*35th EPS Conference on Plasma Phys. Hersonissos, 9 - 13 June 2008 ECA Vol.**32D**, P-4.106 (2008)*

Study of Pellet Clouds in LHD via 2-D Spectroscopy Imaging

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Introduction. Understanding the pellet-plasma interaction and development of pellet ablation models require experimental information about the spatial distributions of plasma parameters and radiation in the pellet vicinity. This paper is devoted to new experimental observations of the polystyrene pellet in LHD by means of NIOS (Nine Image Optical System) using multi-channel filter-lens imaging polychromator described in details in Ref. [1,2]. In Ref. [1] the first evaluations (10-20 eV) of cloud temperature T_{cl} were made using the ratio of H_β and continuum intensities which seems too high and has required verification of the radiation spectral composition measured by the filters.

Spectral composition of filters signals. Thorough analysis of the TESPEL cloud emission spectra measured through the filters has been done using the NIST data [3]. It was found that a fairly noticeable level of CI (493.2 nm) line was measured with the $(\lambda_{centre}, \Delta\lambda_{FWHM}) = (497.05, 5)$ nm filter aimed for continuum radiation measurements. It has caused overestimates of the cloud temperature values mentioned above. To find a more appropriate spectral range for the continuum measurements, the TESPEL ablation cloud emission spectra were measured using an experimental setup described in Ref. [4]. This has allowed to determine $(\lambda_{centre}, \Delta\lambda_{FWHM}) = (630.5, 5)$ nm parameters of a new filter for continuum. The analysis also showed that a strong radiation of CII (657.8 nm and 658.3 nm) and CI (658.7 nm) lines affects measurements done by means of the $(\lambda_{centre}, \Delta\lambda_{FWHM}) = (655.5, 5)$ nm filter and falsified H_α emission measurements. Similar situation occurred with the $(\lambda_{centre}, \Delta\lambda_{FWHM}) = (515.0, 10)$ nm filter that measured radiation of CI (505.2 nm) line together with CII lines radiation. Other filters listed in the Table 1 measured radiations of the corresponding lines properly.

Table 1. Parameters the NIOS interference filters

Wave length	H_α	H_β	Continuum	CII +CI	CII 723	CI 538
λ_{centre}, nm	655.5	486.5	630.45	515.0	723.6	536.93
$\Delta\lambda_{FWHM}$,nm	5	10	4.95	10	5	4.97

Experimental results and discussion. New data were obtained by simultaneous observation of the pellet cloud through interference filters in 6 spectral ranges with 20 μs temporal resolution. The ablation rate evolution measured using H_α emission of TESPEL cloud is shown by blue line in Fig. 1, NIOS exposure interval is marked by vertical red lines. Plasma parameters were $n_e = 6.67 \times 10^{19}$ m^{-3}, $T_e = 0.35$ keV at the region where the image below (Fig.2) was taken. Parameters of #83382 LHD shot were: $W_{Pmax} = 568.6$ kJ, $n_e(0) = 7.34 \times 10^{19}$ m^{-3} electron density, $T_e(0) = 0.75$ keV electron temperature, $R_{ax} = 3.60$ m magnetic axis radius.

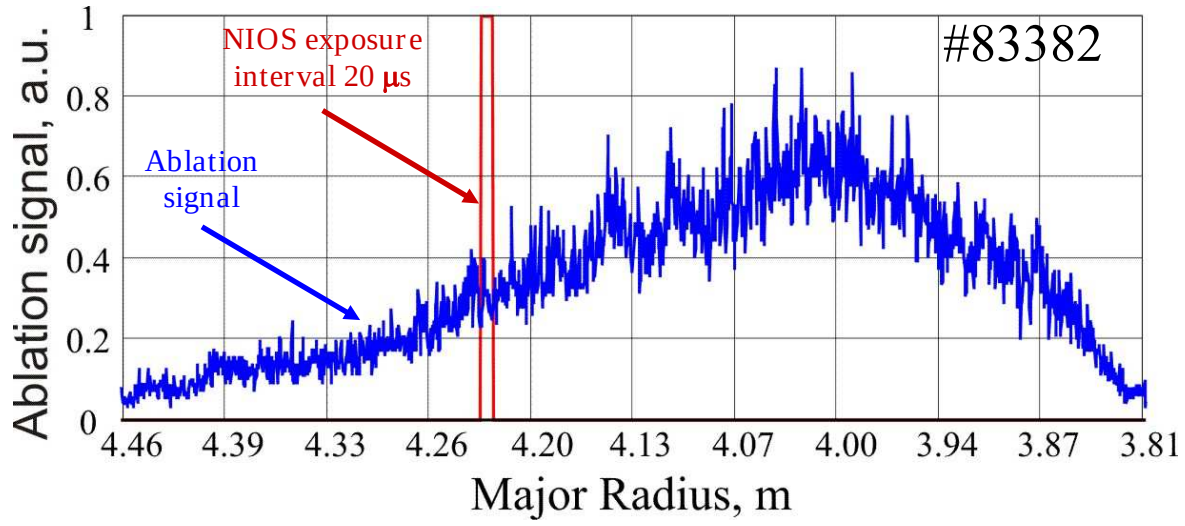
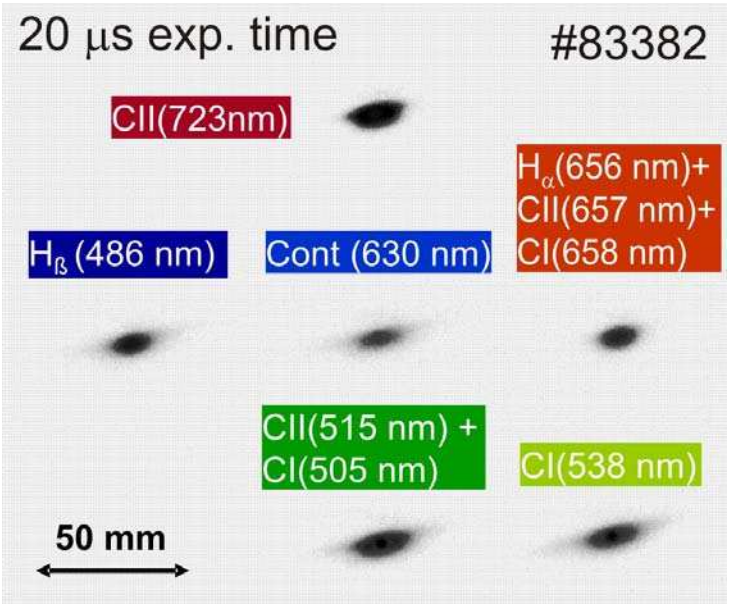


