DOI: 10.34854/ICPAF.52.2025.1.1.228

MEASUREMENTS OF PLASMA DENSITY IN T-11M TOKAMAK BY MICROWAVE DIFFERENTIAL REFRACTOMETRY *)

[1,2]Petrov V.G, [1,2]Dzhurik A.S., [2]Lazarev V.B., [2]AgeevA.V., [2]Shcherbak A.N.

[1] *PC ITER ROSATOM, Moscow, RF, vpetrov1952@yandex.ru*
[2]*JSC "SRC RF TRINITI", Moscow, RF, v_lazarev@triniti.ru.*

The report presents a density measurement system implemented in theT-11M tokamak based on microwave differential refractometers probing by ordinary wave at a frequency of about 140 GHz. The geometry of two-channel probing is described. The differential refractometer measures the time-of-flight delay of the microwave signal transmitted through the plasma [1, 2, 3]. The delay time of the signal in the plasma is determined by the formula:

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

where φ(ω,z) is the phase of the probing wave on chord with a coordinate z, ω is the cyclic frequency of the probing wave, indices 1 and 2 refer respectively to the 1st and the 2nd waves of the differential refractometer [2]. In a differential refractometer, plasma is probed by two waves with close frequencies ω_1 and ω_2, and the phase difference between the two waves is measured as they pass through the plasma. The frequency difference is selected in such a way that the measured phase difference does not exceed 2π. Thus, the unambiguity of density measurements is ensured, while at the same time it leads to a decrease in an accuracy of density measurements. The first results obtained using a two-channel refractometer in lithium experiments [4] are presented. It is shown that the measurement accuracy of the instrument is ±0.1 degrees (in terms of the integral of the probing chord nl = $\pm 2\cdot10^{12}$ cm^{-2}). In plasma experiments, the error in phase measurements increased and amounted to ± 1 degree with time resolution of 10 μs; after averaging a signal with a deterioration in time resolution up to 100 μs, the error in phase measurements was ±0.33 degrees (in terms of nl: $\pm 6.7\cdot10^{12}$ cm^{-2}) in the density range nl = $10\text{-}75\cdot10^{13}$ cm^{-2}. In the low-density regimes, the minimal measurable density in terms of nl was $0.5\cdot10^{12}$ cm^{-2}. The data is recorded in digital and analog forms as well.

Such instrument can be useful in devices with a long discharge, for example, in the conditions of the ITER tokamak, where it was proposed for measurements of the average plasma density along the chord (with probing by X-wave in the plasma transparency region between the low cut-off frequency and the frequency of the electron cyclotron resonance), as an additional channel of the reflectometry system from the high magnetic field side currently being implemented in the Russian Federation [5].

The work was performed under contracts with State Corporation "Rosatom" No. N.4k.241.09.22.1061 dated 14.04.2022 and No. N.4k.241.09.24.1040 dated 16.04.2024.

References

[1]. Petrov V.G. et al. Instrum. and Exper. Techn. V. 49. No. 2. 2006. P. 238–243.
[2]. Petrov V.G. et al. Plasma Phys. Reports. V. 32. No. 4, 2006. P. 317–322.
[3]. Petrov V.G. et al. Proceeding of 51 Zvenigorod conference18-22 March 2024. ICPAF-2024. P. 274.
[4]. Mirnov S.V., et al, Plasma Physics and Controlled Fusion 48 (2006) 821S.
[5]. A.V. Krasilnikov, et al. Progress with the ITER project activity in Russia. Nuclear Fusion. 2015. V. 55. No 10. P. 104007.

*) abstracts of this report in Russian