Initial Tests of a Position-Sensitive Ionization Chamber

T. Gog, D.M. Casa, I. Kuzmenko (CMC -CAT @ the APS)

Position-sensitive ("split-") ionization chambers offer a convenient way of measuring the total intensity of an x-ray beam and its position along a line perpendicular to the optical axis with μm-precision. In a position-sensitive ion chamber the collection electrode is split into two halves, which symmetrically overlap the beam center line. When the x-ray beam passes the device in an off-center position, one half will generate a stronger signal than the other, the difference providing a good measure of the beam position.

Two modified Oxford ion chambers of type "YMCS0002 IC PLUS 150" were briefly evaluated at the CMC-CAT beamline 9-ID at the Advanced Photon Source, Argonne Nat'l Laboratory. The "zigzag" overlap pattern of the split 147 mm-long collection electrodes is indicated in Fig.1, overlap width was 16 mm for the first chamber with a period of 6 mm, 24 mm for the second chamber, with a period of 10 mm. Standard counting chains as employed on all conventional ion chambers at CMC were used, together with He at atmospheric pressure as a counting gas.

The performance of the split ion chambers during these initial tests was stable, reliable and reproducible. Measurements of the beam position for the two chambers were linear within 1% tolerance for ranges of 6.55 mm and 13.2 mm, within 10% tolerance for ranges of 14.2 mm and 23.9 mm, respectively. Positional uncertainties were determined to be 3.5 μm and 5.0 μm, and could possibly be improved by optimization of the counting chains.

Experimental Set-up and Configuration

A beam of monochromatic X-rays at an energy of 8.0 keV and an approximate absolute flux of $5.0 \ 10^{12}$ photons/s was used in the present tests. These X-rays originated from an undulator source, followed by a cryogenically-cooled Si(111) double-crystal monochromator, as shown in Fig.1. Horizontal and vertical focussing mirrors reduced the beam size to 150 μm x 700 μm (v x h) at the detector. The position sensitive ion chambers were mounted on a vertical translation stage at a distance of 33.5 m from the monochromator. A set of guard slits in close proximity to the ion chamber completed the x-ray optics.

The split ion chambers were operated with flowing He-gas at approximately atmospheric pressure and a high voltage of –310 V. This combination of x-ray flux, counting gas and supply voltage establishes the working point of the ion chambers on the plateau of the input voltage/output current characteristics.

