amplitude of several hundred Oe. To return the magnetization to the initial state, a restoring inverse field pulse H_r is applied along the EMA. The repetition frequency of the magnetization-reversal pulses is ∿100 Hz, so that at the instant of the next high-speed magnetization reversal the electronic and nuclear spin systems are in the state of equilibrium (for Co^{59} films the time of nuclear longitudinal relaxation is $T_1 \sim (2 - 3) \times 10^{-4}$ sec).

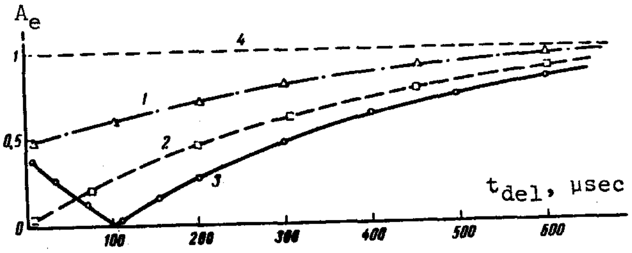

Fig. 2. Plot of $A_e(t_{del})$ at different growth rates of the magnetization-reversing field: 1 - $<0.8 \times 10^{11}$ Oe/sec, 2 - 1.5×10^{11} Oe/sec, 3 - $>3 \times 10^{11}$ Oe/sec, 4 - without remagnetization ($H_p = 0$).

With increasing delay t_{del} between H_p and h_1, as μ_z recovers to μ after perturbation by the remagnetization pulse, there will be observed also a recovery of A_e to $A_e = 1$. The experimental data for different growth times of the pulse field H_p are shown in Fig. 2. For small rates of magnetization reversal, A_e increases from a value $0 < A_e < 1$ to $A_e = 1$ (curve 1 of Fig. 2). At a rate of rotation of M such that $\mu_z = 0$ immediately after the magnetization reversal, the recovery curve $A_e(t_{del})$ emerges from the origin (curve 2). Finally, if $\mu_z < 0$ after the magnetization reversal, then $|A_e| > 0$; with increasing t_{del}, $A_e \to 0$ ($\mu_z(t) = 0$) and then recovers to $A_e = 1$ (curve 3). All three curves are exponentials ($T_{1_p} = 3 \times 10^{-4}$ sec). Curve 3 indicates that an inversion $\rho = 70\%$ was attained after the magnetization reversal, and its value was greater than 50% for about 100 μsec.

Thus, we have demonstrated experimentally the possibility of obtaining inverted population of the levels of a nuclear magnetic system, we obtained a stable NMR signal from a nuclear system inverted by a pulsed magnetic field.

In conclusion, the authors are grateful to V.I. Ignatchenko and Yu.A. Kudenko for useful discussions.

[1] V.A. Ignatchenko and Yu.A. Kudenko, Izv. AN SSSR ser. fiz. 30, 933 (1966).
[2] W. Dietrich and W. Proebster, Elektronische Rundschau 14, 2 (1970).
[3] A. Loesche, Nuclear Induction (Russian translation), IIL, 1963.

COMPRESSION OF PLASMA BY A GROWING LONGITUDINAL MAGNETIC FIELD IN THE TOKAMAK

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One of the possible methods of heating a plasma in Tokamak systems is to compress the plasma by increasing the main longitudinal field H. Simple considerations based on ideal magnetohydrodynamics show that the plasma density n(r, t) in the center of the pinch should increase linearly with the field, and the temperature of the ions T_i and of the electrons T_e, should increase like $H^{2/3}$. However, compression of the plasma gives rise to a number of new effects, greatly changing its energy balance. First, there occurs a "detachment" of the plasma from the walls of the chamber (or the diaphragm), as a result of which the heat flux to the wall decreases greatly. Second, when the current is compressed, the Joule heat released in the central part of the plasma increases quadratically, and a current in the opposite direction (anticurrent) appears in the surface layer of the plasma. These effects should lead to an additional heating of the ions and electrons.

To verify the foregoing considerations, a numerical integration was carried out of the system of equations for the balance of the particles and energy of the plasma [1, 2]:

$$\frac{\partial n}{\partial t} = \frac{1}{r}\frac{\partial}{\partial r}\left(rD\frac{\partial n}{\partial r}\right) + \alpha n + \frac{\alpha}{2} r \frac{\partial n}{\partial r},$$

$$\frac{\partial T_i}{\partial t} = \frac{1}{nr}\frac{\partial}{\partial r}\left(r n \chi_i \frac{\partial T_i}{\partial r}\right) - \frac{Cn}{T_e^{3/2}}(T_i - T_e) + \frac{2}{3}\alpha T_i + \frac{\alpha}{2} r \frac{\dot{\partial}\;{}_{i}}{\partial r},$$

$$\frac{\partial T_e}{\partial t} = \frac{1}{nr}\frac{\partial}{\partial r}\left(r n \chi_e \gamma_1 \gamma \frac{\partial T_e}{\partial r}\right) + \frac{Cn}{T_e^{3/2}}(T_i - T_e) +$$

$$+ \frac{2}{3}\alpha T_e + \frac{\alpha}{2} r \frac{\partial T_e}{\partial r} + \frac{B\gamma}{n T_e^{3/2}}\left[\frac{1}{r}\frac{\dot{\partial}}{\partial r}(r^2\mu)\right]^2,$$

$$\frac{\partial \mu}{\partial t} = A\frac{1}{r}\frac{\partial}{\partial r}\left[\frac{\gamma}{T_e^{3/2}}\frac{1}{r}\frac{\partial}{\partial r}(r^2\mu)\right] + \frac{\alpha}{2} r \frac{\partial \mu}{\partial r}.$$

