Analogous phenomena should be expected also when waves of arbitrary type propagate in a medium in which the properties that govern the propagation of waves of this type exhibit anisotropy.

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[1] Kroger, Prohofsky, and Damon, Phys. Rev. Lett. 11, 246 (1963).
[2] Damon, Kroger, and Prohofsky, Proc. IEEE 52, 912 (1964).
[3] E. W. Prohofsky, Phys. Rev. 134A, 1302 (1964).
[4] E. Conwell, Phys. Lett. 13, 285 (1964).
[5] Hutson, McFee, and White, Phys. Rev. Lett. 7, 237 (1961).
[6] D. L. White, J. Appl. Phys. 33, 2547 (1962).
[7] H. N. Spectro. Phys. Rev. 127, 1084 (1962).
[8] Uchida, Ishiguro, Sasaki, and Suzuki, J. Phys. Soc. Japan 19, 674 (1964).
[9] Ishiguro, Uchida, and Suzuki, IEEE Intern. Conv. Record, Part 2, 93 (1964).
[10] J. Von Mertsching, Phys. Stat. Sol. 4, 453 (1964).
[11] G. S. L'vov, Diploma Thesis, Moscow Physico-technical Institute, 1961.

INVESTIGATION OF THE STRUCTURE OF THE FRONT OF A STRONG MAGNETIC-SOUND WAVE IN A RAREFIED PLASMA

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This paper is devoted to an experimental investigation of the structure of the front of a strong magnetic-sound wave propagating in a rarefied plasma transverse to a magnetic field. In laboratory experiments, an essential factor for such waves is the nonstationarity of the wave motion.

A theoretical description of nonstationary magnetic-sound wave of finite amplitude is the subject of [1-3]. In [1] Adlam and Allen solved numerically the problem of unsteady motion of a magnetic piston in a rarefied plasma for two concrete time variations of the magnetic field on the plasma boundary:

$$H_n(t_n) = 1 + \alpha t_n \tag{1}$$

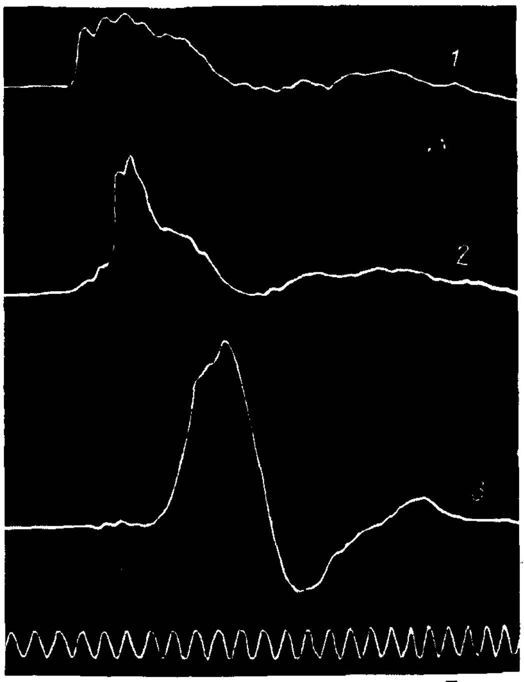
$$H_n(t_n) = 1 + \beta[1 - \exp(-\alpha t_n)] \tag{2}$$

Here $H_n = H/H_0$ is the magnetic field normalized relative to the constant field H_0; $t_n = t/\tau_{ei}$ is the time normalized relative to $\tau_{ei} = c\,[mM]^{1/2}/eH_0$, while α and $\beta = H_n(\infty) - 1$ are constants.

For $\alpha = 1$ and $\beta = 1$ the authors found the profile of the magnetic field in the plasma at certain values of t_n. They showed that in case (1) the magnetic-field front, which increases linearly on the plasma boundary, is transformed inside the plasma into an exponentially growing front with characteristic scale c/ω_{pe}. In case (2), the magnetic-field profile calculated for t_n = 5, 7, and 9 also has an exponentially growing leading section with the same scale but, unlike in case (1), the oscillating structure of the front comes into play here.

The experiments were carried out under the conditions described in our earlier paper [4]. The wave was excited by a trapezoidal pulsed magnetic field H, produced on the boundary of a cylindrical plasma column (diameter 6 cm and length 30 cm) in a constant magnetic field H_0. The pulse growth time was $\tau_0 = 5.5 \times 10^{-8}$ sec. The plasma density n_0 ahead of the wave front ranged from $\sim 0.5 \times 10^{12}$ to $\sim 6 \times 10^{13}$ cm^{-3}. In the section of small n_0, in the region where the time of propagation of the wave along the cylinder axis was $\Delta t < \tau_0$, case (1) of the boundary conditions was realized. In the section where n_0 was large, the condition $\Delta t > \tau_0$ was satisfied and case (2) was realized. The magnetic Mach number μ varied in the range ~1.3 - 4.2.