Two identical electronic counting chains, similar to the ones used for conventional ion chambers at CMC-CAT, were employed with the split ion chamber. They consisted of a discrete current amplifier, NIM-based voltage-to-frequency converter and VME-scaler. The particular types and settings are listed below. The normalized differential output (S1-S2)/(S1+S2) was calculated by the control computer from the separate scaler readings S1 and S2.
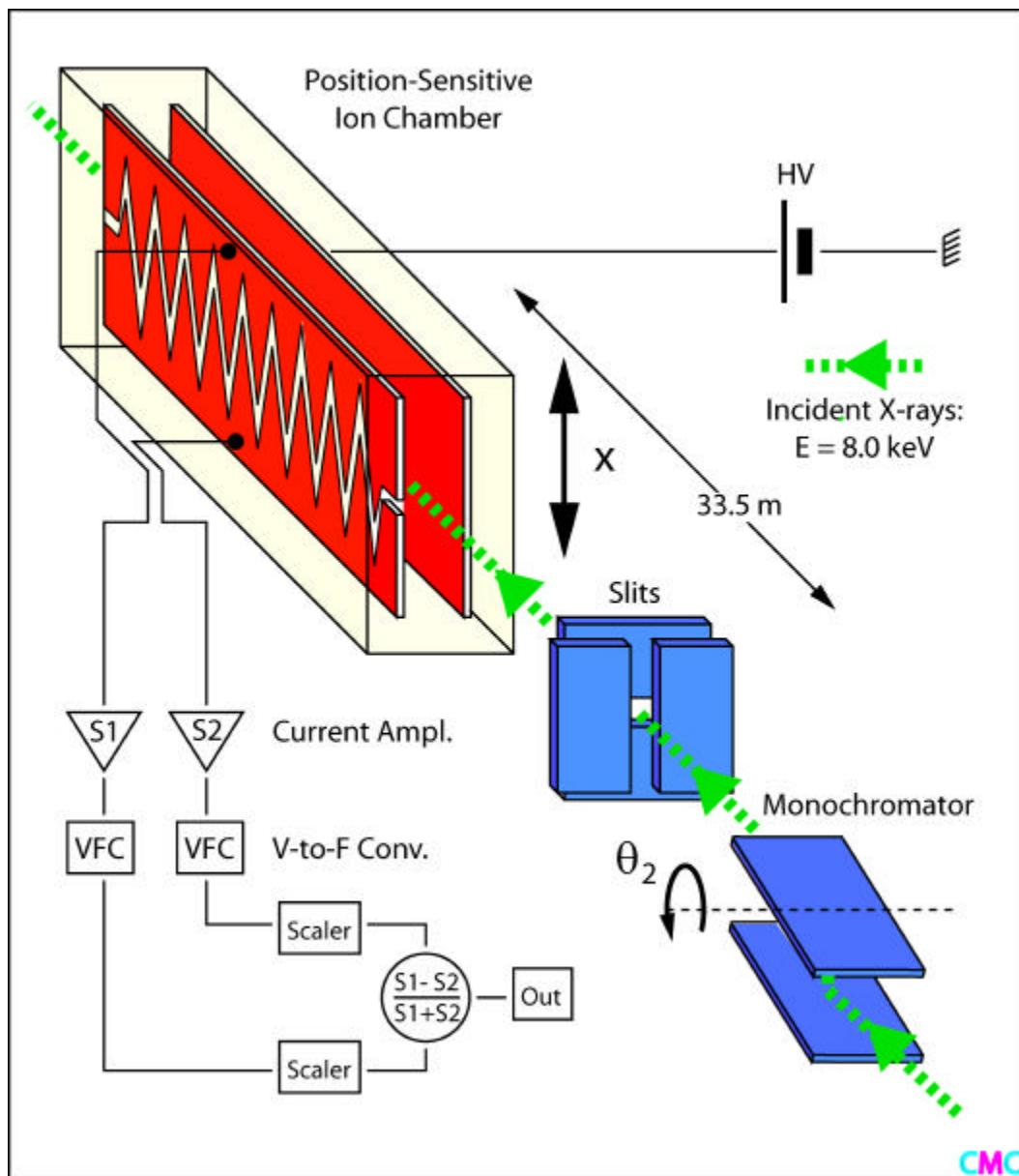
Fig. 1: Experimental Set-up

Counting Chain Configuration

High Voltage Supply: CANBERRA 3106D, -310 V
Current Amplifiers: Stanford Research Systems (SRS) Model SR570
                        Sensitivity: 20 nA/V
                        Gain Mode: Low Noise
                        No Filter

Voltage-to-Freq. Conv:	Nova R&D, Inc., Model N101VTF
	Gain: x1 (0.1 MHz/V)
Scaler:	Joerger Enterprises, Inc., Model VSC 16/8

Linearity and Positional Uncertainty

The linearity of the normalized differential output $(S_1-S_2)/(S_1+S_2)$ as a function of actual beam position was measured by vertically translating the split ion chamber with respect to the fixed incident beam over the range where the two sides of the split collection electrodes overlap (active width). The results are shown in Fig. 2 and Fig. 3 for the chambers with 16 mm and 24 mm active width respectively.

Allowing deviations of up to 1%, the linear range for the first ion chamber (16 mm) was found to be 6.55 mm, 14.2 mm for deviations up to 10%. Typical fluctuations of the signal in the center of the linear range are shown in the inserts of Fig. 2 and Fig. 3. For the chamber #1 these fluctuations amount to a positional uncertainty of 3.5 μm. This uncertainty can possibly be reduced by trimming the noise levels in the electronic counting chains.

For the second ion chamber (24 mm) linear ranges were found to be 13.2 mm (1%) and 23.9 mm (10%) at a positional uncertainty of 5.0 μm.