Fig. 1. Temporal evolution of H_α emission of TESPEL cloud in LHD shot #83382.



It is seen that the cloud tilt angle is the same in all images and its value is close to the vacuum magnetic field tilt angle value of 10 degree calculated for the TESPEL position. 2-D images of the pellet clouds presenting radiation distributions $I_\lambda(x,y)$, were processed using Abel inversion for determining radiation distributions $I_\lambda(r,z)$, in cylindrical co-ordinates r and z with the latter being oriented

Fig. 2. Sample of NIOS measurements in the #83382 LHD shot. Exposure time is 20 μs. NIOS was triggered at R =4.23 m (t_{inj}= 2.492 sec).

along the pellet cloud axis and parallel to the magnetic field in plasma.

Contour plots of H_β line $I_{H\beta}(x,y)$ and continuum $I_{Cont}(x,y)$ intensities for this shot are shown in Fig. 3a,b correspondingly. Relevant intensity distributions $I_\lambda(0,z)$ in longitudinal and $I_\lambda(r,0)$ in transversal directions relative to the magnetic field direction are shown in Fig. 3c. These intensities were smoothed during Abel inversion with the characteristic scale of 3 mm. One can see that longitudinal pellet cloud dimensions are more than 2 time larger than those transversal and there are plateaus inside the cloud core.

Cloud temperatures $T_{cl,H\beta}(r,z)$ were determined using $I_{H\beta}(r,z)/I_{Cont}(r,z)$ ratios by means of the known relationship from Ref. [5] under assumption of the LTE.

