Concerning the article by L. P. Zakatov and A. G. Plakhov "Mechanism of plasma heating by an electron beam in a probkotron machine"

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We compare the experimental results obtained in [1] with the model proposed in [2,3] for plasma heating under the condition of two-stream instability in a probkotron. It is shown that the experimental data given in [1] can be qualitatively explained by the model stochastic cyclotron heating.

The mechanism proposed in[2,3], whereby the electronic plasma component is heated under the conditions of two-beam instability in magnetic traps of the probkotron type, is questioned in[1]. The authors state that the principal experimental fact given in[2,3] in favor of the stochastic cyclotron heating mechanism "is the observed temporal correlation between the x-ray flashes and the radiation in the region of the cyclotron frequencies of the probkotron," and that the conclusions of[2,3] concerning the heating mechanism are based exclusively on observation of a correlation between the flashes x-ray and the excitation of oscillations in the region of the cyclotron frequencies.

This statement is incorrect. Actually, the conclusion concerning the mechanism whereby the electronic component of the plasma becomes heated was based in[2,3] on the following: 1) measurements of the total oscillation spectrum excited by the electron beam in the plasma; 2) an investigation of the mechanism of absorption of these oscillations in the inhomogeneous magnetic field; 3) measurements (probe and x-ray) of the electron temperature. It was shown that effective heating of the electronic component of the plasma is observed when the spectrum of the oscillations excited by the beam lies in the range $\omega_{c\,\min} \leqslant \omega \leqslant \omega_{c\,\max}$, where $\omega_{c\,\min}$ and $\omega_{c\,\max}$ are the minimal and maximal cyclotron frequencies of the probkotron (see Fig. 2 of[2] and Figs. 5 and 6 and[3]; the absorption of the oscillations was investigated in greater detail in[4]).

Let us compare the experimental results of[1] with these premises. In[1] they observed a correlation between the increased energy content of the plasma and the microwave emission at double the plasma frequency. The presence of emission at this frequency is believed in[1] "to be evidence of the development of intense Langmuir oscillations" that are responsible for the plasma heating. According to the data of[1], as given in Fig. 2, $\omega_{c\,\min} = 1.8 \times 10^{10}$ sec^{-1}, $\omega_{c\,\max} = 9 \times 10^{10}$ sec^{-1}, and $\omega_p \sim (5.6-7.8) \times 10^{10}$ sec^{-1}. Thus, the increase in the energy content of the plasma correlates with the excitation of plasma oscillations in the range $\omega_{c\,\min} \leqslant \omega \leqslant \omega_{c\,\max}$ of frequencies that are well absorbed, according to[2,3] in the regions of the cyclotron resonance of the inhomogeneous magnetic field of the probkotron. These results are in full accord with the model of stochastic cyclotron heating.

Unfortunately, the authors of[1] do not show the oscillation spectrum responsible for the plasma heating nor its spatial distribution. An investigation of the microwave radiation $\omega \sim \omega_{c\,\min}$, which is only a small fraction of the oscillation spectrum excited in the plasma,[2,3] is not enough to construct the complete picture of the phenomenon.

It appears that the x-ray flashes observed in[1] and the cyclotron-frequency microwave flashes that correlate with them are connected with the instability of a plasma with hot electrons. It should be noted, however, that it is probable that this instability does not always develop, since one of the principal measured quantities used in the earlier experiments[5] to confirm the diffusion model of heating was the time of appearance of the x-ray flash from the target probe, and this time was strongly dependent on the radius at which the probe was located.

Without measuring the width of the spectrum in the region of the plasma frequencies responsible for the heating of the electronic component of the plasma, there are no grounds for the statement made in[1] that the energy content of the plasma should increase with increasing magnetic field intensity in the first mirror along the path of the electron beam. It is clear that an increase in the energy content of the plasma will be observed if the increase of the mirror magnetic field is accompanied by an increase in the spectrum of the plasma oscillations that fall in the cyclotron-resonance region. Since the plasma electrons pass many times through the cyclotron-resonance region, an important role is played by the time of containment of the electrons in the trap, a time determined by the minimal mirror ratio of the asymmetrical trap. It follows therefore that an increase in the energy content can most probably be observed when the magnetic field is simultaneously increased in both mirrors, which is in agreement with the results of[1].

Thus, a qualitative explanation of the results of[1] can be found within the framework of the model of stochastic cyclotron heating, and the author's conclusión that their experimental data contradict the results of[2,3] are unfounded.

[1]L. P. Zakatov and A. G. Plakhov, ZhETF Pis. Red., 20, 87 (1974) [JETP Lett. 20, 37 (1974)].
[2]R. A. Demirkhanov, A. K. Gevorkov, A. F. Popov, and O. A. Kolmakov, ZhETF Pis. Red., 15, 389 (1972) [JETP Lett. 15, 274 (1972)].
[3]R. A. Demirkhanov, A. K. Gevorkov, A. F. Popov, and O. A.

Phys.-JETP 36, 874 (1973)].
[4]R. A. Demirkhanov, A. K. Gevorkov, A. F. Popov, and O. A. Kolmakov, Zh. Tekh. Fiz. 43, 294 (1973) [Sov. Phys.-Tech. Phys. 18, 192 (1973)].

Mezhdunar. konf. po fizike plazmy i issledovaniyam po upravlyaemomu termoyadernomu sintezu (3rd Internat. Conf. on Plasma Physics and Controlled Thermonuclear Fusion Research), Novosibirsk (1968), Paper SN-24/L-3.