Method for detecting and counting X-Rays

The most common electron temperature diagnostics, Thomson Scattering (TS) and Electron Cyclotron Emission (ECE), both require large diagnostic footprints and expensive optics.

Another electron temperature diagnostic is the Pulse-Height-Analysis (PHA) system, which derives the electron temperature from the x-ray bremsstrahlung continuum [2, 7]. However, the main disadvantage of the PHA method is poor temporal resolution of the Si(Li) diode detectors [1].

The detector configuration is optimized by Shannon-sampling theory [5], such that spatial profiles of the x-ray continuum intensity can be obtained simultaneously for different energies. The exponential-like dependence of the x-ray intensity with photon energies is compared with a model describing the Be filter, attenuation in air, and detector efficiency, as well as different sets of energy thresholds [6].

The energy thresholds are set to give the picture of the rate of decay of the bremsstrahlung radiation in the line free region of the plasma [2].

To isolate the continuum emissions, we are concerned with picking an energy window which avoids impurity lines. The most common impurities in C-Mod are Molybdenum from the plasma facing components and Argon (trace amounts) which is used for diagnostic purposes [7, 9]. The energy thresholds are set between 4 eV and 16 keV, at 1 keV intervals, where Mo and Ar are line free.

The exponential integral and exponential solutions do not include the physics of the transmission or the electric response of the detector and thus do not fit the data as well but still provide an interesting comparison to the numerical solution of the integral.

Conclusions

State of the art x-ray detection can be used to infer the central electron temperatures without the diagnostic footprint, complications and cost of ECE and TS systems. Adequate spatial and temporal resolution can be obtained. The Bremsstrahlung emission can be used as long as line free regions of the spectrum can be found and detected. This technique will be explored in tokamaks with W walls. Radiation hardened detectors and shielding will be needed.

References


Future Work

Our line of sight integral measurements can be inverted to find the emissivity at each flux surface. The emissivity ratios of each surface gives us an electron temperature profile of the plasma.

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Methods for detecting X-rays and setting different energy thresholds.

The number of X-rays detected from the Dectris photodiode is given by the density and temperature expression below. Where C is a constant n is electron density, Z is the effective charge of the plasma.

The transmission terms inside the integral, Tr can be approximated with an exponential, while the SI absorption is formulated from T = 1 - 1/2 Ab - 1/2 Ac - 1/2 Ab.

In addition we account for the electrical response of the detector which is fit with an error function and an exponential term used in the transmission calculation [10].

The detector works by exciting a potential difference across each pixel when a photon is struck by a photon. If the potential difference is greater than the threshold voltage, the photon is counted [3].

Count Measurements from X-Ray Detector

Brightness intensities are measured (line integrated) on each channel (insets plots b and c) for the duration of the plasma shot at C-Mod [7].

The decay of intensities as a function of energy can be resolved for each “energy channel” of the detectors.

The primary times of interest are before and during the ion cyclotron resonance heating (ICRH), highlighted in red.

We calculate electron temperature before, during and after transitions between low (L) and high (H) confinement modes present.

The results for electron temperature are plotted against each other over the duration of the shot.

Intensities were recorded with 20 ms exposure times to ensure counts high enough at all energies to be statistically relevant.

The parameter determining the rate of decay of x-ray intensity determines the electron temperature for each fit.

The numeric fit captures the physics of the x-ray transmission as photons reach the detector. The numeric fit temperatures are compared against ECE and TS.

Appendix

The emissivity ratios of each surface gives us an electron temperature profile of the plasma.