TEMPERATURE DETERMINATION FROM X RAY EMISSION OF THE TOKAMAK TM-3 APPARATUS

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In the Tokamak T-3 and TM-3 installations, under conditions in which the energy input per particle is large, diamagnetic measurements yield for the average transverse particle energy $T_{\perp}$ a value on the order of several hundred electron volts [1], whereas the ion temperature determined from the spectrum of the neutral charge-exchange atoms is several dozen electron volts [2]. Consequently, the diamagnetic signal is connected essentially with the electrons. It is therefore of definite interest to study the spectrum of the x-ray quanta emitted by the plasma under such conditions.

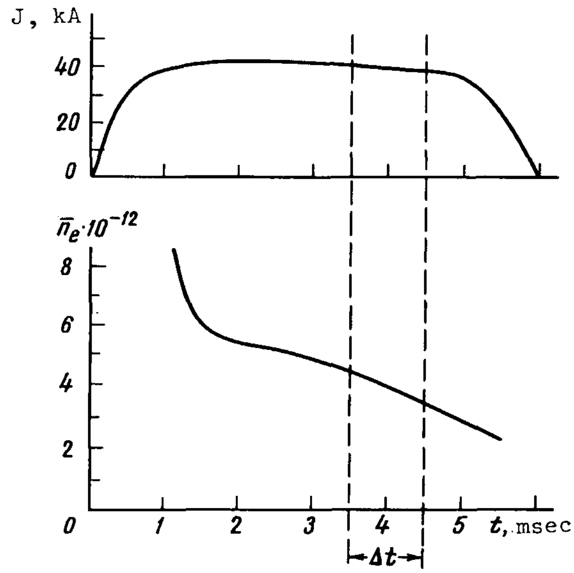

Fig. 1. Current in plasma and average electron density n_e in TM-3 installation. Initial hydrogen pressure $P_0 = 4.5 \times 10^{-4}$ mm Hg, longitudinal magnetic field H_Z = 26 kOe, plasma current 40 kA.

1. The conditions of the TM-3 installation of interest to us are characterized by the following: a - a quasistationary magnetic field with a half-period of 80 msec; b - constant current during one part of the process; slow time variation of parameters such as the displacement of the current pinch, conductivity, density, etc. (Fig. 1). This makes it possible to perform measurements with averaging over a time interval ~1 msec, for example, amplitude analysis in a "window" of duration Δt = 1 msec; c - high reproducibility of the plasma parameters from discharge to discharge, making it possible to compensate the low radiation power by accumulating statistics for a large number of discharges under identical conditions.

2. The soft x-radiation (quantum energy range 3 - 12 keV) was investigated by means of an amplitude analysis performed with a flow-through gas proportional counter as a detector. The auxiliary media for the study of the spectrum were absorbing filters made of different materials (aluminum, copper, nickel, terylene, lead). One of the ob-

tained radiation spectra is shown in Fig. 2. We see that this spectrum can be approximately represented in the form $I_x \sim \exp(-h\nu/\theta_x)$, introducing thereby some energy parameter θ_x and considering the electron distribution function in the indicated electron energy range as part of a Maxwellian distribution with temperature θ_x. The value of θ_x for the spectrum of Fig. 2 is 1.2 keV.

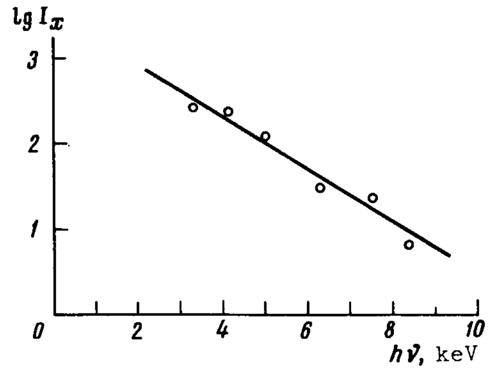

Fig. 2. Logarithm of x-ray intensity vs. quantum energy under the conditions of Fig. 1.

3. On the basis of the measurements of the absolute intensity of the soft x-radiation and of a spectroscopic study of the composition and concentration of the impurity ions it is possible to estimate the number of "hot" electrons in the plasma for different concrete types of plasma-parameter distribution over the smaller radius of the torus. A typical figure obtained from concrete estimates of this type is ~50% of the total number of electrons.

4. Can these results be explained as due to the existence of current of accelerated electrons having a Maxwellian energy distribution and moving along the torus axis? It turns out that the current of such electrons would exceed by several times the measured total current in the plasma. Consequently, the velocity directions of the "hot" electrons should be sufficiently randomized, and it is meaningful to compare θ_x with the results of the diamagnetic measurements. For the experimental conditions listed above, diamagnetic measurements yield $T_\perp$ = 800 eV, which is in good agreement with the results of the x-ray measurements.

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[1] L. A. Artsimovich, G. A. Bobrovskii, et al., Atomnaya energiya 22, 259 (1967).
[2] V. V. Afrosimov and M. P. Petrov, Zh. Tekh. Fiz. 37, 1955 (1967) [Sov. Phys.-Tech. Phys. 12, (1968), in press]