§16. Imaging Spectroscopy of TESPEL Cloud in LHD

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Spatial distribution of plasma parameters and radiation in the pellet vicinity is highly needed for the further development of plasma-pellet interaction models and pellet applications for plasma fueling, control and diagnostics. Previous studies have demonstrated the approximate linear dependence of the averaged pellet cloud density on the ablation rate for both hydrogen[1] and polystyrene[2] pellets. This work is devoted to the study of polystyrene pellet clouds in the Large Helical Device. The observation of the pellet cloud radiation was performed using a 9-channel filter-lens imaging polychromator (NIOS)[3, 4]. The recent improvement of the NIOS setup allowed us to obtain and analyze dependencies of the 2D electron temperature and density distributions on both the pellet ablation rate and the ambient plasma density and temperature. In the experiments, snap-shots of sight-line integrated pellet cloud images were obtained simultaneously through interference filters in 9 spectral intervals with 10 - 30 μs exposure time, which is much shorter than a typical pellet ablation time, 0.4 - 0.6 ms. Assuming that a cigar-like pellet cloud shape elongated along the local magnetic field lines, the cloud images were processed using Abel inversion procedure to determine local radiation distributions $I_\lambda(r, z)$, in cylindrical co-ordinates where z is oriented along the pellet cloud axis, i.e. parallel to the magnetic field lines. Seven filters with narrow spectral characteristics (~0.3 nm of bandwidth) were used to get the 2D local distributions of the cloud electron density from the width of Stark broadened Balmer-beta line[4]. The electron temperature was determined from a ratio of the intensities of Balmer-beta line emission and the continuum[4] using images obtained through the other two filters. Previously reported data[4] were measured with a filter set which was not optimized. It led to the underestimation of the Balmer-beta line width and consequently to that of the pellet cloud electron density. This problem was resolved with the new filter set which enables to measure higher cloud electron densities up to 2×10^{23} m^{-3}. This setup was used to obtain cloud images of the 900-μm-diameter polystyrene pellet with an approximately 500 m/s velocity for a wide range of the target plasma parameters: ambient plasma density $(1 - 5) \times 10^{19}$ m^{-3}, temperature (0.8 - 1.5) keV and pellet ablation rate $(1 - 12) \times 10^{22}$ atoms/s (see Fig. 1). The polystyrene pellets were injected into the NBI-heated plasmas of LHD. The absorbed powers of co- and counter NBIs were nearly balanced. The 2D distributions of the electron temperature and density in the polystyrene pellet cloud were obtained simultaneously in a wide range of the ambient plasma parameters (see Fig. 2). The longitudinal profile of electron temperature in the clouds has a zone with fast temperature growth (from 5 - 7 eV to 10 - 11 eV) and a plateau zone. It should be noted here that these values are obtained under the assumption that the contribution from the carbon into the continuum radiation is equal to that from the hydrogen. An accurate calculation of the continuum intensity taking into account different ionization states of the carbon could reduce the reported values of the electron temperature by a factor of 3. The measured electron density distributions in the ablating polystyrene pellet cloud show the different behavior depending on the ambient plasma density. In the lower density plasmas, there is a decay of the electron density along the magnetic field lines. The decay length is much longer than the growth length of electron temperature. In higher density plasmas, the electron density in the cloud was higher than that in the lower density plasma and almost no decay of that was observed. The spatial distributions of electron density and temperature in the polystyrene pellet cloud are mainly influenced by the ambient plasma density rather than the ambient plasma temperature and the pellet ablation rate. A similar dependence of the carbon cloud size on the bulk plasma density has been also measured in carbon pellet injection experiments on W7-AS [5].

1) D.H. McNeil et al.: Phys. Fluids B, **3**, (1991) pp. 1994-2009.
2) N. Tamura et al.: 30th EPS Conf. on Plasma Phys., (2003) St. Petersburg, Russia, P-1.59
3) N. Tamura et al.: Rev. Sci. Instrum. **79** (2008) 10F541.
4) I.V. Miroshnikov et al.: 36th EPS Conf. on Plasma Phys., (2009) Sofia, Bulgaria, P1.171 (http://epsppd.epfl.ch/Sofia/pdf/P1_171.pdf).
5) O.A. Bakhareva et al.: Plasma Physics Reports, 31 (2005), pp. 282-291.

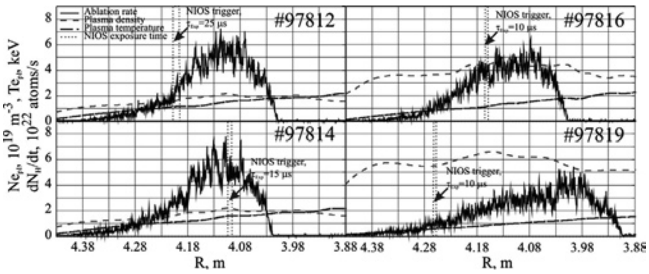

Fig. 1. Pellet ablation rates and ambient plasma parameters in LHD shots #97812, #98814, #97816, #97819.

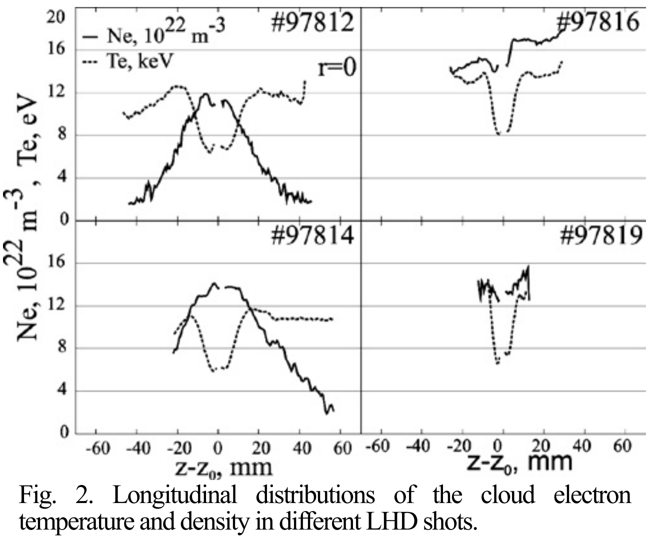

Fig. 2. Longitudinal distributions of the cloud electron temperature and density in different LHD shots.