From the obtained values of $\Delta\ell$ we can find the dependence of the cross-section area S of the corresponding part of the Fermi surface on the components of the stress tensor σ_{ik}, inasmuch as (see [5, 6])

$$u_{ik} = -\left(\frac{\partial\Phi}{\partial\sigma_{ik}}\right) = \frac{\partial \ln S}{\partial\sigma_{ik}} HM$$

Here u_{ik} is the strain tensor, Φ the oscillating part of the thermodynamic potential, and M the oscillating magnetic moment. The ratio

$$\frac{\partial \ln S}{\partial\sigma_{ik}} \Bigg/ \frac{\partial \ln S}{\partial\sigma_{\ell m}} = u_{ik}/u_{\ell m}$$

is determined directly from experiment and is independent of M. Thus, for example, for the section τ_2^1 (electron surface in zone VI) we obtain

$$\frac{\partial \ln S}{\partial\sigma_{100}} \Bigg/ \frac{\partial \ln S}{\partial\sigma_{001}} = -2{,}9 \pm 0{,}2.$$

The dependence of S on the stresses is usually extracted from direct experiments on the influence of the pressure (10^2 - 10^4 kg/cm^2) on the Fermi surface of a metal [7]. The advantage of the dilatometric measurement method lies in the fact that the investigated sample is not subjected to strong mechanical stresses. Thus, in the described experiments, the forces exerted on the sample by the holder (Fig. 1) did not exceed the weight of the sample. The Dingle temperature, which characterizes the quality of the crystal and is determined experimentally from the field dependence of the oscillation amplitude, was approximately 0.02 - 0.05°K for the sample employed.

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PRODUCTION OF A RELATIVISTIC PLASMA BY ADIABATIC COMPRESSION IN A PLASMA-BEAM SYSTEM

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Interaction of an electron beam with a cold plasma in an adiabatic trap with a large mirror ratio gives rise to a high-temperature electron component that is retained in the trap for a long time [1]. Under certain conditions, it is possible to accumulate in a considerable volume ($V \sim 20$ liters) electrons with an average energy $T_e \sim 200$ keV and a concentration $n = 2 \times 10^{10}$ cm^{-3}. It is important that these conditions are satisfied in rather weak magnetic fields, 0.8 - 1 kOe.

Adiabatic compression of a plasma produced by turbulent heating was investigated earlier in [2], where it was shown that this is an effective method of obtaining a dense ($n \sim 10^{13}$ cm^{-3}) high-temperature ($T_e \sim 30$ keV) plasma. In the present paper we consider the possibility of obtaining a relativistic dense plasma by adiabatic compression of the high-energy component of a plasma produced in a plasma-beam system.

Let us see how the plasma parameters are altered by adiabatic compression, with allowance for relativistic factors. By starting from the transverse adiabatic invariant

$$\frac{\gamma^2 \beta^2}{H} = \text{const} \qquad (1)$$

and from the expression for the total energy, $mc^2 = m_0 c^2 + T$, we can obtain the increase of the kinetic energy of the electron when the magnetic field intensity is changed by a factor $\alpha = H/H_0$

$$T = m_0 c^2 \left[\sqrt{1 + \alpha \frac{T_0}{m_0 c^2} \left(\frac{T_0}{m_0 c^2} + 2 \right)} - 1 \right] , \qquad (2)$$

where $\beta = v/c$, $\gamma = (1 - v^2/c^2)^{-1/2}$, T_0 is the initial electron energy, and H_0 and H are the field intensities corresponding to the start and end of the compression.

