RADIAL PROFILE OF METALLIC IMPURITIES OBTAINED FROM X-RAY PULSE HEIGHT ANALYZER IN LHD

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1. Introduction

Measurement of x-ray spectrum is important to investigate fundamental properties of magnetically confined high temperature plasma, since it can give information on electron temperature, impurity, and nonthormal electron [1,2]. Recently, it is intended to rise up the spectral, spatial and temporal resolution in the x-ray diagnostics, because it is required to obtain important information such as the shift of magnetic axis, T_e profile, spatial distribution of metallic impurities and especially spatial distribution of nonthermal high energy electrons driven by electron cyclotron heating. However, in the energy range of x-ray it is fundamentally difficult to get simultaneously high spectral, spatial and temporal resolution. Recent technology dose not yield any applications which can fully accomplish this problem.

An assembly of pulse height analyzer (PHA) has been constructed in Large Helical Device (LHD) [3,4]. The assembly is equipped with a utility called a radial scanning system which modulates and identifies the sight line of PHA along major radius direction of LHD. It is the advantage of the system that permits adjustable acceptance of the sight line and improvement of scanning time. The scanning range of the system fully covers the plasma in the radial direction.

The radial profiles of K_α lines of metallic impurities such as titanium, chromium and iron have been successfully observed with the assembly. The energy shift of K_α line is also observed for each radial viewing chord. In addition to the experiment the radial distribution of line intensity emitted from each ionic state of metallic impurity is calculated as a function of electron temperature and density profiles. As a result, absolute density has been estimated from the comparison with the experimental result and the calculation. In the present article radial distribution of respective ionic state of metallic impurity is reported.

2. Radial scanning PHA system

The assembly is equipped with four x-ray detectors arranged along major radius direction with a space interval of 300 mm. Each detector consists of four pre-amplifiers, a portable liquid nitrogen cryostat, and four Si(Li) elements mounted inside a vacuum enclosure with a 12.5-μm-thick beryllium window. Each of the four elements is arranged on the corners of 13 mm square. The diameter of each element is 8 mm. Since the semiconductor x-ray detector is easily influenced by electromagnetic noise and mechanical vibration, the detectors are electrically and mechanically isolated from a supporting stage and fully covered with a copper shield. These special items of the isolation and shield are intrinsic to avoid a systematic error in signal. Main amplifiers are set into a copper box which is close to the detector. A calibration of the detector has been carried out using an x-ray source which emits intense lines of iron K_α and K_β. The energy resolution of the detectors has been adjusted to 170 eV at 6.5 keV.

The radial scanning system consists of four movable circular slits, and can modulate and identify the sight lines of the PHA along the major radial direction of LHD in a time interval of a few hundred msec. As a result, the data are successfully obtained with a spatial resolution of a few millimeters.

3. Experiment and discussion

Figure 1 shows typical profiles obtained with the assembly. The spatial resolution is roughly 30 mm in the major radial direction. Each point for impurity represents the integrated emission which has been observed through each sight line with a time integration of 240 msec. The radial profile of electron temperature estimated from continuous spectrum is also indicated. At present the duration of the scanning was approximately 8 s. The time resolution will be improved in next step. The plasma parameters were constant during the accumulation of the data. The assembly also makes it possible to estimate the line intensity and electron temperature near $\rho = 1.0$, as is shown in the figure.

Figure 2 shows line spectra observed through two different positions of sight line. These spectra have been measured through a 1-mm-thick beryllium. In the figure reduced intensities are described. In comparison with the two lines it is remarkably indicated that there is a shift between the K_α lines of iron. The photon energy is different between K_α lines emitted from respective ionic state. It qualitatively reflects K_α lines from lower charge states increase at the position of $\rho = -0.54$ in comparison with the case of the position of $\rho = 0.0$.

Radial profile of K_α line emitted from metallic impurities has been analyzed to estimate the radial distribution of respective ionic state of each metallic impurity. Figure 3 shows radial profiles obtained from the experimental result and a cord calculation. In the calculation the diffusion coefficient of each impurity is assumed to be 0.2 m^2/s. Each calculated radial profile of line spectrum emitted from respective ionic state is shown in Fig.4.

