NOVEL ENERGY RESOLVING X-RAY PINHOLE CAMERA ON ALCATOR C-MOD

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Introduction

A new energy resolving x-ray pinhole camera has been recently installed on Alcator C-Mod.

A novel calibration technique is employed that allows the lower energy detection threshold of every pixel on a pixelated x-ray detector to be independently configured.

• 1D or 2D imaging.
• Pixel on a pixelated x-ray detector to be independently configured.
• A novel calibration technique is employed that allows the lower energy detection threshold of every pixel on a pixelated x-ray detector to be independently configured.
• A new energy resolving x-ray pinhole camera has been recently installed on Alcator C-Mod.

Installation on Alcator C-mod

The diagnostic is currently installed on a small radially viewing port.

• 50 um beryllium window.
• Swapable pinhole.
• Detector distance from the pinhole is adjustable.
• Air gap between pinhole and detector.

For the results shown on this poster:

• 2 mm diameter pinhole.
• 15 cm distance between the camera and the pinhole.

Spatial resolution is determined by the pinhole size and the distances between the detector, pinhole and plasma.

Initial results are taken during a low powered plasma shot

• $n_e = 1 \times 10^{19} \text{m}^{-3}$
• $T_e = 1 \text{keV}$
• 1 MW of RF heating

Detector Calibration

The energy resolving camera is based on a Pilatus 100K-S pixelated x-ray detector.

• CMOS hybrid-pixel detector
• Size: $195 \times 487$ pixels ($33.8 \times 83.8 \text{mm}^2$)
• Pixel pitch: $0.172 \times 0.172 \text{mm}$
• Readout time: 2.7 ms

Each pixel contains a pulse height discriminator with an adjustable lower energy threshold and a 20 bit counter.

• The lower energy threshold on each pixel is adjusted by a global threshold adjustment and a 6-bit programmable threshold adjustment.

The trimbits were designed to allow the variations in energy thresholds of each pixel to be corrected.

• Can also be used to set each pixel to have a different energy threshold.

Trimbit calibration procedure:

1. With the trimbits off, set the global threshold to allow x-ray detection at the lowest energies.
2. With the trimbits fully on, set the adjustment strength of the trimbits to reach the highest energy thresholds.
3. Determine the relation between the trimbits and the lower energy threshold on each pixel using a series of trimbit scans with different incident x-ray energies.

For a trimbit scan, the detector is illuminated with monochromatic x-ray line emission and the response of each pixel is recorded.

• Produces an s-curve response: $E_{\text{cal}} = \frac{x + \text{const}}{\sqrt{D_{\text{cal}}}}$
• Energy threshold corresponding to the incident x-ray energy is given by the inflection point.
• Energy resolution is given by the width of the s-curve.

Energy resolution

• Due primarily to electronic noise.
• 1.0 - 1.4 keV depending on the x-ray energy.

Courseness of the 6-bit trimbit adjustment also produces a scatter in the final energy thresholds.

The actual thresholds are recorded and can be used as part of the data analysis.

Experimental results

Images were taken during a plasma discharge using the metapixel configuration:

• The 9 pixels within each 3 x 3 metapixel were set with lower energy thresholds evenly spaced between 4 and 12 keV.
• 2 ms integration time, 5 ms framing time.

Initial results show the flexibility and effectiveness of this diagnostic technique.

Vertical profiles of the line integrated x-ray energy emission with different lower energy thresholds. The top plot is taken with 2 ms integration time, in the bottom plot 100 frames have been averaged together. The scatter in the profiles is from the variation in the lower energy thresholds caused by the finite stepsize of the trimbit adjustment.

Pixel configurations

Once calibrated, any configuration of lower energy thresholds on the detector is possible. Two configurations are of particular interest for diagnosis of fusion plasmas.

Metapixel configuration

Provides energy resolved 2D imaging.

• The detector is split into 3x3 metapixels.
• Each of the 9 pixels within the metapixel is given a different lower energy threshold.

1D imaging using vertical strips

Well suited for imaging toroidally symmetric plasmas where no variation in the image is expected in the horizontal direction.

• Each column of the detector is set to different threshold.
• Provides high resolution 1D imaging.
• Multiple columns with the same threshold can be used to improve photon statistics at the higher thresholds.

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References


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