The following results were obtained. Nonlinear twisting of the wave front in the plasma, compared with the front given by expression (1) or (2) was observed for all the indicated values of μ. 1) The profile of the magnetic field in the plasma was in good agreement with the profile calculated in [1] within the accuracy of the cylindrical effect. The width of the transition region coincides, with ~50% accuracy (taking nonstationarity into account), with the width calculated in [1], and its duration, as a function of μ, is described with the same accuracy by the formula [5]



t, f = 10^{-7} sec

Fig. 1

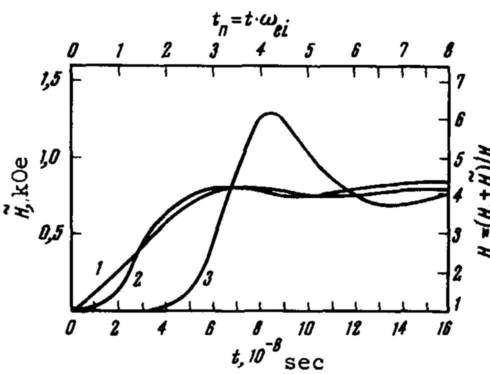


Fig. 2

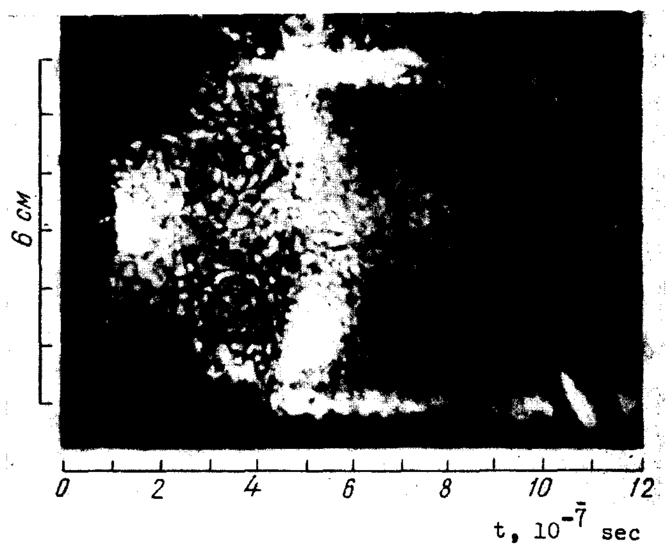


Fig. 3

$\tau = 1.5\omega_{ei}^{-1}(\mu^2 - 1)^{-1/2}$. It is interesting that in the region $2 < \mu < 4.2$ no anomalous increase of the front width, corresponding to a "collapse" of the wave [6], was observed. This is apparently connected with the unsteady character of the wave in our experiment [3].

By way of illustration of the foregoing conclusions, Fig. 1 shows oscillograms of the magnetic-probe signals obtained at an initial helium pressure $P_0 = 3 \times 10^{-3}$ mm Hg, $H_0 = 250$ Oe, $\tilde{H} = 800$ Oe, 1) $n_0 = 0$, 2) $n_0 = 0.5 \times 10^{13}$, and 3) $n_0 = 10^{13}$ cm^{-3}. The profiles of the magnetic field in the plasma, obtained by integrating the probe oscillograms, are represented by curves 1, 2, and 3 of Fig. 2, respectively. We see that the front of the magnetic field, which increases linearly on the plasma boundary, changes inside the plasma into an exponentially growing front with a gradually increasing slope. Its duration is approximately two periods of oscillation at the geometric mean frequency $(2c[mM]^{1/2}/eH_0)$. Curve 3 exhibits the first maximum of the oscillating structure of the front ($\alpha t_n \approx 3.5$). The value of the maximum exceeds the amplitude of the vacuum pulse given by expression (2). The reflected wave could become manifest on this curve only if $t > 12 \times 10^{-8}$ sec.