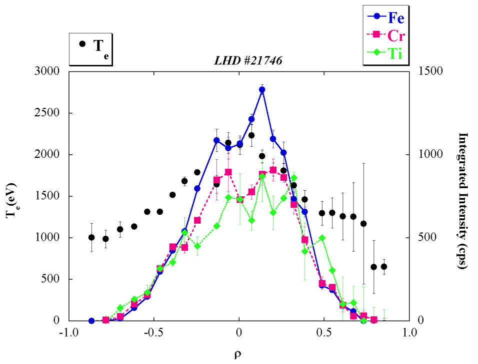


Fig.1. Radial profiles of electron temperature and each K_α line emitted from metallic impurities of iron, chromium, and titanium, respectively. For K_α lines the vertical axis means the line integral along the sightline, while the horizontal axis means the position of sightline.

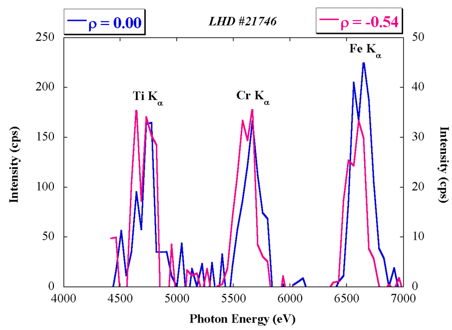


Fig.2. Each K_α line of titanium, chromium, and iron. The scale of vertical axis is different between the two positions of sight line. The vertical axis indicates the intensity which is line integral along the sightline. The intensity of continuous spectrum is subtracted.

In the case of the temperature, as is shown in the Fig.1, it is shown that the intensity of the line spectrum is mainly contributed from He-like, Li-like, Be-like, and B-like. In the case of iron the most intense line is emitted from Li-like ion within ρ = 0.6. As is shown in Fig.5(a), it suggests no emission to the line from H-like ion. The concentration of iron is estimated to be approximately 0.008 % from the comparison shown in Fig.3. By the same method the concentrations of chromium and titanium are also estimated to be approximately 0.003 % and 0.001 %, respectively.

The calculation is also consistent with the experimental result on spectral profiles taken from ρ = 0.62 (see Fig.5(b)). The photon energy of K_α emission depends on the ionic state as mentioned above. The detector equipped with the assembly has energy resolution enough to obtain the energy shift of the line.

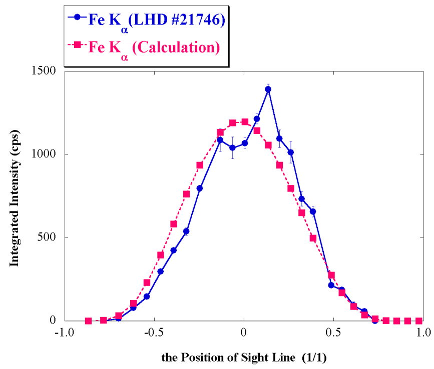


Fig.3. Comparison of radial profiles between an experimental result and a cord calculation.

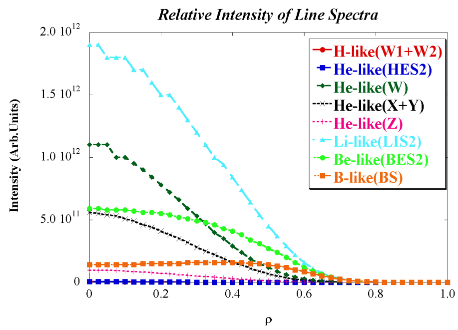


Fig.4. Calculated radial profile of respective ionic state of iron. In the calculation the diffusive coefficient is assumed to be 0.2 m^2/s. The intensity emitted from the ionic state of H-like is at zero level in the figure.

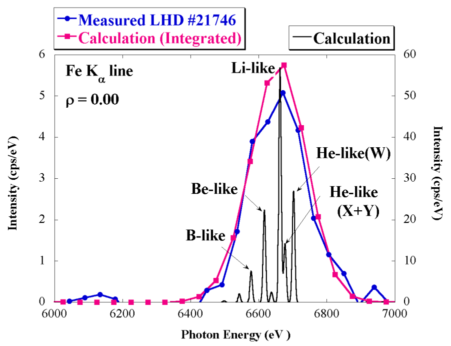


Fig.5(a). Comparison of integrated intensity profiles between the experimental result and the calculation. The intensity is integrated along sight line in a case of ρ =0.0. The intensity of respective line structure is also indicated.

