Development of laser induced fluorescence system for ITER divertor plasmas

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1. Introduction

ITER specifications for divertor plasma measurements [1] include rather serious problems for spatial and temporal resolution requirements; for example, requirement for spatial resolution of ion temperature measurements is equal to 3 mm across divertor leg. It seems to be evident to apply laser methods in such situation. The functions of laser induced fluorescence (LIF) system under development are measurements of helium atom density (n_{He}) and ion temperature (T_i). Interpretation of LIF-signals with aim to infer n_{He} density values via collisional-radiative model (CRM) needs information on electron temperature and density. Co-operative arrangement of LIF and Thomson scattering (TS) systems in the same divertor port of ITER seems to be of importance from the point of view of providing the necessary information. Doppler measurements of ion temperature will be performed by laser spectroscopy method (by scanning narrowband laser line over absorption spectral line profile). Integration of LIF technique into ITER diagnostics system, optical arrays, laser source of probing radiation, detection system are briefly described in the paper.

2. Integration of LIF technique into ITER diagnostic system

The LIF and TS systems use common in-vessel optics in ITER divertor port(see Fig. 1)

The optics designed for Thomson scattering system is planned to be used for application of LIF technique as well. Important feature of the arrangement is combining of beam direction of both diagnostics. It is also necessary to separate scattered and fluorescent light signals after common collecting by in-vessel optics. A number of decisions to combine two laser beams has been proposed; Figure 2 shows these schemes.

The choice of optical scheme described above gives an opportunity to make more precise estimate of relevant divertor plasma parameters. The results of 2D-modelling of ITER divertor plasmas [2] for spatial points on lasers beam line have been used for *a priory* estimate of fluorescence signals. An example of spatial distribution for electron density and temperature, helium density $n_{He\,I}$ and ion temperature is shown in Figure 3.

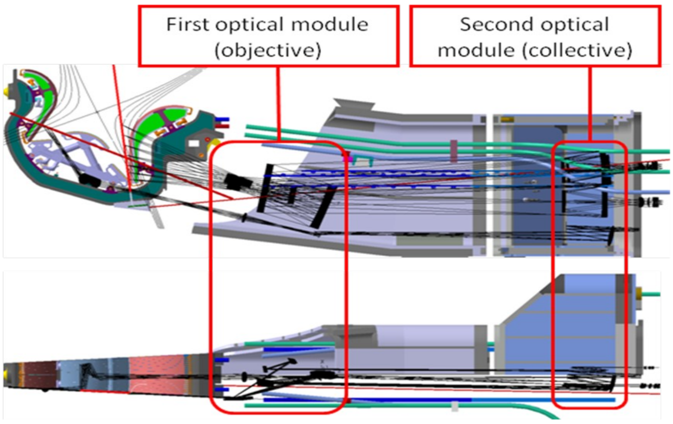

Fig. 1. Schematic view of LIF and TS systems installed in ITER divertor port.

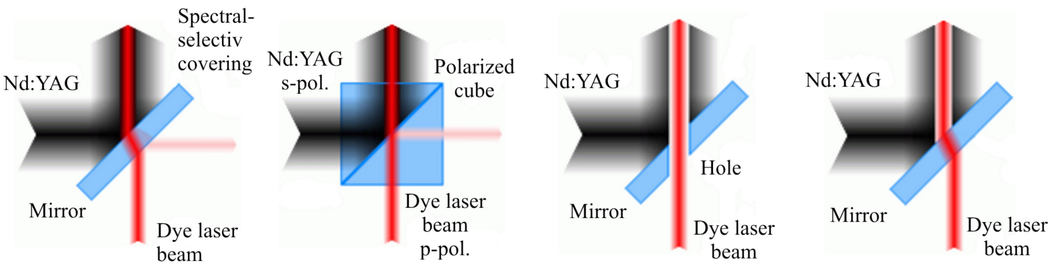

Fig. 2. Optical scheme of combining probing laser beams of LIF and TS systems.

