RADIAL PROFILE OF METALLIC IMPURITIES IN THE HT-7 TOKAMAK

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1. Introduction

A compact soft x-ray pulse height analyzer (PHA) to obtain spatial profile of electron temperature and metallic impurities has been developed in the HT-7 superconducting tokamak. This diagnostic system combined with recently introduced Silicon Drift Detector (SDD). This system consists of a 6-channel horizontal SDD system and a 15-channel vertical SDD linear array as shown in Fig.1 [1, 2]. SDD allows the measurement of x-rays at count rates of about 100 kHz without significant signal distortion due to pile up, while maintaining a good energy resolution. The effective time response of the SDD PHA is 50 ms. And it can be cooled only by a single stage peltier element, does not require a liquid nitrogen cooling system, so the SDD system is very compact. The profile of electron temperature and the intensity of metallic impurities can be obtained with a spatial resolution of 3 cm. The energy resolution of SDD can achieve 150 eV at 5.9 keV, so it can be used to analyze the impurities. The above advantages make the SDD PHA very suitable for the impurities investigation.

The K_{\alpha} lines of chlorine, chromium, iron and titanium have been successfully observed...
with this system after the injection of low hybrid wave (LHW). And the radial profiles of $K_\alpha$ lines have been analyzed to estimate the radial distribution of each heavy impurity by Abel inversion, it can be seen that the $K_\alpha$ lines were mainly emitted from core plasma column. And the concentrations of each impurity have also been estimated. In this article the first experimental results of radial profile of heavy impurities are presented.

2. First experiment results

In the HT-7 2005 spring campaign, several detectors broke down, only 12 vertical SDD and 4 horizontal SDD can work, so in this article we only use data from 12 vertical SDD.

A typical waveform of long-pulse discharge is shown in Fig.2. The plasma current was 68kA, the central chord average electron density was about $0.75 \times 10^{19} \text{m}^{-3}$, and the LHW power was about 210 kw. Fig.3 shows the spectra observed through two different detectors, the time resolution is 500 ms in the long-pulse discharge. The electron temperature measured with the PHA diagnostic was 0.65 kev at $\rho=0$ and 0.5 kev at $\rho=0.44$. From the spectra we can get the $K_\alpha$ lines of chlorine, chromium, iron and titanium, and we also can see that there is a shift between the $K_\alpha$ lines of each impurity. The photo energy is different between $K_\alpha$ lines emitted from respective ionic state. It qualitatively reflects $K_\alpha$ lines from lower ionic states increase at the position of $\rho = 0.44$ in comparison with the case of $\rho = 0$. Fig.4 shows the $K_\alpha$ line of each impurity observed through two different detectors, the intensity of continuous spectrum has been subtracted from the whole spectrum. From fig.4 we can see the intensity of each impurity’s $K_\alpha$ lines at $\rho = 0.44$ is
far weaker than that at $\rho = 0$, and the shift between the $K_{\alpha}$ lines of each impurity can be obtained. From fig.4 we also can see that the intensity of Cl $K_{\alpha}$ line is very violent, it is because a worker put a cable into the HT-7 main chamber before closing the chamber carelessly, this can indicate that the SDD diagnostic system is credible. The cable influenced the plasma’s confinement largely, so the plasma’s performance was very bad during the whole campaign.

Fig.5 shows the radial profiles of each $K_{\alpha}$ line emitted from chlorine, chromium and iron respectively. Fig.6 shows the Abel inverted radial profiles of each $K_{\alpha}$ line exhibited in Fig.5. It can be seen that the $K_{\alpha}$ x-rays of each heavy impurity were mainly emitted from core plasma column of $\rho < 0.2$.

Together with the electron density measured by HCN interferometer and the electron temperature measured by SDD PHA system, the profile of impurity concentration also can be obtained through the spectra of soft x-ray. The temperature average excitation cross sections for each impurity are used to calculate the concentration of each impurity respectively. The power radiated in $K_{\alpha}$ transition can be expressed as $P_{L}(T_e) = n_e n_i <\sigma v>_{Te,K_{\alpha}} E_{K_{\alpha}}$, where $<\sigma v>_{Te,K_{\alpha}}$ is the temperature average excitation cross section, $n_e$ is electron density, $n_i$ is the impurity...
density, $E_{K_a}$ is the energy of the $K_a$ line. The estimated concentrations of chlorine, chromium and iron in the core plasma range are about 0.15%, 0.02% and 0.08% respectively.

3. Conclusion

A compact PHA system based on the Silicon Drift Detector (SDD) has been applied to magnetically confined high temperature plasma in the HT-7 tokamak. It is used to measure the electron temperature and the $K_a$ lines of heavy impurities. The $K_a$ lines have been successfully observed with good energy resolution enough to analyze the energy shift of the $K_a$ lines, and the concentrations of each heavy impurity have also been estimated.

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Reference:


Fig.5. Radial profiles of $K_a$ lines emitted from chlorine, chromium and iron. The intensity of chlorine $K_a$ has been divided by 50.

Fig.6. Radial profiles of the $K_a$ intensity of chlorine, chromium and iron by Abel inversion. The intensity of chlorine $K_a$ has been divided by 50.