§16. Pellet Cloud Investigation via Imaging Spectroscopy in LHD

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Understanding a plasma-pellet interaction and pellet applications as a diagnostic tool (e.g. the fast ion Pellet Charge eXchange diagnostics) requires experimental information about the spatial distribution of radiation and plasma parameters in the pellet vicinity. Stark broadening and the ratios of hydrogen lines intensity to continuum intensity could be used for measurements of spatial distributions of the electron temperature and density in the cloud. In order to obtain new data on these spatial distributions (especially on TESPEL ablation cloud), cloud intensity structures of hydrogen lines, continuum and different charge states of carbon ion for short time interval during pellet ablation imaging spectroscopic system NIOS (Nine Images Optical System) is used as shown in Fig. 1. It is designed to obtain pellet cloud images up to nine narrow spectral intervals simultaneously. NIOS consists of 9 filters (7 filters are used for Balmer-beta line shape measurements, 1 filter is used for measuring an integral Balmer-beta line intensity and 1 for measuring of intensity in continuum spectra), 9 identical lenses, field lens and CCD camera with objective. It allows to measure nine snap-shots of pellet cloud using the CCD camera. Dimensions of view region are about 16 on 16 centimeters. Spatial resolution is about of 0.7 mm per pixel. A minimal time resolution is 10 microseconds. After taking into account all necessary calibrations, such as sensitivity of CCD camera pixels, filter and lens system transparencies and geometric transformations, Abel inversion procedure is applied to each image under assumption of axial symmetry of the pellet cloud. The ratios of the integral Balmer-beta intensity to the continuum intensity are calculated and the electron temperature distribution is determined under assumption of partial LTE (Local Thermodynamic Equilibrium) existence[1]. Images in 7 narrow band pass filters are used for the Balmer-beta line shape reconstruction in each spatial point. After the determination of line's FWHM parameter, electron density distribution is evaluated by the use of equation in Ref. 2.

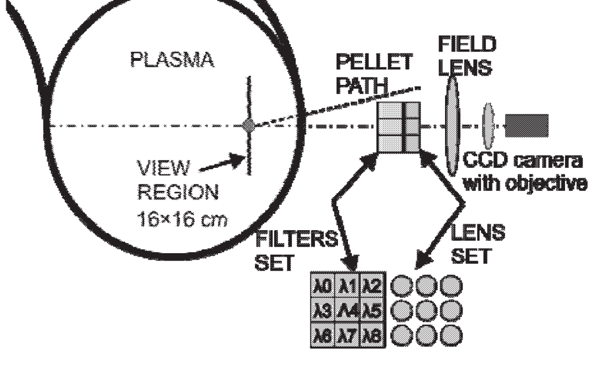

Fig. 1. Scheme of experimental setup (NIOS)

Result of such calculations for LHD shot #91250 is presented in Fig.2. Parameters of the shot #91250 were: W_{Pmax} = 1.18 MJ, central electron temperature of $T_e(0)$ = 1.46 keV, magnetic axis radius of R_{ax} = 3.80 m. Background plasma temperature in the region where NIOS image was taken: T_e = 1 keV. TESPEL diameter was 900 μm. For the first time the electron temperature and density 2D distributions are obtained simultaneously for the TESPEL ablation cloud. Both distributions of $T_{cl}(r, z)$ and $N_e(r, z)$ demonstrate a wide plateau region. Cloud temperature profiles have a colder region in the pellet vicinity. The temperature of ablating TESPEL is about of 6 - 7 eV in the core region of the cloud and about of 10 - 12 eV in the plateau region. These values give the upper limit of cloud temperature because of substantial contribution of carbon ions to the continuum radiation. For now carbon ions' contribution into the continuum intensity is assumed equal to the hydrogen ions' contribution. In fact this contribution is expected to be much higher. Taking it into account accurately, this effect can reduce the resulting temperature by a factor of 2. Further investigation on this matter is needed. Nevertheless, the values measured are in a reasonable agreement with predictions of the carbon pellet cloud parameters[3]. The 2D distribution of local electron density in the cloud is obtained using Balmer-beta line Stark broadening measurements. The density of ablating TESPEL is about of 3 x 10^{22} m^{-3}, which are close to the average TESPEL cloud density value evaluated earlier[2].

1) H.R. Griem: Plasma spectroscopy, MVGRWA-Hill, NY, 1966.
2) N. Tamura et al.: Rev. Sci. Instrum. **79** (2008) 10F541.
3) D. Kh. Morozov et al.: Nucl. Fusion **44** (2004) 252.

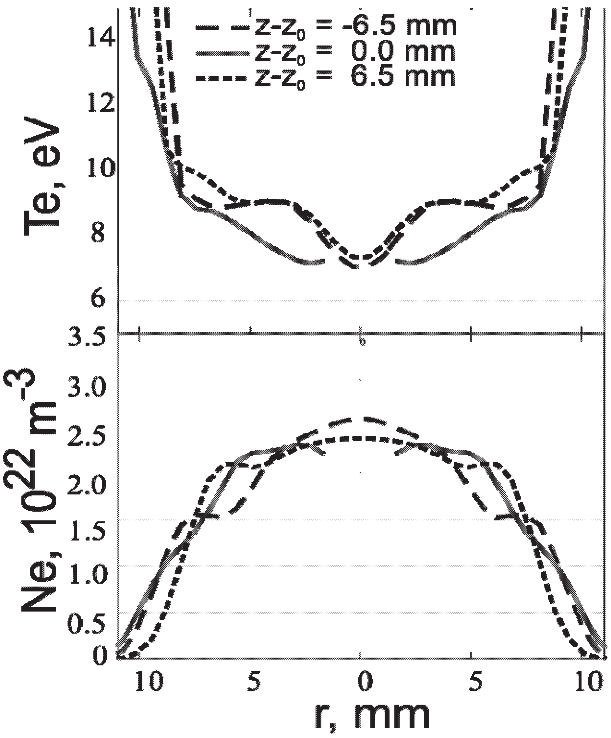

Fig. 2. Radial distributions of a) electron temperature and b) electron density for different points along pellet cloud axis.