§12. Electron Density Distribution Measurement Technique in the Ablating TESPEL Cloud

Sergeev, V. (St. Petersburg State Polytechnical Univ.),
Sharov, I. (St. Petersburg State Polytechnical Univ.),
Miroshnikov, I. (St. Petersburg State Polytechnical Univ.),
Kuteev, B. (Kurchatov Inst.), Tamura, N., Sudo, S.

The injection of hydrogen/deuterium and impurity pellets is widely used in magnetically confined devices with hot (T_e = 0.1 - 10 keV) and rare ($n_e = 10^{19-20}$ m^{-3}) plasmas for fuelling, disruption mitigation and numerous diagnostics. In such plasmas, the solid pellets ablate with the rate of about 10^{20-23} atoms/s (in impurity case) 10^{22-24} atoms/s (in hydrogen/deuterium case). A cold dense plasmoid exists in the vicinity of the ablating pellet. Previously, the electron temperature T_{cl} and density n_{cl} averaged over the pellet cloud has been measured so far[1-5]. It was observed that pellet cloud densities of 10^{22-23} m^{-3} for impurity pellets and 10^{23-24} m^{-3} for hydrogen/deuterium ones, which were approximately proportional to the pellet ablation rates. The measured T_{cl} of 3 – 10 eV for impurity pellets was higher than that of T_{cl} of 1 – 5 eV for hydrogen/deuterium pellet clouds. There is a substantial gap in the temperature and density values of between the plasmoid and the ambient hot plasma. Most of pellet applications require knowledge of spatial distributions the plasmoid parameters, which is a complex experimental task. Under this circumstance, in LHD, the distributions of T_{cl} and N_{cl} in the cloud of ablating TESPEL shell have been investigated by using a 9-channel filter-lens imaging polychromator NIOS[6]. Relation of H_β line radiation intensity to continuum radiation intensity was used for the estimation of T_{cl} whereas H_β line spectral shape was used for the estimation of N_{cl}. Present status of this study is reported here. Measurements are made using 7 channels of the NIOS[6,7] which are equipped with narrow-band (typical FWHM ~ 0.3 nm) interference filters arranged within the possible H_β line profile. NIOS system can measure 9 images of the luminous ablation cloud simultaneously in a single CCD image with a very short exposure time, which ranges from 10 μs to 30 μs. All plasmoid images are almost an axially-symmetric cigar shape elongated in the local magnetic field direction. It is observed that the cloud size of 5 – 12 cm along and 1.0 - 1.5 cm across the local magnetic field. Abel inversion procedure (Pirs approach with a Tikhonov regularization) is used to obtain local radiation intensity under the assumption of the cloud transparency for the H_β radiation. The data in seven narrow spectral intervals forms the local H_β line shape with the continuum radiation as a background. These seven-point spectral profiles are fitted with a line shape theoretically calculated $S(\Delta\lambda, n_{cl})$[8] using the $(A \times S(\Delta\lambda, n_{cl}) + B)$ expression, where A and B are linear transform coefficients and free parameters of nonlinear mean least square problem. Examples of the theoretical profile inscription into the experimental data can be seen in Fig. 1. Here, the previous NIOS data[6] were analyzed using an improved processing algorithm. Resulting electron density in the cloud are in the range of 10^{22} - 2×10^{23} m^{-3} depending on the region of cloud, the ambient plasma density and the ablation rate. These values are somewhat lower than those previously obtained[6]. However, it is confirmed that the dependences on the ambient plasma parameters as well as the proportional relation between the cloud density and the ablation rate. There are some characteristic features in the differences between the H_β line profile observed and that calculated[8]. Relative intensities close to the line center systematically exceed those predicted theoretically. Especially, the intensities at λ = 485.39 nm and λ = 486.94 nm are particularly prominent (up to 50 % lower than that predicted). The reasons for these features are not clarified yet. Following physical processes could be a possible candidate to explain those: an influence of carbon ions on the Balmer-beta line shape and/or line shape distortion by fast particles (both electrons and ions) penetrating into the cloud from the hot ambient plasmas.

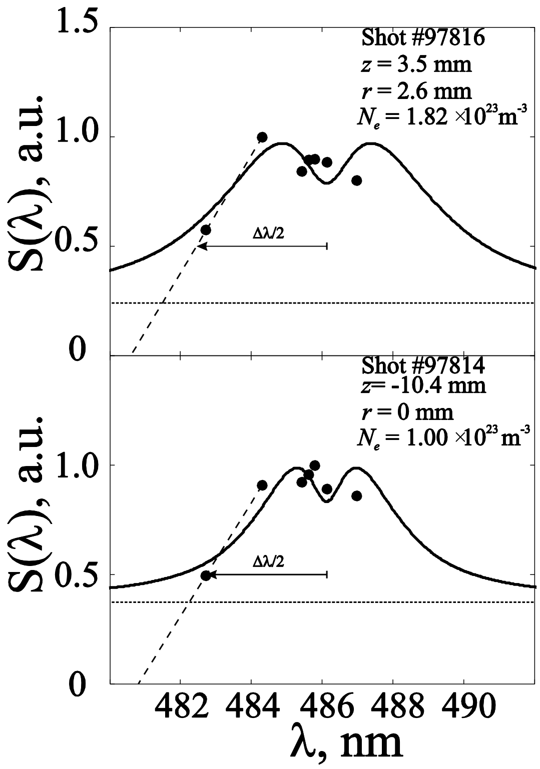

Fig. 1. Local H_β line profiles in different LHD shots. Solid lines indicate the profiles predicted theoretically and full circles do the profiles measured experimentally.

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