

Investigation of the NBI heated plasma on the Globus-M tokamak with the use of Thomson scattering diagnostics.

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Abstract. Electron temperature and density spatial distribution dynamics on the Globus-M ($R=0.36$ m, $a=0.24$ m, $B=0.4$ T, $I=0.2$ MA) spherical tokamak was investigated during the NBI heating. The key tool of this research was the upgraded Thomson scattering diagnostics with variable intervals between probing pulses (20 pulses in total). The scattering points were placed along the major plasma radius from the inner to the outer plasma border (10 points in total). Simulation of the electron transport in the L and H-mode, based on experimentally measured $n_e(R)$ $T_e(R)$ profiles was carried out using the code ASTRA for the OH and NBI dischargers.

1. Thomson scattering diagnostics at the Globus-M tokamak

The Thomson scattering diagnostics with a variable delay between probing pulses [1] became

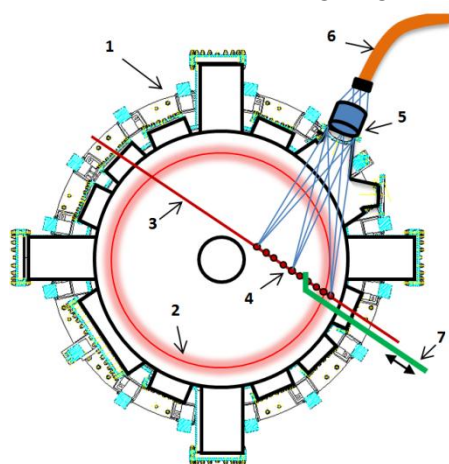


Figure.1. TS light collection system. 1- Globus-M vacuum vessel, 2 – outer plasma border, 3- laser beam, 4 – TS measurement points, 5- collection lens, 6- fiber line, 7- magnetic drive

the key instrument to perform the dynamic measurements of the electron temperature and density profiles. The Nd-glass laser (the basic wavelength 1.054 μm) can generate up to twenty 2-4 J pulses with intervals of 0.3 -1000 ms. During 2008-2009 the Thomson scattering (TS) diagnostics upgrade was made. The layout of the experiment is shown in figure.1. A new observation point and high quality collection lens allowed to pick up the scattered radiation from inner to outer plasma border with minimal light losses. The TS system was equipped with the five novel 4-channel filter polychromators. It allowed us to decrease the measured electron density down to 10^{18}m^{-3} owing to the optical scheme optimization and the reduced noise amplifiers for avalanche photodiodes (APD). A new magnetic drive can move the beam-marker (7 in figure 1) along the laser axis to align collection system and promptly check the position of the ten TS measurement points without vacuum break. The filter polychromators and the

registration system were placed to the special thermo stabilized room. The optical connection was performed though the fiber lines with low losses.

2. Experiment and modelling.

1.5D code ASTRA [2] was used for experimental data processing. The following experimental data was used in modeling: plasma current, the shape of the plasma boundary (taken from the equilibrium reconstruction EFIT [3]), spatial distribution of the electron temperature and density, measured with

