Observation of x-ray spectra of chromium and iron in the plasma of the "tokamak-10"

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The T-10 installation was used to obtain the x-ray spectra of highly ionized Fe and Cr atoms, with an energy resolution 20 eV. The plasma parameters were $n_e(0) \sim 7\times10^{13}$ cm^{-3} and $T_e(0) \sim 1.2$ keV. The chromium admixture estimatec from the analysis of the spectrum is $n_{Cr} = 10^{10}$ cm^{-3}.

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A study of the spectra of multiply charged ions is not only of general physical interest but (also be used as an effective method of measuring the parameters of a high-temperature plası This explains the large number of both experimental and theoretical papers devoted to recording and the analysis of such spectra in cosmic and laboratory plasma.[1-7]

Using the T-10 installation, we have recorded the x-ray spectrum in the quantum-ene range $E=5$, 3–7 keV with an energy resolution 20 eV. We used an LiF crystal, cut along the (2 plane and bent with a radius of 30 cm, in a Johann-type spectrograph. The position of spectrograph on the installation is shown in Fig. 1.

The exposure was effected in runs of ~ 80 discharges, most of which had parameters close those described in[8]: the current in the plasma was 400 kA, the longitudinal magnetic field was kOe, and the electron temperature and the density inside the pinch were 1.2 keV and 7×10^{13} cr Sections of a spectrum obtained in one of the runs are shown in Fig. 2, which gives also positions of the principal lines of the $1s$–$2p$ transition for different ionization states (spectrosco symbols are used).

Notice should be taken of the similarity between this spectrum and the results given in[3-5], ε particularly with the iron spectrum obtained using a crystal monochromator on the ST tokamak the same electron temperature in the center of the plasma pinch.[5] However, both the iron x-

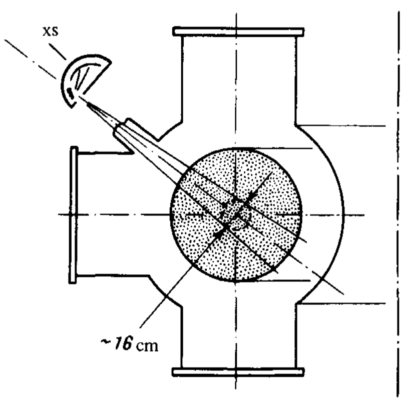

FIG. 1. Position of the spectrograph on the tokamak-10 installation.

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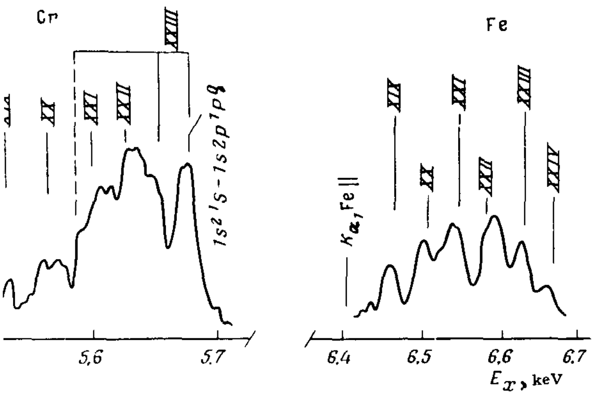

. 2. Averaged micrograms of the x-ray spectra of one run of T-10 discharges.

trum obtained with the ST installation and the iron spectrum obtained with T-10 differ from ·esult of calculations performed in[7] within the framework of the stationary model. This applies .lly well to the chromium spectrum calculated by the authors and measured with the T-10. nates show that it is impossible to explain fully the difference between the calculated spectrum the experimental spectrum obtained with the T-10, even if account is taken of the radial ibutions of the electron temperature and of the density, or of the contribution of the radiation ng the initial and final stages of the discharge. It is possible that the explanation requires vance for such factors as the finite time that the ions stay in the hot central zone of plasma h, and also for the inaccuracy in ionization and recombination rate coefficients used in the ılations. Thus, for example, the experimental spectra of iron obtained with ST and T-10 are : similar to that variant of the theoretical spectrum which was obtained in[7] by decreasing the :ation rate by one-half (compared with the principal variant of the calculation) (see also[9]).

The obtained spectra of the heavy impurities, together with the absolute measurements of the of the quanta of these groups of lines, can be used to estimate the concentrations of chromium iron in the central zone of the plasma pinch. One of the approaches to these estimates is based ıe use of the radiation power of the entire group of "K-lines" at a specified temperature T_e, and parison with this power with the measurement results. Another approach is to use measure- ts and calculations of the powers of the individual spectral lines, and can be applied, for ıple, to the He-like chromium ion Cr XXIII (see the $1s-2p\ {}^1P_1$ transition on Fig. 2). To ıate the total chromium content it is necessary in this case to calculate the fraction of the He- ions. Calculation of the radiation power of all the ions is not necessary, and consequently, in rast to the first case, there is no need for knowing a number of rate coefficients. The use of the nd approach yielded for chromium an estimated concentration $n_{\mathrm{Cr}}=10^{10}$ cm^{-3} in the central ›n of the plasma pinch. This estimate was obtained by using the experimental results, cited in[8], ıeasurements made in this region of the spectrum with the aid of a proportional counter.

We note that for T-10 the measurements of the chromium concentration are of particular ·est. The point is that the structural materials of the vacuum seem to contain approximately a ·tant percentage of chromium relative to the total amount of iron and nickel, a fact that can be to estimate the contribution of all three impurities to the effective charge of the plasma ions ıming that the concentration ratio of these elements in the plasma is a reflection of their entage contents in the chamber walls). In this case the estimates yields for the central region of pinch $\Delta Z_{\mathrm{eff}}=0.3$, in good agreement with the result obtained by other methods.[8]

It should be noted in conclusion that an analysis of the x-ray line spectra is a most useful a effective method for the investigation of impurities in closed systems such as the tokamak.

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