*33rd EPS Conference on Plasma Phys. Rome, 19 - 23 June 2006 ECA Vol.**30I**, P-4.094 (2006)*

SIMULATION OF PLASMA RADIATION FOR OHMICALLY HEATED T-10 DISCHARGES.

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Results of numerical simulation of plasma radiation for Ohmically heated T-10 discharges with different parameters for SS wall and carbon limiters are presented. Comparison with the experimental data helps to obtain an extensive information about impurity behaviour and about some parameters of the bulk plasma. In experiments plasma radiation in wide photon energy range was measured by 16-channels system of silicon AXUV-photodiodes, total radiation energy losses including neutral particle fluxes were measured by the scanning pyroelectric detector and Si(Li) X-ray spectrometer has been used for the measurement of spectrum in the energy interval 3-20 keV.

Modelling of impurity behaviour was performed by the ZIMPUR impurity code [1], which allows simulation of transport, charge state and the total spectrum of radiation for a complete ion set of impurities under consideration. In this series of simulations impurities behaviour has been considered using experimental radial profiles of the bulk plasma temperature and density by ASTRA transport code [2]. Investigations have been done for the steady-state stage of discharges with the plasma current I_p= 200-300 kA and the line averaged plasma density n_e~ (3–5)$\cdot 10^{19}m^{-3}$. Fig. 1 shows main discharge characteristics, signals from different chords of scanning bolometer and summary power measured by scanning bolometer and AXUV detectors for the discharge with B_o = 2.4 T , I_p = 300 kA, n_e ~ 3.8 $10^{19}m^{-3}$.

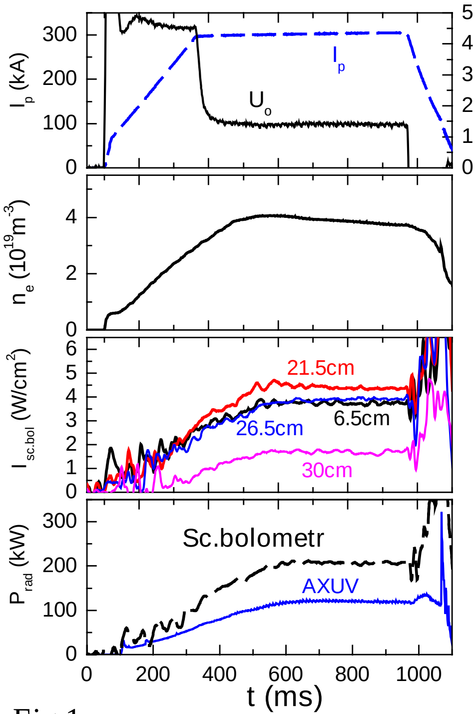

Fig.1

At the modelling of impurity ions transport we take into account both the neoclassical and anomalous transport coefficients, relation of which was selected to reproduce radial profiles of impurity ions which give the best description of time dynamics of experimental radial profiles of radiation. Simultaneously we tried to reproduce the value of loop voltage what help to fit necessary concentration of light impurities (because light impurities have more strong effect on Z_{eff} than on a plasma radiation) and reproduce soft X-ray spectra to verify high-Z impurity content in plasma. To fit necessary impurity contamination in simulations we change impurity fluxes on the plasma boundary. Iron impurity was used as a characteristics of the wall material (other components Cr and Ni have closed charges and masses). Relation of light impurities C and O was fitted to produce more smooth profile of radiation more closed to the experimental one (maxima of these elements radiation have some shifts), but without special spectroscopic measurements this division of light impurities has small accuracy and its summary concentration is more adequate value.

Comparison of radiation measured by AXUV detectors and pyroelectric bolometer (which measures a sum of radiation and neutral particles fluxes) allows estimation of neutral deuterium concentration in plasma column and more exactly taking into consideration influence of neutrals on ionization state of impurities and its radiation. Calculation of plasma radiation spectrum in the small quantum energies region permits to take into account variation of sensitivity of AXUV detectors in this region.

