The experimentally obtained distribution of the number of domains by dimensions was a symmetrical curve with a maximum. The domain width ranged from 6×10^{-4} to 11×10^{-4} cm. In the experiments that yielded the sharpest diffraction pattern, the domain dimension distribution had a rather sharply pronounced maximum. The position of the diffraction maxima corresponded to diffraction by a grating having a period $d = 9 \times 10^{-4}$ cm (Fig. 1). The same domain dimension corresponds to the maximum of the domain dimension distribution.

In the case when two mutually perpendicular diffraction patterns were observed simultaneously, a direct examination of the domains has shown that the illuminated part of the crystal contains domains with walls parallel to the xz plane, domains parallel to the yz plane, and a region intermediate between the two (Fig. 3).

The obtained average domain dimensions make it possible to determine the energy σ of production of a unit surface of the domain wall of the KDP crystal, using the formula: $\sigma = 3.4d^2P_0^2[(1 + \sqrt{\epsilon_x\epsilon_y})t]^{-1}$, where t is the crystal thickness, P_0 the spontaneous polarization, and ϵ_x and ϵ_y the dielectric constants [4]. Substituting in the foregoing formula the values $d = 10^{-3}$ cm, $t = 1$ cm, $P_0 = 4 \times 10^{-6}$ C/cm^2 and recognizing that $2[1 + \sqrt{\epsilon_x\epsilon_y}]^{-1} = 1/5$, we obtain $\sigma = 50$ erg/cm^2.

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[1] B. Zwicker and P. Scherer, Helv. Phys. Acta 17, 346 (1944).
[2] T. Mitsui and I. Furuichi, Phys. Rev. 90, 193 (1952).
[3] R. M. Hill and S. K. Ishiki, ibid. 135, 1622 (1964).
[4] W. Kanzig, Ferroelectrics and Antiferroelectrics, in Solid State Physics, v. 4, Academic Press, 1957.

ATTENUATION OF A MAGNETOSONIC WAVE IN A TURBULENT PLASMA

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As indicated in a number of theoretical papers, the turbulence of a plasma can greatly alter its dispersive and dissipative properties [1,2]. Measurement of the size of the anomalous skin layer in a turbulent plasma has confirmed the existence of such changes [3]. In the present paper we demonstrate the influence of turbulence excited in a plasma by a straight discharge current on the damping of magnetosonic waves. The described experiments [4] were performed under the same conditions as the investigations of turbulent plasma heating by a strong current along the force lines of a magnetic field [5-7]. The excitation of the current instability leads to a sharp increase of the effective electron and ion collision frequency and to the appearance of an anomalous resistance. As a result, the magnetosonic wave propagating in the region where the plasma has an anomalous resistance should be absorbed more strongly. Thus, it becomes possible to compare the collision frequencies calculated from the values of the anomalous resistance and from the wave damping coefficient.

A diagram of the experimental setup is shown in Fig. 1. A surge circuit was located

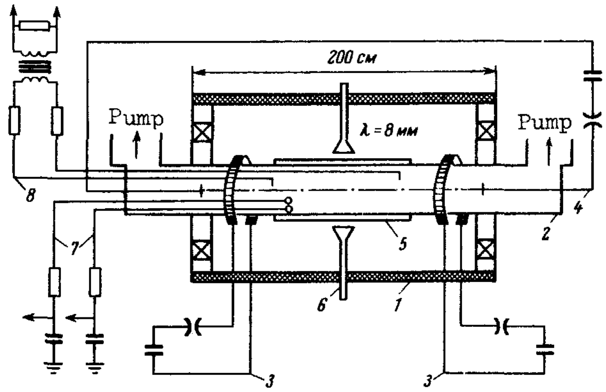

Fig. 1. Diagram of NV-1 setup: 1 - solenoid, 2 - vacuum changer, 3 - inductive plasma sources, 4 - straight-discharge circuit, 5 - surge-circuit loop, 6 - microwave interferometer, 7 - magnetic probes, 8 - double electric probe.

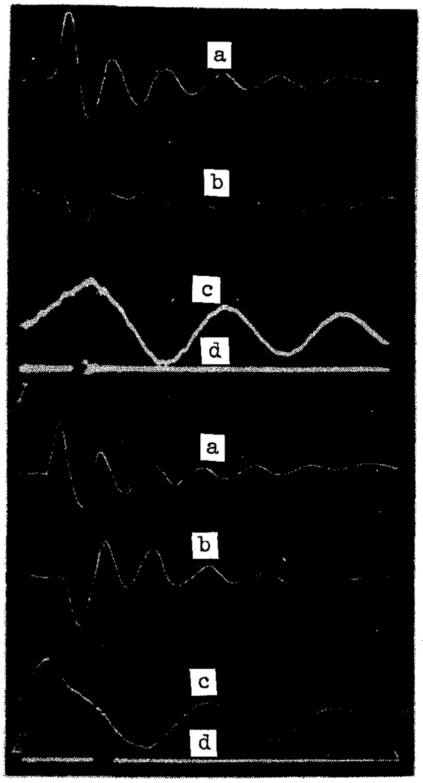

Fig. 2. Magnetic field of wave in plasma. $I_{max} \simeq 3700$ A, $H_0 = 600$ Oe, $n = 6.5 \times 10^{12}$ cm^{-3}, $\tilde{H}_B = 90$ Oe. Curves I and II correspond to different delays between the triggering of the surge circuit and that of the straight current: a) H_z in the plasma-loop gap, b) H_z in the plasma ($r = 2$ cm), c) straight discharge current I, d) marker indicating triggering of the surge circuit.

