# §9. Soft and Ultra-Soft X-ray Detector Array Systems for Measurement of Edge MHD Modes in the Large Helical Device

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In the Large Helical Device (LHD), several 20-channel Soft X-ray (SX) detector arrays are used to observe the radial structures of SX fluctuations related to MHD instabilities. Recently, 20-channel absolute extreme ultraviolet (AXUV) detector arrays have also been installed inside the vacuum vessel in the vertically and horizontally elongated sections of LHD to monitor MHD fluctuations in AXUV emissions emitted from edge plasma region.

An SX detector array manufactured by Hamamatsu Photonics is supplied as a one-body detector with a pre-amplifier is installed [1]. On the other hand, an AXUV detector array manufactured by International Radiation Detectors Inc. is available only as a detector [2]. Originally, the AXUV array was made to detect VUV light. Recently, the AXUV array is also used to measure plasma radiation power and impurity emission [3-5]. We have also used an AXUV array with a pre-amplifier made by Clear Pulse Inc. For direct conversion of photoelectric current into voltage, SX and AXUV pre-amplifiers are used with a fixed conversion ratio of $10^4$ V/A and $10^5$ V/A, respectively. Also, AXUV photodiodes do not need external negative bias for operation. Therefore, AXUV detector is resilient against electrical noise introduced through a circuit of a bias power supply, e.g. surge voltage caused by breakdown of high voltage power supplies for neutral beam injector (NBI) systems.

The SX and AXUV detector arrays are installed inside the vacuum vessel in vertically and horizontally elongated sections of LHD. The viewing sight of each detector array is adjusted through a pinhole slit. The arrangement of these detectors was done, being focused on the measurement of edge plasma region. A rectangular pinhole is placed in front of these SX and AXUV detector arrays in order to ensure good radial separation and avoid overlapping the viewing sight zone for each channel. They are also installed with and without attaching a beryllium foil, respectively. Then, these path integrated SX and AXUV signals due to Bremsstrahlung and radiative recombination emissions will be expressed as Eqs. (1) and (2),

$$I_{SX} \propto \int_l n_e^2 \varsigma \sqrt{T_e} \exp\left(-\frac{E_c}{T_e}\right) dl \qquad (1)$$

$$I_{AXUV} \propto \int_l n_e^2 \varsigma \sqrt{T_e} dl \qquad (2)$$

where $\zeta$, $E_c$ and $l$ are the enhancement factor for Bremsstrahlung from pure hydrogen plasma, cutoff energy by beryllium foil and path length of SX and AXUV detector array, respectively. As shown in Eqs. (1) and (2), SX and AXUV emission depends on electron temperature, electron density and impurity contents.

Radial information of an edge MHD mode ($m/n$ = 2/3) obtained by the SX and AXUV detector arrays on the vertically elongated sections of 6.5U and 3.5U ports is shown in Fig. 1 as a function of the major radius which is defined by the intersection points of the line sights of the SX and AXUV detector arrays with the mid-plane of LHD. Here, the magnetic surfaces for $\beta$ = 0.14% and 2.07% are shown in Figs. 1(A-C). Figures 1(D-F) show the SX and AXUV intensity profiles and the fluctuation profiles of the $m/n$ = 2/3 mode, where these SX and AXUV fluctuations $\delta I$ have a high coherence with the magnetic fluctuations (Figs. 1(G-I)). However, several channels have a low coherence because of cancellation by the path integral effect of the line of sight. This cancellation effect is often given important information of the edge MHD mode pattern. In addition, the phase difference among these channels gives information of the mode structure, that is, the 'even' or 'odd' character of the poloidal mode number m (Fig. 1(G-I)), where the phase difference between the SX channels at the inboard and outboard plasma edge is ~ 2π (~ π) for an even (odd) m number. Also, the edge AXUV emission in the low temperature and density plasma region can be detected, having significant DC and fluctuation levels, while the SX emission is too weak to derive radial information of the MHD modes in such plasma (Fig. 1(D-F)).

The AXUV fluctuations behave similarly to the SX fluctuation related to MHD instabilities. The AXUV fluctuation amplitudes are often clearer than the SX fluctuation ones, i.e. AXUV detector array is suitable for the measurement of low electron temperature and low density edge plasmas. The emission signal from the SX with a beryllium foil is sensitively dependent on electron temperature because of low edge $T_e$, while the signal from the AXUV detector array without the foil is mostly dependent on the products of electron density and impurities. This different sensitivity should be reminded for both SX and AXUV detector arrays on LHD. In conclusion, the combined utilization of the SX detector array and the AXUV one is very powerful for investigation of edge MHD instabilities observed in high beta plasma and ETB plasmas in LHD.

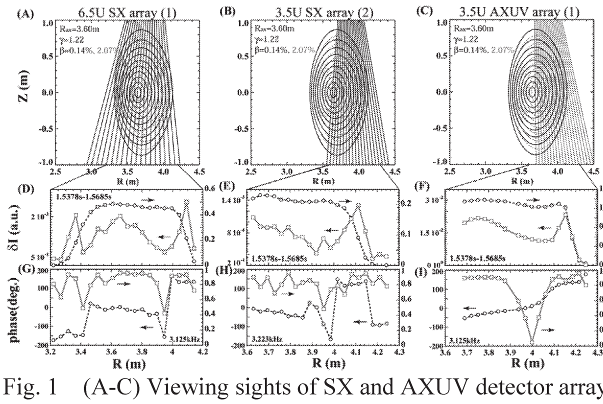


Fig. 1 (A-C) Viewing sights of SX and AXUV detector arrays on 6.5U and 3.5U port. (D-F) SX and AXUV emission profiles $I$, fluctuation profiles of edge MHD mode ($m/n$=2/3) $\delta I$. (G-I) Phase between each SX channel and coherence with magnetic fluctuation.

Reference

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