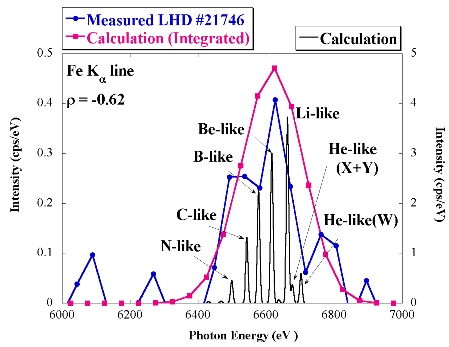
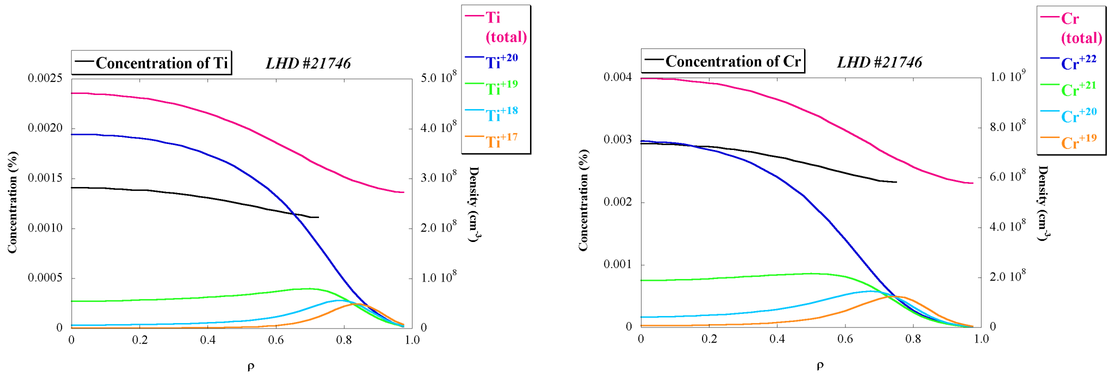


Fig.5(b). The integrated intensity along sight line in a case of ρ = -0.62.

Figure 6 shows the radial distribution of each metallic impurity estimated from the analysis. The concentration of each metallic impurity is also indicated. The dominant ionic state is

He-like in each case around plasma center, while the concentration of bear ion and H-like ion are much lower than that of He-like ion.



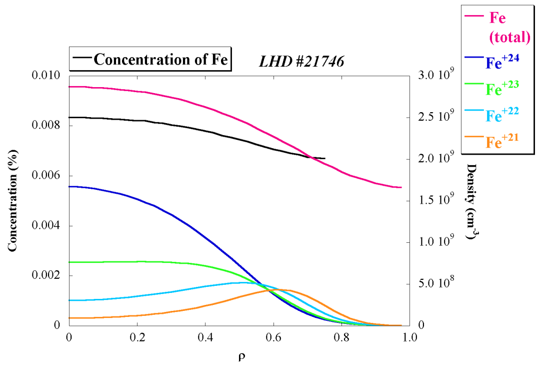


Fig.6. The estimated radial distribution of each metallic impurity. The concentration and the density are estimated from the comparison with the experimental result and the calculation. Only ionic states mainly contributing to the line intensity are shown.

3. Conclusion and future prospect

Development of an assembly equipped with a radial scanning system has attained a remarkable progress on method for radial profile of x-ray spectrum in connection with conventional utilization of PHA. The line spectra have been successfully observed with good energy resolution enough to analyze the energy shift of the K_α line. From the analysis of observed profiles, the radial distribution of each ionic state is estimated in the case of titanium, chromium, and iron, respectively.

Although improvement of the assembly must be made in order to achieve better counting rate, the further operation of the assembly will greatly contribute to studies on high temperature plasma concerning metallic impurities.

Mounting of a detector sensitive to hard x-ray region is currently in progress. Studies on the radial profile of high energy tail driven by electron cyclotron heating are the next target.

Reference

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