DOI: 10.34854/ICPAF.51.2024.1.1.225

# THE FIRST RESULTS OBTAINED ON THE T-11M TOKAMAK USING MULTICHANNEL DIFFERENTIAL REFRACTOMETRY DURING LITHIUM EXPERIMENTS *)

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The report presents a density measurement system implemented on the T-11 M tokamak based on differential refractometers (DR) with ordinary wave, and describes the first results obtained with its in-lithium experiments [1] on the T-11 M tokamak. In addition to the existing refractometer channel, which measureв electron density along the central chord -1 cm, two more channels have been added recently, measuring density along the two chords -9 cm and +7 cm. Additional channels are also made on the basis of a differential refractometer, with plasma probing by microwaves in the frequency range of about 140 GHz. Position of the lateral probing chords can be changed from discharge to discharge, thus allowing, in principle, to measure the electron density profile in several discharges. The central channel is used in this case to control the average electron density during the discharge. The physical basis of the differential refractometer, which measures the delay time of the microwave signal transmitted through the plasma, was described earlier in [2, 3]. The delay time of the signal in the plasma is determined by the formula:

$$\Delta t_{gr,O} = \frac{d\varphi(\omega,z)}{d\omega} \approx \frac{\Delta\varphi_1(\omega_1,z) - \Delta\varphi_2(\omega_2,z)}{\Delta\omega} = \frac{\Delta\varphi_{12}}{\Delta\omega}, \quad (1)$$

where $\varphi(\omega, z)$ is the phase of the probing wave, $\omega$ is the cyclic frequency of the probing wave, indices 1 and 2 refer respectively to the 1st and 2nd waves of the differential refractometer. In a differential refractometer, the plasma is probed by two waves with close frequencies $\omega_1$ and $\omega_2$, and the phase difference between the two waves is measured as they passed through the plasma. Formula (1) is valid in the approximation of geometric optics, when plasma is probed by microwaves with frequencies higher than plasma frequency (in the case of an ordinary wave). In DR, the frequency difference is selected in such a way that the measured phase difference does not exceed $2\pi$, thus ensuring the unambiguity of density measurements.

A similar measurement principle, but with the use of amplitude modulation (AM) and with probing by X-wave microwaves in the ITER plasma transparency region, will be used at ITER [4], while in TRT tokamak, it is possible to use a DR scheme with different probing frequencies [5]. Not AM, but DR scheme was chosen in the T-11 M tokamak due its higher sensitivity compared to AM scheme in the low-density regimes (in practice, AM-frequency, as a rule, is less than 100 MHz, while $\Delta f$ in DR scheme can be much higher).

The calibration curves of the refractometer (the dependence of the delay time (phase shift) on the average chord density of the plasma) are calculated. The first results of measurements of average density on a tokamak T-11 M during lithium experiments are presented.

The work was carried out under the contract with Rosatom State Corporation No. N.4k.241.09.22.1061 dated 04/14/2022.

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*) abstracts of this report in Russian