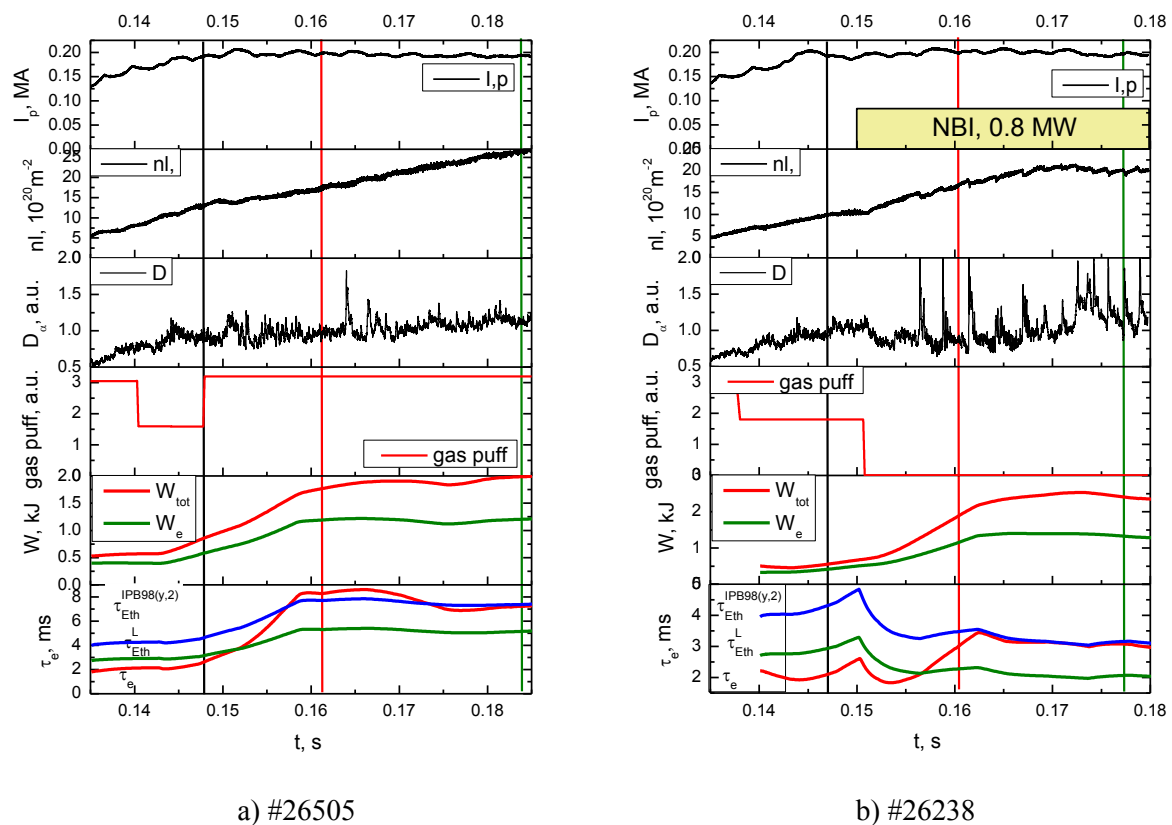


Figure 2. Main plasma characteristics. a) OH discharge. b) NBI discharge. Plasma current, line average density measured along the vertical chord at the position $R=0.42$ m, D_α emission, gas puff rate, plasma total stored energy and electron energy content, confinement time and scalings for H and L modes.

temporal resolution of 5 ms between pulses. The transport model consists of a system of the diffusion equations for electron and ion temperatures, the equation for the poloidal flux and the Grad-Shafranov equilibrium equation. The plasma conductivity and ion heat diffusion coefficients were derived by the neoclassical code NCLASS [4]. The equation for plasma density is not considered in this presentation. The experimental density spatial distribution was taken for modeling. The effective plasma charge was taken in such way that calculated loop voltage should be equal to the loop voltage measured in the experiment. Two discharges are considered in this work, ohmically heated and with NBI injection of hydrogen atoms with energy 27 keV [5]. The temporal distributions of the main discharge parameters are shown in figure 2. The L-H transition is observed in both discharges at the time 150 ms. In the case of NBI heated discharge the L-H is clearly observed: one can see the density rise and drop of the D_α emission. In the case of the OH discharge the moment of the transition is not clearly seen due to the strong gas puff. But the moment of the transition can be observed in the electron temperature and density spatial distribution changes. It also

should be noticed that the effective plasma charge changes from 1.3 to 2.3 during the NBI, that may be the result of plasma-wall interaction growth.

3. Discussion and conclusions.

Electron temperature and density profiles and the calculated electron heat diffusivity are shown in figure 3 for 3 time slices: for L-mode, after L-H transition and in the end of the discharge. The shown profiles corresponds to the vertical markers in figure 2. The density rise

