DOI: 10.34854/ICPAF.51.2024.1.1.122

FORMATION OF SUPRATHERMAL ION DISTRIBUTION IN Z-PINCHS *)

[1]Frolov A.Yu., [2]Vikhrev V.V., [1]Chirkov A.Yu.

[1]*MSTU N.E. Bauman, Moscow, Russian Federation, frolov@bmstu.ru*
[2]*NRC "Kurchatov Institute", Moscow, Russian Federation, vikhrev@mail.ru*

Maxwellian (i.e. thermal) ion distribution is not the best for generating nuclear fusion reactions. It turns out that there are ion energy distributions that have higher efficiency compared to the efficiency of thermal (i.e., Maxwellian) plasma. For example, for a plasma consisting of deuterium, in which the main part of the ions is cold, and a small part of the ions of this plasma is accelerated to 10 keV, then such a plasma for generating a nuclear d-d reaction is more effective compared to one in which the plasma has a thermal distribution of ions .

In the review by L.A. Artsimovich [1] (on page 9) when describing the neutron yield of the d-d reaction for two different laws of ion energy distribution; compared: 1) the distribution of ions corresponding to the Maxwellian distribution and 2) a distribution in which the energies of all ions are equal to each other. Neutron yields were compared from the same numbers of particles and the same total energy in the ions. From the comparison, it was concluded that the Maxwellian ion distribution is the best for generating a nuclear d-d reaction. However, it is not. There are distributions in which the bulk of the ions are cold, and the energy of a small number of (accelerated) ions in it is about 10 keV. Such a plasma, with the same heating costs, turns out to be more effective for generating a nuclear reaction compared to that available with thermal distribution of particles. This desired suprathermal distribution of ions in the plasma occurs when it is heated very quickly and when the ions do not have time to Maxwellize as a result of collisions.

One way to create a suprathermal distribution of ions in a plasma is for the ions to obtain energy directly from energy sources, rather than from collisions with hotter electrons. Moreover, the heating of ions to create a suprathermal distribution of ions must occur quite quickly - less than during ion-ion collisions.

The paper provides a theoretical analysis of the rapid heating of plasma to thermonuclear values in a Z-pinch due to a rapid increase in the magnetic field. This method includes heating as a result of the acceleration of ions in an electric field caused by an increase in the current value in the pinch plasma [2-3]. The increase in the magnetic field in the Z-pinch plasma is caused both by an increase in the current in the system and by compression of the magnetized plasma together with the magnetic field. The electric field arising due to an increase in the magnetic field strength in it accelerates the ions in the direction along their movement along the Larmor circle. As a result of an increase in the magnetic field in the pinch plasma, the energy of the ions increases in proportion to the energy they already have. This leads to the generation of ions in plasma with a suprathermal distribution.

At the final stage of ion acceleration as a result of this mechanism, particles emerge from the pinch, the energy of which exceeds both the thermal energy and the energy of the particles that acquire energy during the full passage of the voltage used to generate current in Z-pinch discharges.

References

[1]. Artsimovich L.A. Controlled thermonuclear reactions, 1961.
[2]. Budker G.I. Plasma physics and the CTR problem, vol. 1, p. 122 (1958).
[3]. Schluter A., Zeitschrift fur Naturforchung, 1957, 12a, 822.

*) abstracts of this report in Russian