32nd EPS Conference on Plasma Phys. Tarragona, 27 June - 1 July 2005 ECA Vol.**29C**, D-5.009 (2005)

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.

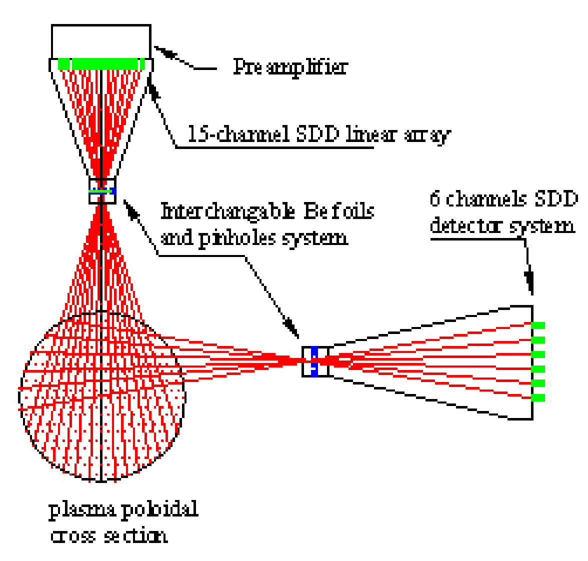

Fig.1. Schematic of the SDD PHA system in the HT-7 tokamak

The K_{α} 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_α lines have been analyzed to estimate the radial distribution of each heavy impurity by Abel inversion, it can seen that the K_α 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.

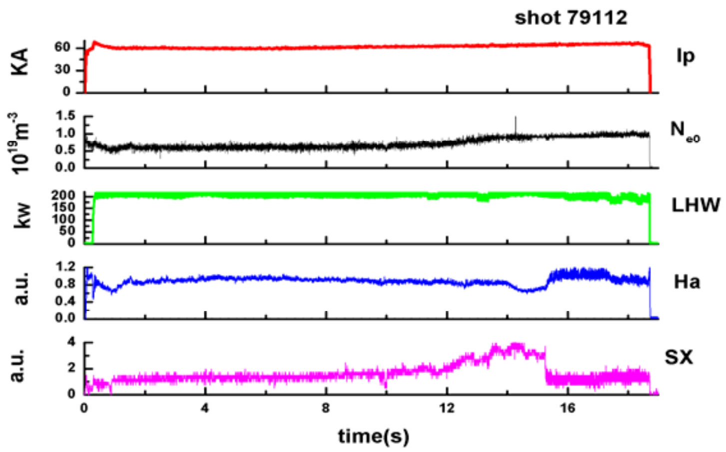

Fig.2. The waveform of shot 79112 with wave-heated long pulse discharge; the pulse was 18.7s. I_p is the plasma current, N_{e0} is the central chord averaged electron density, LHW is the low hybrid wave energy, H_a is the central chord integrated intensity of H_α emission, SX is the central chord averaged intensity of soft x-ray emission

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 $0.75\times10^{19}m^{-3}$, 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 ρ=0 and 0.5 kev at ρ=0.44. From the spectra we can get the K_α lines of chlorine, chromium, iron and titanium, and we also can see that there is a shift between the K_α lines of each impurity. The photo energy is different between K_α lines emitted from respective ionic state. It qualitatively reflects K_α lines from lower ionic states increase at the position of ρ = 0.44 in comparison with the case of ρ = 0. Fig.4 shows the K_α 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_α lines at ρ = 0.44 is far weaker than that at $\rho = 0$, and the shift between the K_α lines of each impurity can be obtained. From fig.4 we also can see that the intensity of Cl K_α 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.

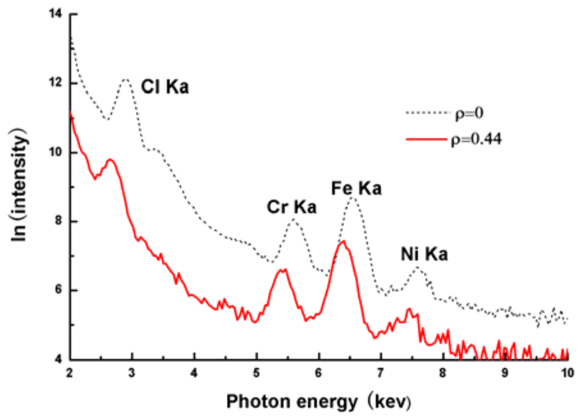

Fig.3. Typical spectra observed with the different detectors at ρ=0 and ρ=0.44. The lines denoted with Cl Ka, Cr Ka, Fe Ka and Ni Ka indicate the K_α lines of chlorine, chromium, iron and nickel, respectively.

