X-ray intra-detector energy calibration for the Tokamak plasma emission

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Introduction

The tokamaks are one of the promising devices for the realization of nuclear fusion which offers magnetically confined high-temperature and density plasma[1]. Tokamak plasma emits a wide range of electromagnetic radiation (EM) depending on the plasma conditions. These EM emissions fall into different energy bands namely, visible, VUV, IR, Soft X-rays, and Hard X-rays [2], a wide-band source. Surely, it is impossible to have one single detector to carry out energy-resolved measurements for this wide range of emissions. Therefore, different detector systems are employed to make these measurements. These detector systems give energy- resolved measurements and have different sizes, detecting materials, efficiencies, sensitivities, and various working principles etc. Hence it is very difficult to compare the output of these detectors directly due to the mentioned differences. These detectors are calibrated individually, but they are not calibrated in such a manner that the data can be directly compared. This contribution puts forward one such attempt at intra–detector calibration to make observations for wide-band tokamak plasma emission. The proposed method not only facilitated having a unified measurement across different detectors as well as emitted power spectra shapes can also be realized.

Experimental setup

The ADITYA tokamak is a midsized, device with R/a = 0.75m/0.25m. Equi-distance 22 toroidal field coils offer ~1.4 T toroidal magnetic field along sets of poloidal field coils [3]. The ADITYA plasma is ohmically heated and the plasma temperature ranges between 300-600 eV and density ~3 x10^{19} m^{-3}. The applied peak electric field is ~4.2 V/m and ~0.5 V/m at the plasma current flat-top. The typical plasma current reaches ~110 kA and with a ~ 100-200 ms discharge pulse length. Such plasma characteristics ensure emissions in a wide band. Here the contribution only concentrates on the X-ray emissions.

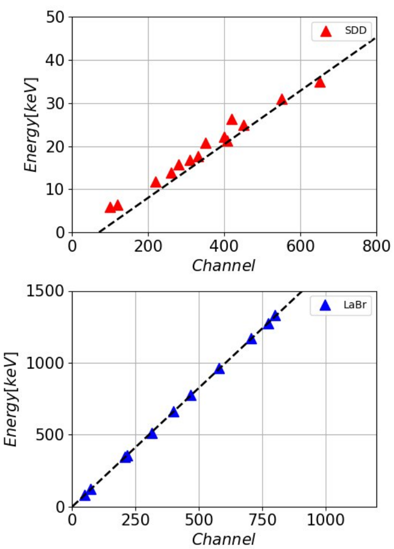

Fig. 1 Detector linearity, ADC channel (X-axis) and photon energy (y-axis)

At ADITYA the X-ray emissions are divided into two categories in terms of energy range i.e. soft X-ray (~1 keV to ~30 keV), SX and hard X-ray (~80 keV to tens of MeV), HX. The SX/HX emissions are observed due to different physics processes. The SX is majorly observed due to the thermal plasma with a minority contribution from the non-thermal plasma component[4]. The HX emission is restricted only to the Runaway

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electrons, which reside at the extreme tail of the electron distribution function and are a major factor for the non-Maxwell character of the plasma[5]. The silicon-based detector system or the thin scintillators/solid-state detector are employed to measure SX emission.

Whereas the HX emission requires more dense detectors and therefore the scintillator-based detectors are the best suited for the job. At ADITYA tokamak, the Silicon Drift detector for SX and $LaBr_3$-based scintillators detectors (1.5 inch x 1.5 inch) for HX are employed in the spectroscopic configuration[4-5]. The systems work at different physic principles for emission measurements and energy range hence can not directly give a unified emission picture.

Results and discussion

Intra-detector calibration has been performed to get a unified picture of the X-ray emission. The two detectors are linear in the operational energy range, see Fig.1. The linearity is evaluated by natural radioactive sources, no source available beyond 1.5 MeV.

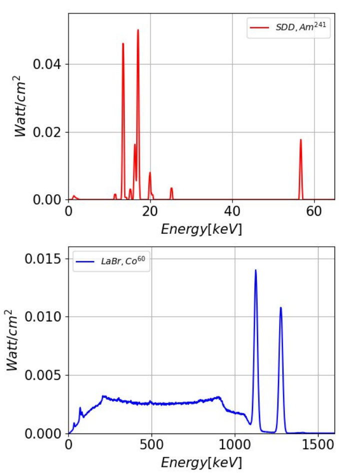

Fig.2 Calibrated spectra for natural radioactive sources for SDD and $LaBr_3$.

The SDD is detector shows higher intensity near 20 keV whereas lower at 59 keV, even this decay probability ~36%. This is mainly attributed to the lower detector efficiency beyond 30 keV.

The detectors are individually calibrated in energy space, SDD (~5-36 keV) and $LaBr_3$ (up to 1500 keV)[5]. See Fig.2, the calibrated spectra are shown for the natural radioactive sources, ^{241}Am and ^{60}Co [5]. Y-axis of the calibrated detectors is kept in terms of the power observed by the detectors. As one can see that both the spectrum are residing on the same axis parameters it is easy to combine the two spectra and provide a unified picture.

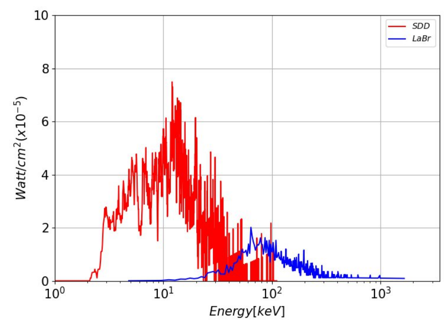

Fig. 3: The unified spectra for a wide band X-ray emission

The calibrated X-ray emission for the ADITYA discharge is shown in Fig.3, experimental data. The SX emissions are depicted in red while the HX emissions are in blue. The non-Maxwellian electron distribution function offers a wide band emission. Both the detectors are calibrated and now can be compared directly within one frame. It is clear that the two spectra match well and form a continuous spectral shape which is expected from the tokamak plasma

Conclusion

Intra-detector calibration is being attempted for the two detector systems of a tokamak plasma. The results of this calibration provide a unified picture to understand the X-ray emissions for a wide band tokamak plasma.

References

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