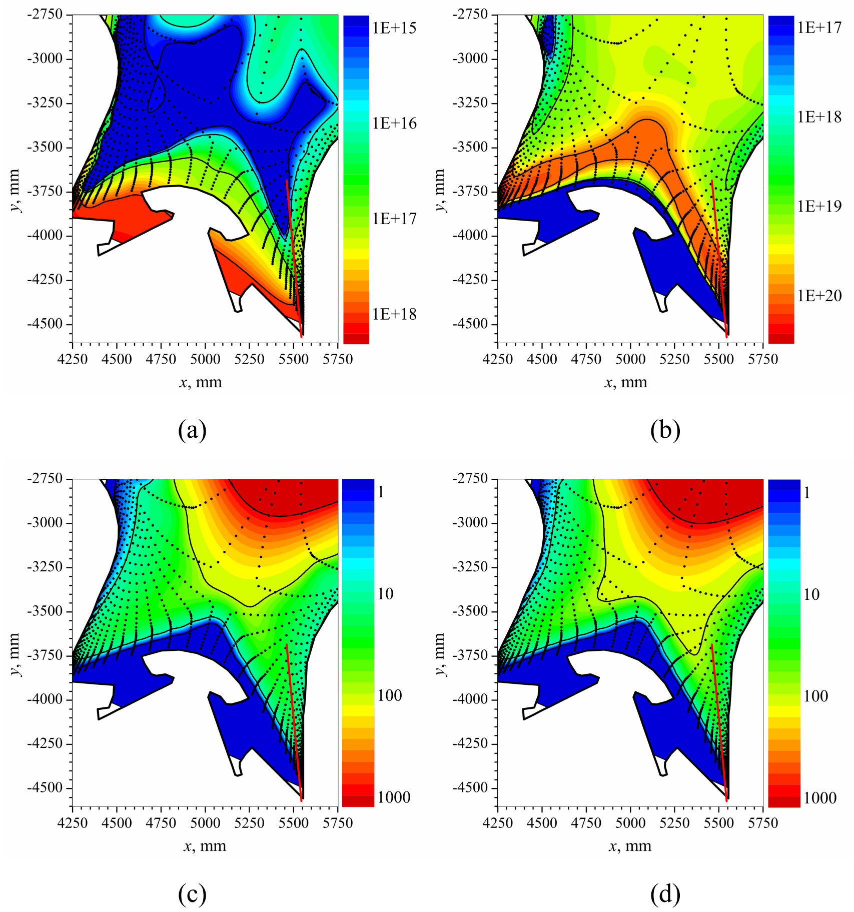

Fig. 3. 2D-modelling of ITER divertor plasma parameters (a) n_e, (b) T_e, (c) n_{HeI} and (d) T_i.

3. Laser transmitter and detection system

Pulse-periodic dye laser considered to be a source of tunable, narrowband probing radiation for application of LIF technique. It is planning to utilize excimer XeCl-laser. Dye laser pumped by harmonics of Nd:YAG laser radiation is also considered now as laser transmitter for application of LIF technique in ITER experiments. (see Fig.4). Although CRM calculations for helium atom in ITER divertor plasmas demonstrated, that laser pulse energy in range of $0.1 < E_L < 1$ mJ is enough for saturation of fluorescence signals, however it is planned to use laser with pulse energy up to $E_L \sim 20$ mJ. It gives opportunity to compensate probable degradation of in-vessel optical array.

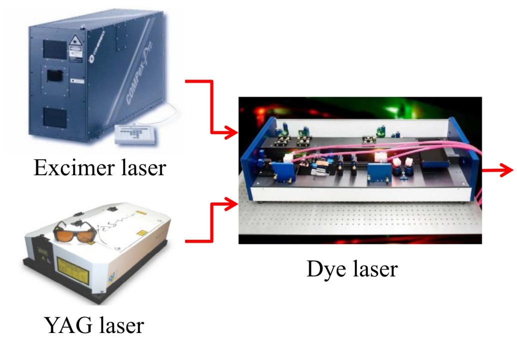

Fig.4 Laser transmitter

The prototype of transmitter for ITER is dye laser pumped by excimer XeCl-laser which has been used in modelling experiments at PNX-U machine in Kurchatov Institute [3,4]. Measurements of density and temperature of helium atom and argon ion Ar II have been carried out; a number of ITER requirements (for example, spatial resolution) were taken into consideration. During long experiments, lasers demonstrated good performance and reliability; an example of fluorescence signal on argon ion Ar II is shown in Fig. 5.

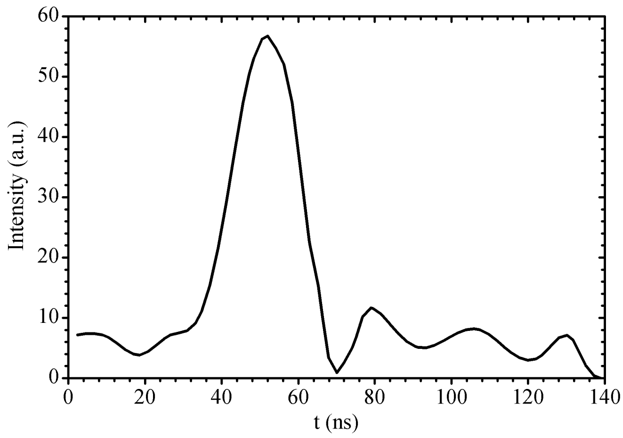

Fig. 5. Typical fluorescence signal waveform at 461.0-nm spectral line of Ar II ion.

The choice of this laser source is optimal from point of view of helium density measurements when laser pumping at λ_L = 587.6 nm is used (fluorescence wavelength is λ_{FLU} = 388.9 nm). Detection system includes: filter spectrometers for spectral selection of fluorescence lines, photomultiplier tubes as detectors of fluorescence light signals and digitizers

4. Ion temperature measurements by laser spectroscopy method

Ions of extrinsic (Ne, Ar and Kr) and intrinsic (Be) impurities are planned to use as "targets" for ion temperature measurements. (Rare gases are planned to inject into ITER plasma in order to obtain "radiative improved" modes). Probability of simultaneous injection of two gases (for example, Ar and Ne [5]) also was taken into account. Under ITER conditions the transition from helium atom density LIF measurements to measurements of ion temperature requires remote handling (change of laser wavelength λ_L without replacing of lasing media). It is possible in the case when both λ_L are in spectral range of the same dye. For application the LIF technique without change of the dyes, the schemes with close values of a wavelength of a probing source (λ_l) are chosen: λ_l = 369.4 nm, λ_{FLU} = 376.6 nm for Ne II; λ_l = 378.6 nm, λ_{FLU} = 488 nm for Ar II. Development of pairs of such spectroscopic schemes is now in progress.

5. Summary

LIF-technique has a huge potential as a diagnostic tool. Method can be used to gain information about such important plasma parameters as atom and ion temperature and density. Another significant feature of the LIF-diagnostic is good resolution in temporal, spatial and spectral units in comparison with other existing diagnostics methods. Taking into account all of the above, significant potential for LIF-technique exists and it would be wise to apply it to the wide field of challenges that still remain in modern plasma physics.

References

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