Looking towards a possible application of these position-sensitive ion chambers as feedback monitors for a double-crystal monochromator, a measurement of the beam position as a function of pitch angle θ_2 of the second crystal was performed with the second split ion chamber (24 mm) and is displayed in Fig. 4. With a distance between the monochromator and the ion chamber of approximately 33.5 m, total beam excursions of 3.3 mm were observed. The positional uncertainty of 5.0 μm results in an angular uncertainty at the maximum of the rocking curve of about 7.0×10^{-6} degree or 0.2% of the rocking curve's FWHM .
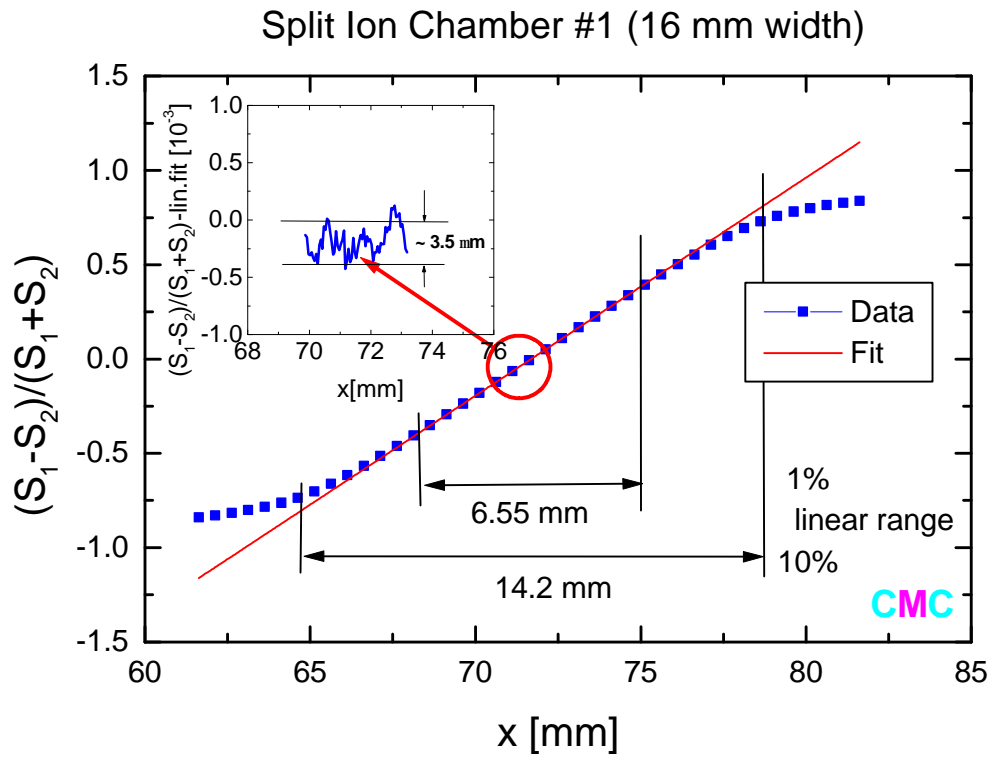
