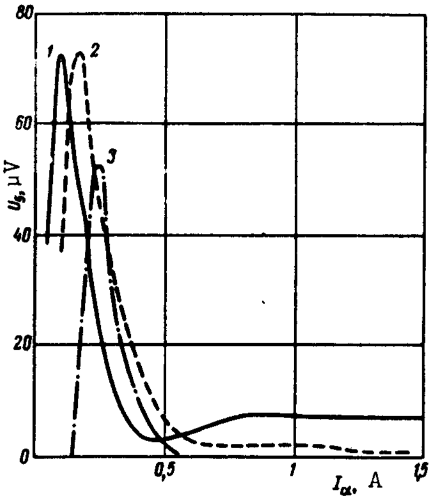

Fig. 3

Fig. 2. Oscillation amplitude vs. discharge current: V_a = 100 V; f = 20 MHz, helium; a) u_5, 1 - screen parallel to the system axis, 2 - screen perpendicular to system axis; b) u_1, u_2 - signals to probes 1 and 2, u_3, u_4, u_5 - difference signals to probes 3, 4, and 5, respectively.

Fig. 3. Oscillation amplitude in region III vs. the discharge current; helium, 1) f = 20 MHz, 2) 25 MHz, 3) 30 MHz.

Figure 2b shows plots of the oscillation amplitude in all three regions of the plasma against the discharge current. We easily see that, first, they have a resonant character and, second, the amplitude of the oscillations decreases sharply in region II, and then increases again in region III. The latter offers evidence in favor of the "induced transparency" of the wave barrier. The presence of oscillations in region II may be due to the buildup of forced oscillations by the bunched electrons.

The resonant character of the obtained relations gives grounds for assuming that the waves excited in regions I and III build up at the frequencies of the electron plasma oscillations. This assumption is favored also by the change of the current at which the resonance is observed with increasing excitation frequency (see Fig. 3).

Similar results were obtained for a discharge in argon. These effects were observed also when the openings in the reflectors were covered with a 2 × 2 mm metallic mesh, and when the vibrator probe was moved radially beyond the limits of these openings. The latter, in particular, indicates that the observed effects on it connected with excitation of the so-called "pseudowaves" in the plasma [4].

Thus, the results reported in the present paper can be regarded as the first qualitative confirmation of the existence of an effect of "induced transparency" of the wave barriers. For a more detailed investigation of this effect, additional experiments are being planned.

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