As a result of the transverse compression, the plasma concentration n increases in proportion to the compression coefficient

$$n = n_0 \alpha . \qquad (3)$$

Compression in the axial direction occurs if the field is not axially homogeneous. Taking relativistic effects into account, the longitudinal invariant in the case of a parabolic magnetic-field profile, takes the form

$$\gamma a^2 \Omega = \text{const} , \qquad (4)$$

where a is the amplitude and Ω the frequency of the electron oscillations between the reflection point, given by

$$\Omega = \sqrt{\frac{\mu_0 \gamma_0}{m_0 \gamma^2}}$$

μ_0 is the magnetic moment, and m_0 is the rest mass of the electron. From the invariant (4) we can determine the connection between the longitudinal compression $\alpha_{\parallel} = a_0/a$ and the transverse one $\alpha_{\perp}$

$$\alpha_{\parallel} = (\alpha_{\perp})^{1/4} . \qquad (5)$$

The plasma concentration thus increases like $\alpha^{5/4}$ in traps of this kind as a result of longitudinal and transverse compression.

The table (lower line) gives the results of the calculation for the case of a hundredfold compression ($\alpha = 100$), the initial data (upper line) being the results obtained with the PN-2 installation [1].

H, Oe	n, cm^{-3}	T, eV	$\beta = 8\pi nT/H^2$	V, cm^3	$W = nTV$, J
$8 \cdot 10^2$	$2 \cdot 10^{10}$	$2 \cdot 10^5$	0.25	$2 \cdot 10^4$	13
$8 \cdot 10^4$	$6 \cdot 10^{12}$	$4.5 \cdot 10^6$	0.17	67	290

The experimental study of adiabatic plasma compression was performed with the PN-2 installation (Fig. 1). The mirror-configuration magnetic field was produced by a system of coils (1, 2). The magnetic field intensity increased from 0 to 3.5 kOe at the center and 18.5 kOe in the mirrors within 0.5 sec. The electron gun (3) (beam current 10 A, energy 35 keV, duration 250 μsec) and the plasma injector (4) filling the trap with cold plasma ($n = 1.5 \times 10^{12}$ cm^{-3} and $T_e = 5$ eV) were turned on at the instant of time corresponding to 1 kOe. The vacuum chamber (5) was 60 cm long and 40 cm in diameter, and was evacuated to a residual pressure 10^{-7} Torr.

The hot-electron component of the plasma, obtained as a result of the plasma-beam interaction, was compressed by the increasing magnetic field. The effect was manifest by a decrease in the visible plasma diameter with increasing magnetic field. The plasma glow following the turning-on of the electron beam is due to excitation of the neutral gas by the hot electrons, and the transverse dimension of the glowing column characterizes the diameter of the high-temperature component of the plasma. Figure 2 shows a time-space scan of the plasma column: a) in a constant 1-kOe magnetic field and b) with compression

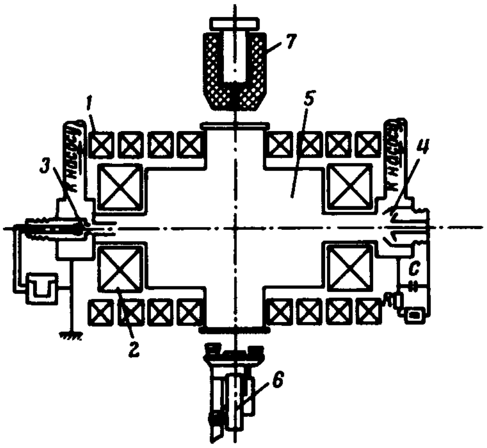

Fig. 1

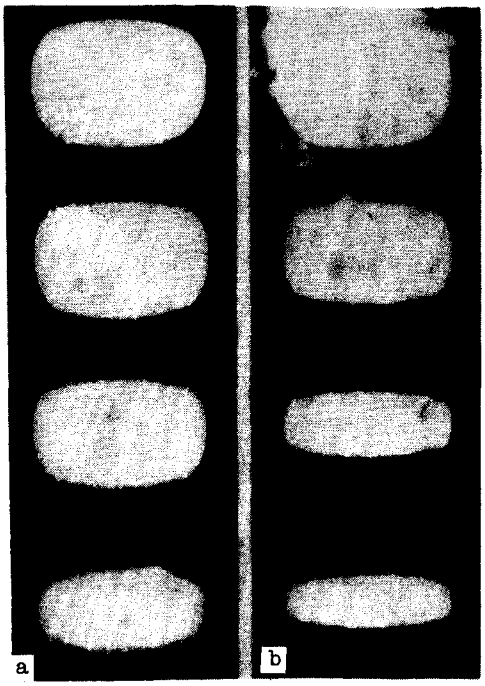

Fig. 2

Fig. 1. Diagram of setup: 1 - main magnetic field coil, 2 - mirror coils, 3 - electron gun, 4 - plasma injector, 5 - vacuum chamber, 6 - "Konvas" motion picture camera, 7 - x-ray pickup.