Figures 2, 3 demonstrate results of simulation for characteristic regime, parameters of which are shown in Fig.1. Comparison of calculated (solid lines) and experimental (markers) chord fluxes of radiation measured by pyroelectric and AXUV detectors is shown in Figs. 2a and 2b. Calculated power of charge exchange neutrals taking account of plasma opacity, which helps to reproduce difference of these signals, is shown on Fig.2a by dashed line. Fig. 2c demonstrates radial profiles of radiation of

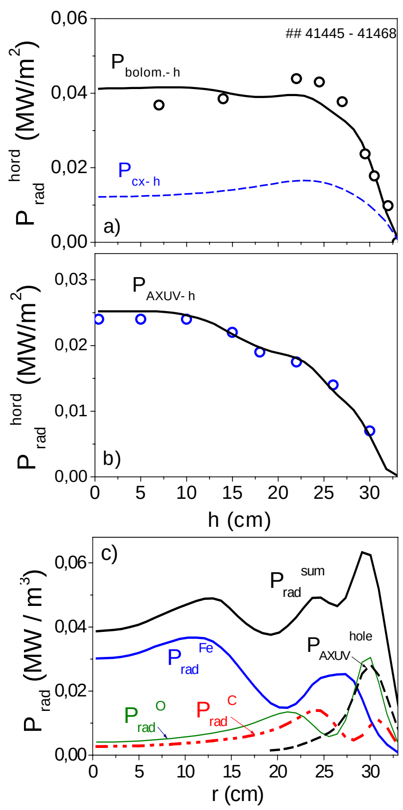

Fig. 2

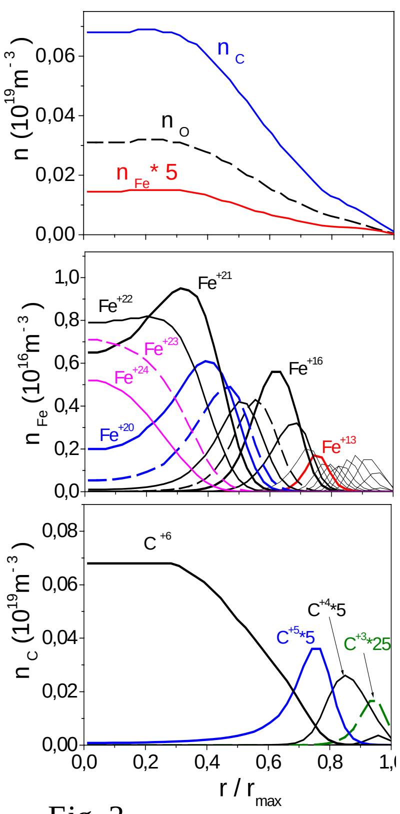

Fig. 3

different impurities and profile of the total radiation for this regime. Modelling shows that enhanced local radiation from the central regions to a considerable extent can be explained by radiation of iron ions. In the outer plasma regions fraction of radiation of light impurities and hydrogen increases. Black dashed line (P_{AXUV}^{hole}) in Fig.2c shows fraction of radiation which does not register by AXUV detectors due to decrease of its sensitivity in small quanta energies region. One can see that these detectors appreciable underestimate radiation in the periphery regions. However, input of this effect in the total radiation is not high. Calculated profiles of different iron and carbon ions concentration and summary profile of impurities density are presented in Fig. 3.

Comparison of experimental and calculated soft X-rays spectrums (Fig.4) confirms iron content in plasma. One can see Fe and Cr k-α lines in the experimental spectrum. Total level of calculated radiation in this energy interval is in a good agreement with the experiment.