Fig. 2: Normalized differential output as a function of beam position for the ion chamber with 16 mm active width. The insert shows a magnification of signal fluctuations in the center region, the amplitude of which is indicative of the positional uncertainty of the measuring system as a whole
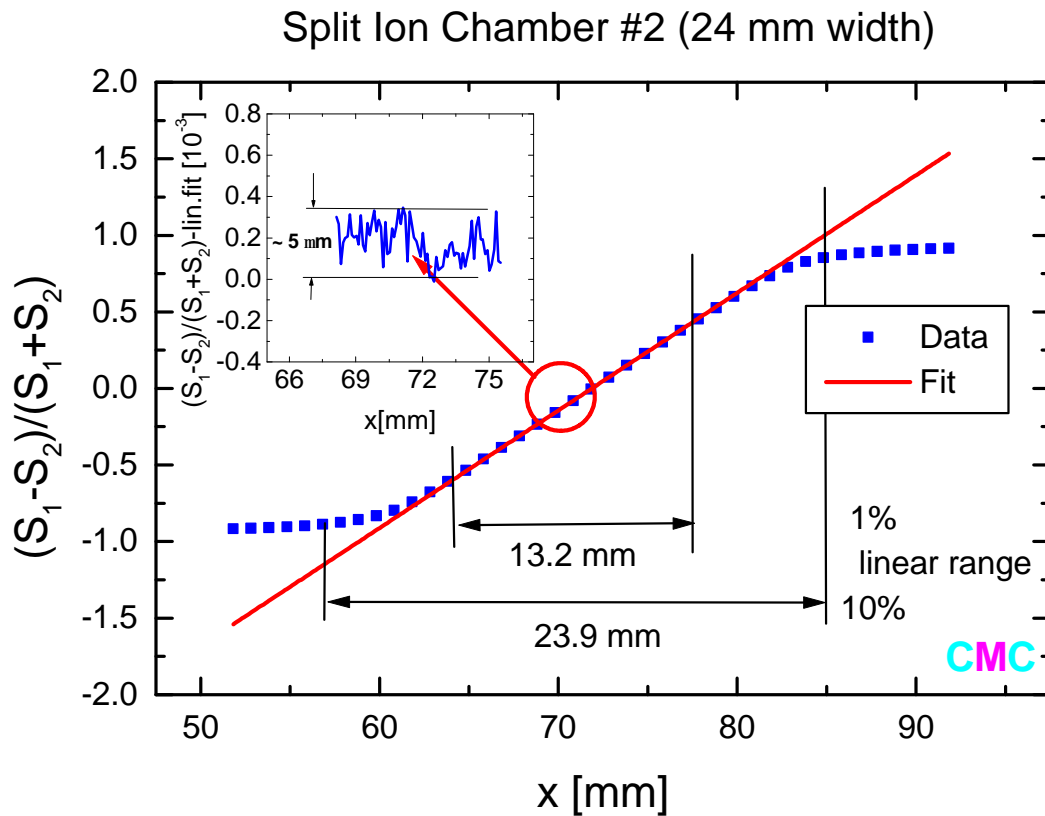
Fig. 3: Normalized differential output as a function of beam position for the ion chamber with 24 mm active width. The insert shows a magnification of signal fluctuations in the center region, the amplitude of which is indicative of the positional uncertainty of the measuring system as a whole
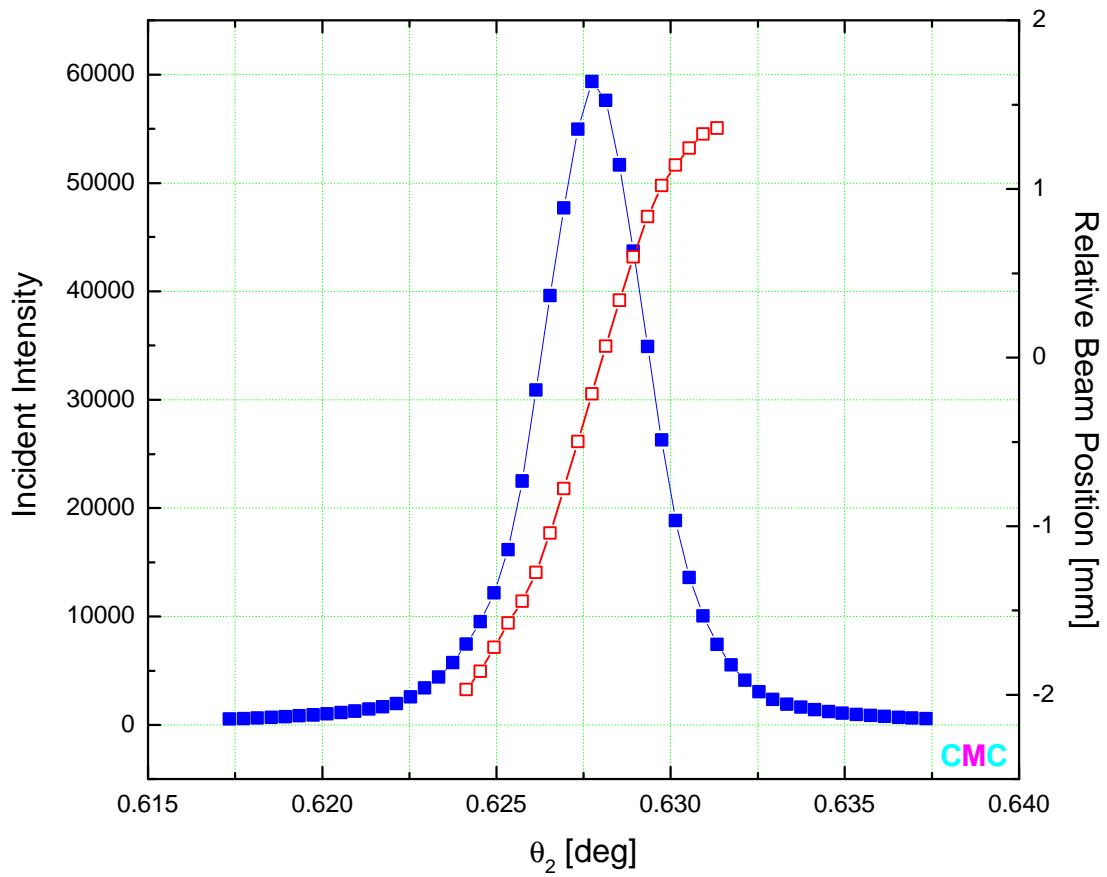
Fig. 4: Intensity and beam position as a function of pitch angle of the second monochromator crystal at a distance of 33.5 m between monochromator and detector