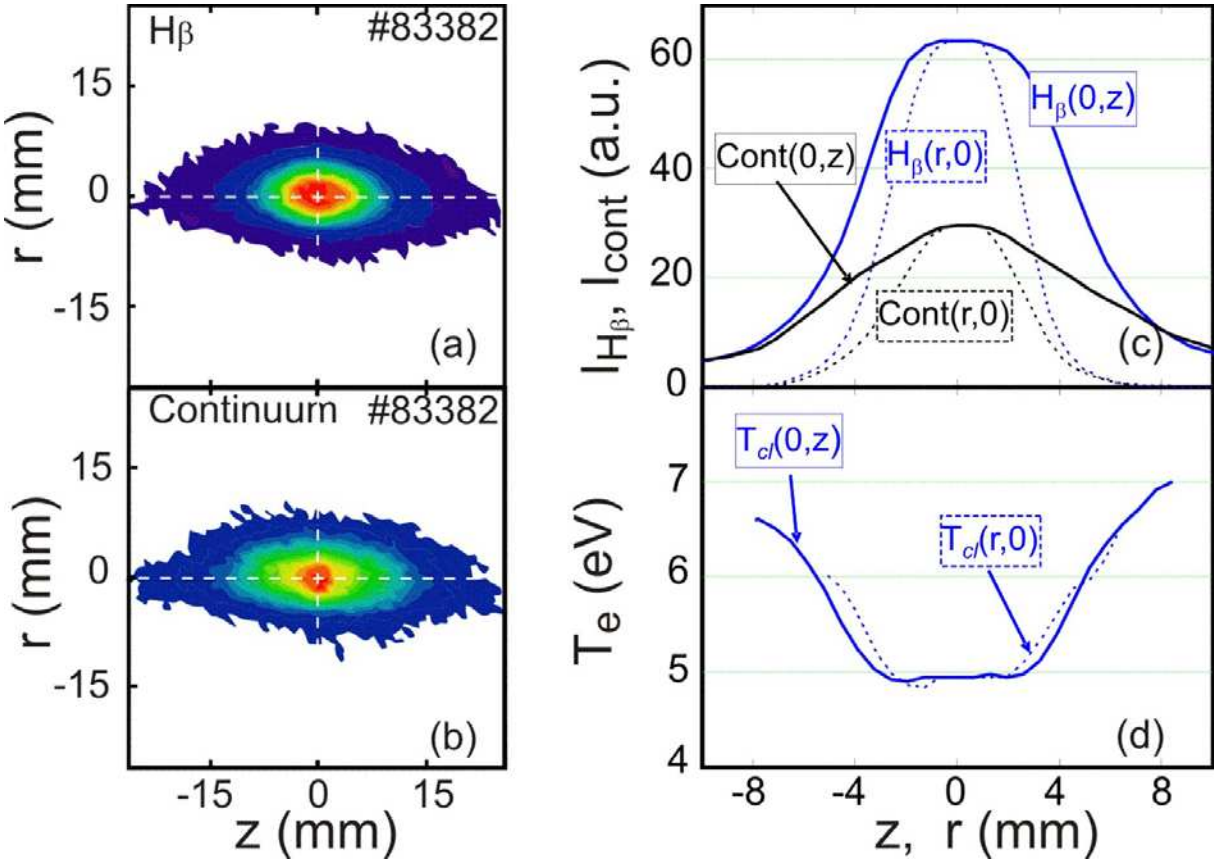


Fig. 3. Processed data of shot # 83382: a,b) contour plots of H_β line and continuum intensities. The (0,z) and (r,0) axes are shown by white dashed lines; c) $I_{H\beta}(0,z)$ (solid blue), $I_{Cont}(0,z)$ (solid black), $I_{H\beta}(r,0)$ (dashed blue), $I_{Cont}(r,0)$ (dashed black) profiles ; d) $T_{cl,H\beta}(0,z)$ (solid) and $T_{cl,H\beta}(r,0)$ (dashed) profiles.

These $T_{cl,H\beta}(r,z)$ profiles along and across magnetic field are shown in Fig. 3d. One can see, that the new spectral range chosen for continuum has allowed us to reduce the influence of the carbon line radiation on the radiation in the continuum range. As the result the values of the temperature in the cloud core have reduced from 20 eV in Ref. [1] to 5 eV, which better agrees with previous measurements of hydrogen pellet clouds [6,7] and predictions of the carbon pellet ablation modeling [8]. It should be noted that the spatial distribution of the

$T_{cl,H\beta}(0,z)$ and $T_{cl,H\beta}(r,0)$ profiles similarly has a 5 eV plateau of about +/- 3 mm in size and it rises up to 6-6.5 eV far away from the pellet although the longitudinal radiation intensities at least two times wider than transversal ones.

Summary. 0D spectra of the whole polystyrene pellet cloud were measured and analyzed. A new spectral interval free of line radiation and suitable for continuum emission measurements was found. New experimental non-saturated images were acquired using new filters. 2D distributions of local electron temperature in the cloud were obtained under LTE assumption. The temperature values in the cloud core of ablating polystyrene pellet are about of 5 eV in a reasonable agreement with previous measurements of hydrogen pellet clouds and predictions of the carbon pellet ablation modeling.

Acknowledgments. The work was supported by RFBR grants #07-02-01492-a and #08-02-01372-a and partly supported by a Grant-in-Aid for Young Scientist (B) (No.19740349) from MEXT Japan and a budgetary Grant-in-Aid No. NIFS07ULHH510 and NIFS07KEIN1018 of the National Institute for Fusion Science.

References

[1] V. Yu. Sergeev, N. Tamura, I.V. Miroshnikov *et.al.*, 33-rd EPS Conference on Plasma Phys., Rome, 19-23 June, 2006. ECA Vol. 30l, O-3.016.

[2] N. Tamura *et al.*, "Spectroscopic Diagnostics For Ablation Cloud Of Tracer-Encapsulated Solid Pellet In LHD", in Proc. the 17th Topical Conference on High-Temperature Diagnostics 2008 (Albuquerque) N41.

[3] NIST data: http://physics.nist.gov/PhysRefData/ASD/lines_form.html.

[4] N. Tamura V.Yu. Sergeev, D. Kalinina *et al.*, Europh. Conf. Abs., (2003) 22C, p.0607

[5] H.R. Griem. Plasma spectroscopy, MVGRWA-Hill, NY, 1966.

[6] Durst, R.D., Rowan, W.L., Austin, R.A. *et al.*, Experimental Observation of the Dynamics of Pellet Ablation on the Texas Experimental Tokamak (TEXT), Nucl. Fusion 30 (1990) p.3.

[7] Sergeev V.Yu., Kostrukov A.Yu, Shibaev S.A., Measurement of cloud parameters near hydrogen and deuterium pellets injected into T-10 plasma, Fusion Eng. And Design 34-35 (1997), p.323.

[8] Morozov D.Kh., Gervids V.I., Senichenkov I.Yu. *et al.*, Nucl. Fusion 44 (2004), p.252.