We note that in our experiments the absorption of the wave energy on the front increased with increasing n_0. At the same time, electrons with energy larger than 50 eV appeared behind the wave front. The latter can be verified on the streak photograph (Fig. 3) of the plasma column diameter in the light of the 4686 Å line of HeII (at $P_0 = 3 \times 10^{-3}$ mm Hg, $n_0 = 10^{13}$ cm^{-3}, $H_0 = 375$ Oe, and $\tilde{H} = 800$ Oe), obtained with the aid of an electron-optical converter.

Among the mechanisms responsible for the energy transfer from the wave to the plasma electrons we can point to the current instability mechanism [7-9] and to a mechanism connected with the ionization collisions of the electrons [4,10] on the wave front.

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[1] J. H. Adlam and J. E. Allen, Proc. Phys. Soc. (london) 75, 640 (1960).
[2] K. W. Morton, J. Fluid Mech. 14, 369 (1962).
[3] V. J. Rossow, Phys. Fluids 8, 358 (1965).
[4] S. P. Zagorodnikov, L. I. Rudakov, G. E. Smolkin, and G. V. Sholin, JETP 47, 1717 (1964), Soviet Phys. JETP 20, 1154 (1965).
[5] Davis, Lust, and Schluter, Z. Naturforsch. 13A, 916 (1958).
[6] R. Z. Sagdeev, Voprosy teorii plazmy (Problems of Plasma Theory), V. 4, Atomizdat, 1964.
[7] E. N. Parker, Phys. Rev. 112, 1429 (1958).
[8] Vedenov, Velikhov, and Sagdeev, Nuclear Fusion 1, 82 (1961).
[9] P. Kellog, Phys. Fluids 7, 1555 (1964).
[10] Zagorodnikov, Smolkin, and Sholin, Paper at the Seventh International Conference on Phenomena in Ionized Gases, Belgrade, 1965.

1) The effect of twisting of the profile of the magnetic field in the plasma, as compared with the perturbation front produced on the plasma boundary, was observed by us earlier

in [4]. Oscillogram b of Fig. 2, from which we estimated the duration of the wave front in that paper, corresponds to case (1) of the boundary condition.

CERTAIN SINGULARITIES OF ELECTROMAGNETIC RADIATION GENERATED BY A SUPERCONDUCTING TUNNEL STRUCTURE

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It was shown in [1,2] that the steps on the voltage-current characteristics of superconducting Sn-I-Sn tunnel structures are the consequence of excitation of resonant modes of electromagnetic waves in the tunnel structure by means of the alternating Josephson current. It is natural to expect some part of the high-frequency energy to be drawn from the tunneling region to the space outside. A study of this radiation is of great interest as a direct method of investigating the alternating Josephson current, since its frequency is uniquely connected with the quantum transitions of the electrons during tunneling, and its power indicates the degree of interaction between the current and the high-frequency field.

We have registered earlier [3] the electromagnetic radiation generated by a tunnel structure , with a frequency corresponding to the ratio of the Josephson frequencies: $\hbar\omega$ = 2 eV. We present here preliminary results of an experimental investigation of the spectral composition of the Josephson high-frequency radiation. Appreciable inhomogeneities in the thickness of the dielectric of the tunnel structures investigated in [3] have resulted in a complicated picture of the steps observed there. The tunnel structure which we have investigated here had a very uniform layer of oxide between metal films, so that a clear-cut picture of the steps was observed. This apparently was the reason why the power radiated by the structures was more than 10 times the power observed in [3], reaching several times 10^{-13} W. This is several hundred times more the noise level of the receiver. The receiver bandwidth was 8 Mc.

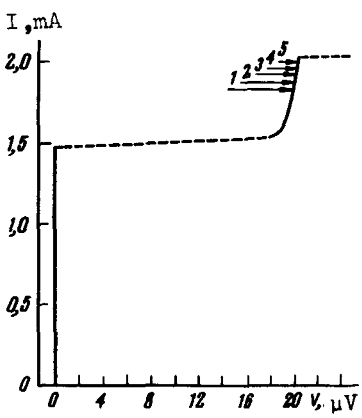

Fig. 1

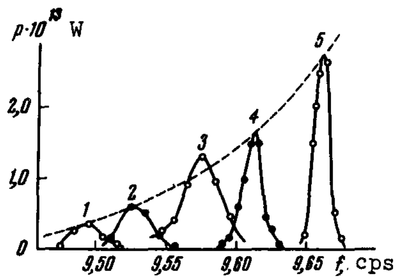

Fig. 2

No attempts were made in the investigations to match the tunnel structure to the waveguide, owing to the technical difficulty of this task. In addition, the nonresonant system used to couple the tunnel junction to the waveguide had apparently the advantage