Fig.5 shows the radial profiles of each K_α line emitted from chlorine, chromium and iron respectively. Fig.6 shows the Abel inverted radial profiles of each K_α line exhibited in Fig.5. It can be seen that the K_α 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_α transition can be expressed as $P_L(T_e)=n_e n_i<\sigma\upsilon>_{Te,K\alpha}E_{K\alpha}$ [3] , where $<\sigma\upsilon>_{Te,K\alpha}$ is the temperature average excitation cross section, n_e is electron density, n_i is the impurity

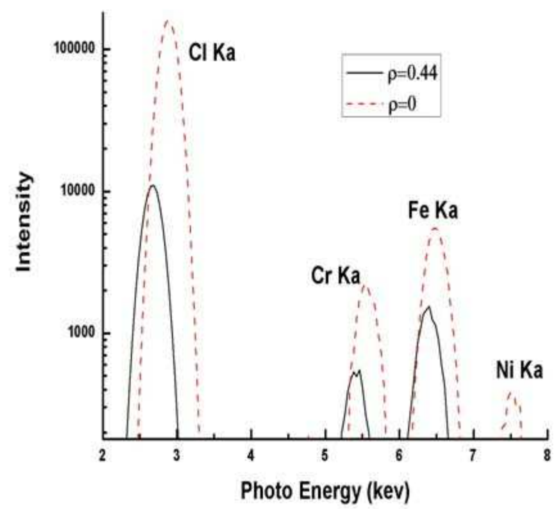

Fig.4. The intensities of K_α lines emitted from chlorine, chromium and iron from different sight line.

density, $E_{K\alpha}$ is the energy of the K_α 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_α lines of heavy impurities. The K_α lines have been successfully observed with good energy resolution enough to analyze the energy shift of the K_α lines, and the concentrations of each heavy impurity have also been estimated.

Acknowledgements:

It is a pleasure to acknowledge the assistance of the HT-7 group. This work is supported by the National Natural Science Foundation of China under Grant Nos 10235010, and 10305012.

Reference:

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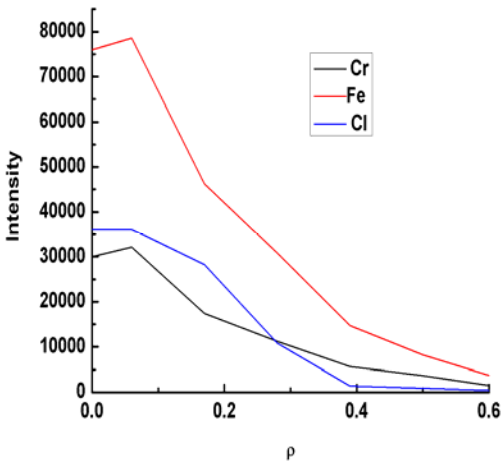

Fig.5. Radial profiles of K_α lines emitted from chlorine, chromium and iron. The intensity of chlorine K_α has been divided by 50.

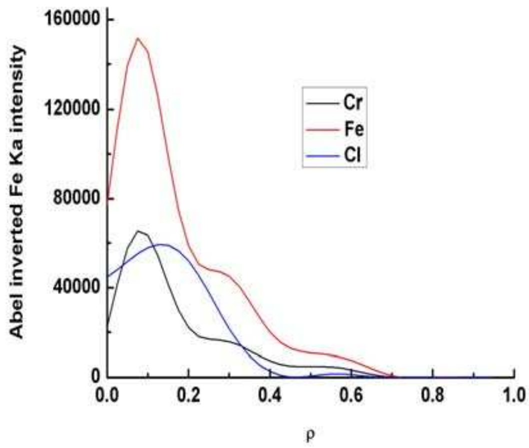

Fig.6. Radial profiles of the K_α intensity of chlorine, chromium and iron by Abel inversion. The intensity of chlorine K_α has been divided by 50.