INTERACTION OF THE INTENSE MICROWAVES WITH A FLOW OF LOW TEMPERATURE PLASMA (I. The experiment)

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The experimental study of effects arising in a course of passing a focused beam of W band microwaves across the argon plasma stream flowing out of an arc plasmatron into rarefied gas through a supersonic nozzle have been carried out. The specific parameter determining a level of the nonlinearity of plasma E/E_p /1/ under the experimental conditions reached the value 5÷10. The parameters of undisturbed plasma in the region of irradiation were: concentration of electrons $n_p=10^{11}\div10^{13}cm^{-3}$, electron temperature $T_e=0,1\div0,3e\text{-}V$, neutral gas density $N_m=10^{14}\div10^{16}cm^{-3}$, velocity of flow $V_o=(1\div2)\cdot10^4 cm.sec^{-1}$.

The diagnostics of plasma was carried out by means of a microwave interferometer with enhanced resolution /2/. The space-time distribution of a microwave field behind a plasma layer was studied with a mobile receiving antenna to determine the effects of self-action of the wave passed through plasma.

The pulse of the microwave signal of 1msec duration at frequency f_1 was mixing with the test signal of 2msec duration at the displaced frequency f_2 (Δf=0,2gcps, $P_2/P_1 \sim 10^{-4}$) in a waveguide line loaded to the horn-lens antenna. The test pulse passed ahead the powerful pulse over 0,5 msec. In plasma region the microwave field represents the almost parallel beam with half-width 3cm and intensity up to 60V/cm. The intensity measurements of the test signal behind a plasma layer have made easy discrimination of the nonlinear effects against a background of the effects related to the nonhomogeneity and nonstationarity of a plasma stream and made it possible to appreciate a character of the relaxation of the plasma disturbance caused a powerful signal.

The time-dependencies of the plasma density on the axis traverse of the micro wave beam and plasma stream and the ampli tude of the passed (on the frequency f_2) wave as a function of gas expenditure by plasmatron and on gas pressure in a vacuum vessel, the space-time distributions of the plasma density and wave amplitude behind plasma flow at various power levels of the microwave beam were studied.

The oscillograms (Fig.1) show a time dependence of the amplitude of the passing signal and electron concentration in a center of the microwave beam on the plasma axis in regimes in which the nonlinear interaction of a wave with plasma is observed. The regimes with nonlinear growth of the intensity of a signal on the axis of a beam (Fig.1a) are observed in the range $n_p > 0,2.10^{12}cm^{-3}$ and $0,12 < p < 0,25$ torr. Specific time of establishing the stationary state is varied from 1msec to 0,1÷0,2msec with the increasing p and n_p. Over this period of time the level of the test beam passed through plasma becomes 2÷8 times as high as the undisturbed one. As seen from the oscillograms the in fluence of a powerful microwave beam on plasma in these regimes leads to essential decreasing the density of plasma on the axis of a beam; this decreasing reaches 50-80% from the undisturbed density and seems to be the determining factor in the process of self-action of a powerful wave. With the increasing n_p and p the growth of intensity during a time of a powerful pulse is changed by its decreasing and further by nonmonotonic time dependence. As a rule, the initial fall is changed by the more weak increasing (Fig. 1b).

In Fig.2 are shown the space profiles of the passed wave intensity. The profiles are plotted for various periods of time after switching the powerful pulse on. The profiles of Fig.2a correspond to the regime in which the oscillograms (in Fig.1a) are recorded. In this regime narrowing the basic lobe of the directivity diagram of the antenna in the nonlinear regime (selffocusing) as well as the increasing the total power passed through plasma ("transparency enhancement" of plasma) takes place. The effect in this regime has pronounced threshold character: the decrease of power 2 times completely takes off the observed effect.

The profiles shown in Fig.2b correspond to the conditions when on the axis of a beam one can observe the fast decrease of the signal intensity in time of action of the powerful pulse or else see the oscillations of this intensity (Fig. 1b). As seen from the plotted profiles the displacement of the maximum intensity region takes place,i.e.the turn of a microwave beam in the direction of moving the plasma,i.e.the nonlinear refraction. The nonmonotonic dependence of the intensity on the axis of a microwave beam on time,as seen from this Fig.is caused by lamination of a microwave beam. The decrease of power of the basic beam leads to decreasing the velocity of the beam turn and decreasing the displacement of the region with maximum intensity from the undisturbed state. The mechanisms of the observed phenomena of the microwave-beam action on the characteristics of the test beam passed plasma may be satisfied from the analysis of the space distribution of plasma density disturbed by a powerful pulse. As seen from the interferograms taken readings in different regions of plasma flow near the axis of a microwave beam under influence of a powerful wave, the density distribution "dip" is formed. This "dip" is smoothly lowered down on a stream and turned more or less sharply into a "hump" on moving the sensor of an interferometer up on a stream to the plasma injector. So the asymmetric nonuniformity of the plasma density distribution across the direction of the microwave beam propagation is developed. Just as the depth of disturbance so its asymmetry depend on the relations between the gas pressure, density of undisturbed plasma and stream velocity. The self-focusing of wave or the nonlinear refraction in the wave caused nonuniformity are observed on dependence on the depth of a "dip" and steepness of incline of the plasma density distribution.

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