Here $\mu = RH_\theta/rH$, H_θ is the field of the longitudinal current I, and D, χ_i, and χ_e are the "neoclassical" transport coefficients [3], $A = 6 \times 10^3$, $B = 2 \times 10^7 H^2/R^2$, $C = 470$, the time t is in milliseconds, T_e and T_i in electron volts, n in 10^{13} cm^{-3}, R and a are the major and minor radii of the plasma torus in cm, $\alpha = (1/H)(dH/dt)$, γ is the anomaly of the resistance relative to the classical value. By γ_1 we denote the phenomenological coefficient of the "superanomalous" thermal conductivity of the electrons. In the T-3 installation at $n \sim 2$ and $T_e \sim 10^3$ we have $\gamma_1 \simeq 7$ [4].

Figure 1 shows the radial distribution of the plasma density at different instants of time at $n(0, 0) = 3.5$, $i = 90$ kA, $a = 15$, and $R = 100$. During the time $\Delta t = 5$, the longitudinal magnetic field changed linearly from $H_0 = 15$ kOe ($t = 0$) to $H = 40$ kOe, after which it remained constant. It is clearly seen that the initial parabolic distribution of the density changes into a distribution that has a low-density plateau on the periphery (the plasma "breaks away" from the walls). The anticurrent amounts to 25 - 30% of the total current. The temperatures T_e and T_i and the energy time τ_E increase strongly from $T_{e0} = 600$ eV to $T_e = 2300$ eV, from $T_{i0} = 350$ eV to $T_i = 1100$ eV, and τ_E from 4 to 100 msec.

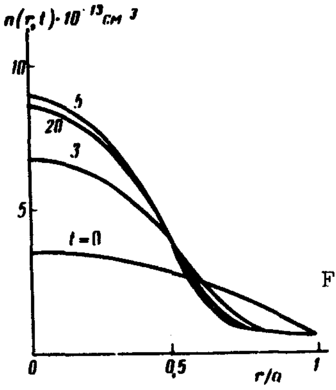

Fig. 1

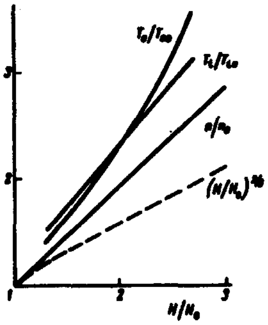

Fig. 2

Fig. 1. Plasma density profiles upon compression at different instants of time for n(0, 0) = 3.5, I = 90 kA, H_0 = 15 kOe, and H = 40 kOe.

Fig. 2. Plots of n/n_0, T_e/T_{e0}, and T_i/T_{i0} vs. the ratio H/H_0 (the dashed line shows a plot of $(H/H_0)^{2/3}$.

Figure 2 shows plots of n/n_0, T_e/T_{e0}, and T_i/T_{i0} against the ratio H/H_0. The dashed curve represents $(H/H_0)^{2/3}$. The considerable rise of the T_e/T_{e0} and T_i/T_{i0} above the dashed curve is determined by the "detachment" of the plasma from the walls, by compression, in the distribution of the current, and by the appearance of the anticurrent. An experimental verification of the aforementioned effects would be of great interest.

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[1] B.B. Kadomtsev, Voprosy teorii plazmy (Problems of Plasma Theory), Atomizdat, No. 5, 1967.
[2] Y.N. Dnestrovskii, D.P. Kostomarov, and N.L. Pavlova, IV European Conf. on Thermonuclear Reaction and Plasma Physics, Rome, 1970, p. 17.
[3] A.A. Galeev and R.Z. Sagdeev, Zh. Eksp. Teor. Fiz. 53, 348 (1967) [Sov. Phys.-JETP 26, 233 (1968)].
[4] L.A. Artsimovich, ZhETF Pis. Red. 13, 101 (1971) [JETP Lett. 13, 70 (1971)].

INFLUENCE OF SPIN RELAXATION OF "HOT" ELECTRONS ON THE EFFECTIVENESS OF OPTICAL ORIENTATION IN SEMICONDUCTORS

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A considerable number of investigations have been carried out to data on the optical orientation of electrons in semiconductors [1 - 6]. In most cases, the effectiveness of the orientation was determined principally by the spin relaxation of the electrons at the bottom of the conduction band. We show in the present paper that the degree of stationary orientation of the non-equilibrium electrons can be determined to a considerable degree (depending on the impurity concentration) by the spin relaxation occurring upon thermalization of the "hot" electrons produced by the light.