Fig. 2. Frame-by-frame scanning of the transverse plasma dimension: a - in a constant magnetic field of 1 kOe, b - with the magnetic field varied from 1 to 3.5 kOe. Photography at 12 frames per second.

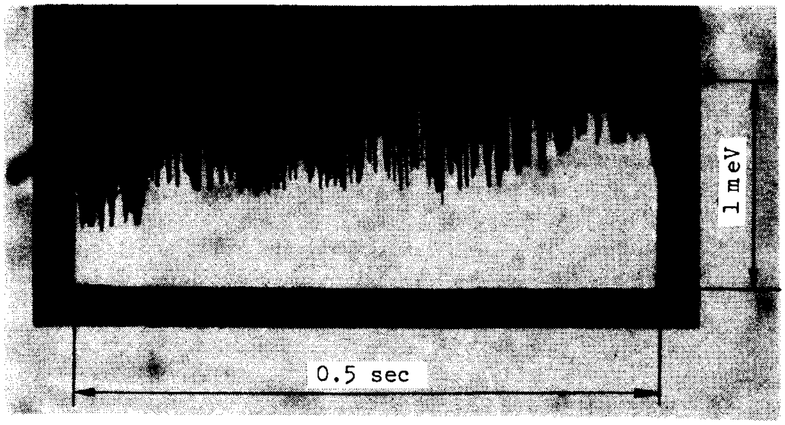

Fig. 3. Oscillogram of bremsstrahlung from plasma with the magnetic field varied from 1 to 3.5 kOe.

from 1 to 3.5 kOe. The photography was at a rate of 10 - 12 frames per second, with a "Konvas" type motion picture camera, through a lateral tube in the vacuum chamber. The plasma diameter was assumed to be the half-width of the radial distribution of the glow intensity of the plasma column. In the case of compression, the ratio of the initial half-width (upper frame of Fig. 2b) to the final one (lower frame of Fig. 2b) is equal to 2.5, and is somewhat larger than the calculated value. This can be attributed to the fact that the upper frames of Fig. 2 are exposed at the initial instant, when the plasma contains an electron beam that maintains a high density level of the cold plasma, whose diameter is larger than that of the hot plasma. It is therefore more correct to compare the half-width of the second frame from the top at a constant field (Fig. 2a) with the half-width of the lower frame in the case of compression (Fig. 2b). When such a correction is introduced, the real compression practically coincides with the expected value.

Some decrease in the diameter with time is observed also in Fig. 2a, where there is no compression. This decrease is due to the noticeable escape of fast particles and to the appreciable decrease of the neutral-gas density in the chamber during the time between the first and last frames. Both factors decrease the plasma glow intensity and consequently lead to an apparent decrease of its diameter.

An increase of the electron temperature of the hot component during the course of compression was revealed qualitatively by the bremsstrahlung from the plasma. Figure 3 shows an oscillogram of the plasma radiation registered by a collimated scintillation pickup. An increase of the quantum energy with increasing magnetic field is clearly seen. A proper choice of the crystal counting rate precluded an increase in the pulse amplitude on Fig. 3 as a result of superposition.

The experiment has shown that the high-temperature component of the plasma remains stable upon compression. One can hope the plasma to remain stable also at higher compression coefficients, so that a dense relativistic plasma becomes obtainable. Such a plasma is of interest for a number of applied problems, such as thermonuclear fusion, acceleration of charged particles, creation of a γ-radiation source of high power, astrophysics problems, etc.

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