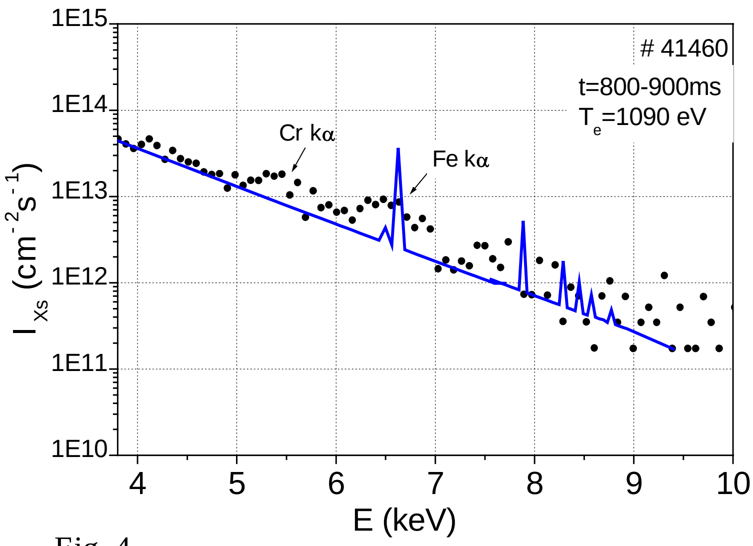

Fig. 4

For the relative impurity contamination in this discharge we obtained values $n_{Fe} / n_e =$ 0.042%, n_C/n_e= 0.95%, n_O / n_e= 0.44%. Estimations of deuterium atomic density on the plasma boundary take into account increase of this density near the limiter (for this we use the relative D_α intensity and estimations of this zone width [3]) give the value ~ $3.4 \cdot 10^{16}$м$^{-3}$.

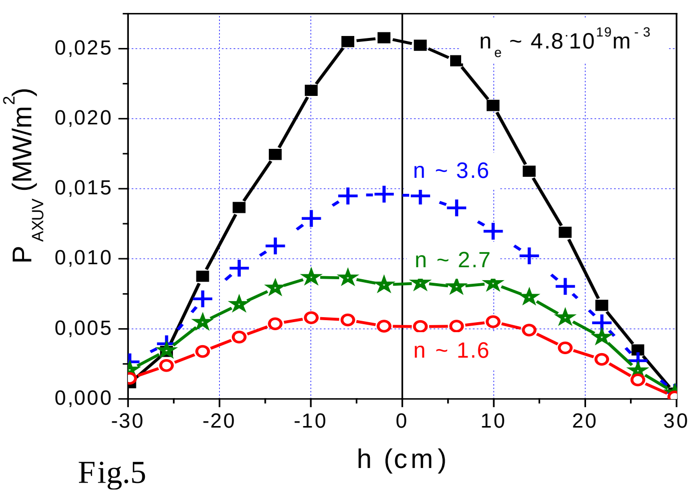

Fig.5

Radial profiles of plasma radiation measured by AXUV detectors (without corrections on change of its sensitivity) in regimes with different density and plasma current ~ 200 kA are shown in Fig.5. This Fig. demonstrates more flat profiles in small density regimes.

Evolution of radial profiles of different impurity ions concentration permits to calculate impurity transport coefficients for discharges under consideration. Simulations for discharges with different plasma densities have been done. At high density (closed to the density limit) results are not contradicted to the assumption on neoclassical impurities transport in the plasma core. For the explanation of more flat impurity concentration profiles and its dynamics at smaller plasma density it is necessary to introduce anomalous transport coefficients which increases with plasma density decrease.

CONCLUSIONS.

Modelling of radial profiles of plasma radiation in different energy intervals for ohmically heated T-10 discharges permits to achieve information about composition of light and heavy impurities in plasma and on radial distributions of concentrations of the total ion set of these impurities.

Calculation of the total plasma radiation spectra allows to take into account variations of sensitivity of AXUV detectors versus quanta energies. As simulations showed, for T-10 plasma parameters this effect is more important for the radiation from the plasma periphery but influence on the total radiation is not high.

Comparison of radiation measured by AXUV detectors and pyroelectric bolometer allows estimation of neutral deuterium concentration in plasma column and more exactly taking into consideration influence of neutrals on ionization state and radiation of impurities.

Modelling showed that the local radiation from the central plasma regions in considered discharges to a great extent can be explained by radiation of iron ions and in the outer plasma regions fraction of radiation of light impurities and hydrogen increases. Rise of the radiation profiles peaking factor with increase in the plasma density indicates increase of impurity accumulation.

Modelling of radial profiles of impurity concentration and its dynamics demonstrated considerable role of the neoclassical impurity transport in plasma core for regimes with middle and high plasma density. For the explanation of more flat impurity concentration profiles and its dynamics at smaller plasma density it is necessary to introduce anomalous transport coefficients role of which increases with plasma density decrease.

The work is supported by Nuclear Science and Technology Department of Minatom RF and grant SS-1880.206.2.

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