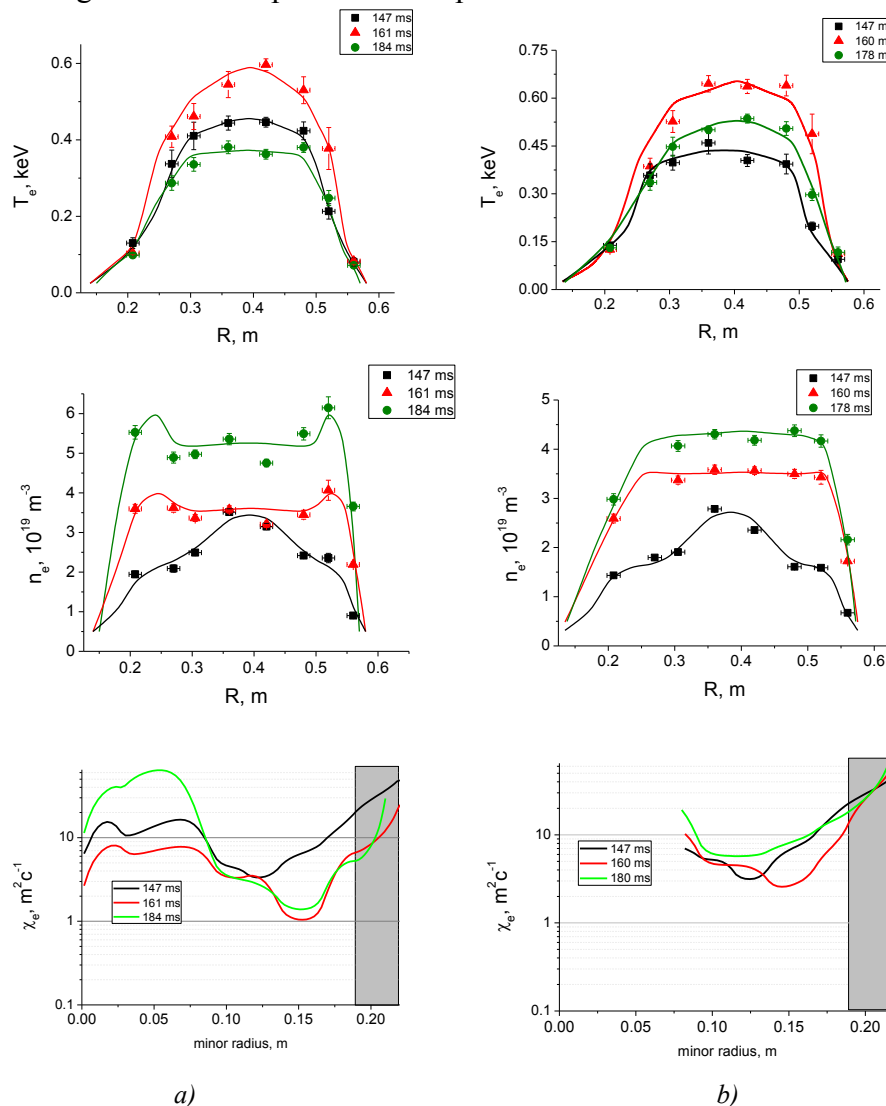


Figure 3..Measured electron temperature and density spatial distribution and calculated electron heat diffusivity – a) OH, b) NBI.

moment. At this moment one can see the high gradient region in the temperature profiles in the point $r/a \sim 0.65$, that is typical for both discharges. The electron heat diffusivity drops at this point by 6 times in OH discharge, and by 10 times in NBI discharge. This allows to suggest an internal transport barrier (ITB) formation there. As the density rises further, the temperature decrease is observed, so the energy content doesn't change. The confinement time coincides with IPB98(y,2) scaling. Usually L-H transition occurs when the heat power in the ion channel exceeds the value of the threshold power P_{th} [7]. In the NBI discharge the

and the formation of the “flat top” density profile are observed during the L-H transition in both cases, that is usual for H-mode. The density rise is the result of the drop of the diffusivity at the plasma edge and formation of the transport barrier for particle diffusion [6]. Electron heat diffusivity decreases by 3-4 times in OH discharge and by 2-3 times in the discharge with NBI. During the density rise, electron temperature rises too, and reaches maximum value after 10 ms after the L-H transition

value of the P_{th} is equal to 72 kW during the L-H transition. The part of the NBI heating power is 28 kW at the moment of transition. The moment of the L-H transition in the OH discharge is suggested between 147 ms and 152 ms, according to the TS data. During this period the heat power in the ion channel rises from 63 kW to 80 kW, and reaches the value of 70 kW at the 150 ms. The value of P_{th} derived in this discharges is higher than prediction of the scaling obtained on MAST and NSTX [6], $P_{th}=20$ kW.

The measurements performed with upgraded TS diagnostics at the Globus-M tokamak allowed to obtain electron heat diffusivity spatial distribution. The transport analyses was performed for the OH and NBI heated discharges, and in both cases occurrence of the ITB formation in the region $r/a \sim 0.65$ was found during L-H transition. Also it was discovered that the electron heat diffusivity rises toward the edge of the plasma. In this case further investigation is required. Influence of the spatial distribution of Z_{eff} and radiation losses should be more carefully analyzed. Values of electron temperature, density and neutrals density at the plasma boundary are also required.

References

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