in a trap with mirror ratio 2 in the region where the field was homogeneous. The loop surrounding the chamber was 100 cm long. The frequency of the circuit was close to 7 MHz, and the intensity $\tilde{H}_B$ of the alternating magnetic field at the boundary of the plasma pinch reached 90 Oe. The direction of the alternating magnetic field of the circuit coincided in the first half-cycle with the direction of the constant field H_0. The intensity of the constant field H_0 ranged from 600 to 1000 Oe. The working gas was hydrogen, the initial pressure of which in the chamber did not exceed 10^{-3} mm Hg. The plasma was produced by two inductive sources of the θ-pinch type, located at the edges of the setup. The plasma density ranged from 10^{12} to 2×10^{13} cm^{-3}. The effective plasma-column diameter was 10 cm, and the inside diameter of the glass chamber was 16.5 cm.

The straight-discharge voltage V_T was applied to electrodes located in the magnetic-mirror region and spaced 200 cm apart. The straight discharge was turned on 100 - 150 μsec following the triggering of the inductive injectors. During that time interval, the plasma had time to fill the trap uniformly. The frequency of the straight-discharge current in the oscillatory mode was 330 kHz. The voltage V_T across the capacitance $C = 0.25$ μF did not exceed 30 kV, and the discharge current did not exceed 5 kA. It was shown with the aid of a microwave interferometer that the plasma concentration increased during the first quarter-cycle of the straight current by 30 - 60%, depending on the initial conditions. The absence of hydromagnetic instability was verified by measuring the magnetic fields of the straight discharge.

The surge circuit was triggered at an adjustable time delay following the triggering of the straight discharge. A typical oscillogram of the magnetic field of the wave and of the excitation field is shown in Fig. 2 for two values. The largest wave damping corresponded to maximum plasma resistance. The resistance was measured in a section of the plasma column located under the loop of the surge circuit, i.e., in the region of wave excitation. To this end, single and double electric probes were used to register the active voltage drop in the plasma.

The increase of the wave damping in the turbulent phase of the current can be attributed either to dissipation of the wave energy in the noise, or to excitation of instability of the proper currents of the wave; this excitation is apparently facilitated by the presence of an initial noise level in the plasma. However, the second assumption is unlikely in our case, for on the basis of the measurements of the diamagnetic signal $(nT \sim 2 \times 10^{15}\ \mathrm{eV/cm^3})$ it follows that the relation $\gamma\tau_f \lesssim 1$ holds for all the known types of the wave-current instability. Here τ_f is the characteristic rise time of the field on the wave front, and γ is the instability increment. Thus, the only reason for the damping is the scattering of electrons by the turbulent pulsations of the electric fields of the straight current. This assumption is also favored by a comparison of the effective collision frequencies ν_{eff} calculated from the values of the wave damping coefficient and from the anomalous plasma resistance averaged over the length of the circuit.

The wave damping coefficient was determined from the ratio of the wave amplitude measured in the turbulent plasma to the wave amplitude measured in the plasma without the current. The amplitudes were compared by using the oscillograms of the signal from a magnetic probe located 2 cm away from the chamber axis, with H_0, $\tilde{H}_B$, and n kept constant. From the expression for the damping coefficient of a magnetosonic wave [7]

$$\chi/k = \omega\nu_{eff}/2\omega_i\omega_e$$

we can find that under the conditions of Fig. 2 $\nu_{eff} \approx 8 \times 10^8\ \mathrm{sec}^{-1}$. Under the same conditions it follows from the electric-probe readings that the electric field intensity reaches ~30 V/cm, and $\nu_{eff} \approx 8 \times 10^8\ \mathrm{sec}^{-1}$. These results agree satisfactorily with the data given in [4,6,7] and obtained under analogous conditions.

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[1] A. A. Vedenov, A. V. Gordeev, and L. I. Rudakov, Second Intern. Conf. on Plasma Physics, Culham, 1965, Paper 21/155.
[2] V. N. Tsytovich, Nelineinye effekty v plazme (Nonlinear Effects in Plasma), Atomizdat, 1967.
[3] V. A. Skoryupin, Zh. Eksp. Teor. Fiz. 53, 1213 (1967) [Sov. Phys.-JETP 26, 711 (1968)].
[4] G. P. Maksimov and V. P. Smirnov, Preprint 1645, Atom. Energy Inst.
[5] M. V. Babykin, P. P. Gavrin, E. K. Zavoiskii, S. L. Nedoseev, L. I. Rudakov, and V. A. Skoryupin, ibid. 52, 643 (1967) [25, 421 (1967)].
[6] S. D. Fanchenko, B. A. Demidov, N. I. Elagin, and D. D. Ryutov, ibid. 46, 497 (1964) [19, 337 (1964)].
[7] D. A. Frank-Kamenetskii, Lektsii po fizike plazmy (Lectures on Plasma Physics), Atomizdat, 1964.