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Ionization Chamber Detector for X-ray with Beam Position Monitoring

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Abstract. Ionization Chambers have been commonly used at beamlines in many synchrotron radiation facilities. Typical ADC ion chambers are pictured in Figure 1. The chambers generate a current proportional to the incident X-ray beam intensity. The ionization chamber allows users to determine the change in beam position in a single axis by comparing two signals that are created as the beam passes through the Ion Chamber [1]. By connecting two Ion Chambers together at 90° you can determine the horizontal and vertical beam position. One unique feature of the new precision ion chambers is the incorporation of a split collector plate. The electrode is split in a saw tooth configuration with a height of approximately 10mm, 15mm, and 25mm such that, when the differential current is computed, allows use as a beam position monitor. A summary test results from the hard X-ray beamline, BL06, at bending magnet source of SAGA Light Source in Japan is presented.

(a) (b) (c) (d)

FIGURE 1. (a) & (b) ADC's IC-400 Series, (c) ADC's IC-500 Series, (d) ADC's Micro Ion Chamber

INTRODUCTION

The reliable monitoring of the intensity of the X-ray beam in the case of synchrotron-radiation-induced measurements is crucial for correcting the intensity change caused by the different optical and beam influencing elements at the beam line. In order to probe precisely the change in the intensity of the X-ray radiation penetrating the sample, a counter should be introduced between the last optical or beam influencing element and the sample.

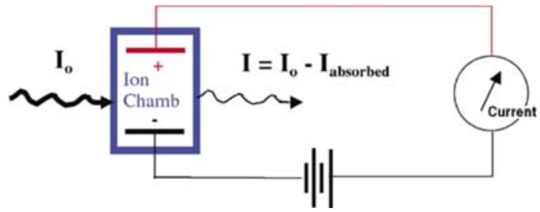


FIGURE 2. Parallel Plate Geometry

Typical ionization chambers are constructed with the parallel plate geometry as illustrated in Figure 2. As the voltage is increased, the resulting electric field begins to separate electron-ion pairs generated by ionizing radiation more rapidly, and the recombination process between the electrons and the ions are diminished. At a sufficiently high applied voltage, the electric field becomes strong enough to suppress the recombination process to a negligible level, and all the charges initially created through the ionization process contribute to the ionization current. Under these conditions, the current measured in the external circuit can be regarded as an indication of the formation rate of all charges due to ionization by the incident X-ray photons. Absorption of x-ray photons in materials follows the rule, I = Ioe-μt where I is the x-ray intensity after passing through a material, Io is the initial intensity, μ is the absorption coefficient for that particular photon energy and t is the thickness of the absorbing material. This photon absorption results in an electron/ion pair being produced in the absorber material. All an “ion chamber” does is to apply a potential held around these newly created electron/ion pairs, separate them and measure the resulting electric current to determine how many pairs were created and thus how many photons were absorbed [2].

Device Overview

ADC's ion chambers are designed for precise, low noise x-ray measurement. The electrodes are constructed of nickel plated copper on fiberglass supports, all housed within a nickel plated aluminum frame. The high voltage electrode is connected to an SHV connector. The low voltage electrodes are connected to BNC connectors. The system can be configured for air or vacuum operation through one of two interfaces. The air system stands alone mounted to the system table. The vacuum configuration interfaces are through a bulkhead fitting style NW40 and NW25 or a conflat 4” and 6” in size.

The device allows user to determine the change in beam position in a single axis by comparing two signals that are created as the beam passes through the Ion Chamber. By connecting two Ion Chambers together at 90° you can determine the horizontal and vertical beam position. The system can be configured for air, vacuum, or ultra high vacuum operation through one of three interfaces. One unique feature of ADC's precision ion chambers is the incorporation of a split collector plate. The electrode is split in a saw-tooth configuration with a variable height from 10mm to 25mm that, when the differential current is computed, allows the use as a beam position monitor.

Ion Chamber Key Features includes; The standard operating pressure range 0.7 to 1.3 bars absolute. Operating potential up to 1.7 kV, available with three different electrode lengths; 50 mm, 100mm, and 200 mm, electrode separation is factory installed at 25mm which can be changed in 5mm increments down to 10mm, Kapton foil thickness installed default from factory is 25um.

Experimental Test Results:

A test was set up at the Kyushu University Beamline (SAGA-LS /BL06) as shown in Figure 3. The IC-400-100 was mounted on a precision motion lifting system [3].

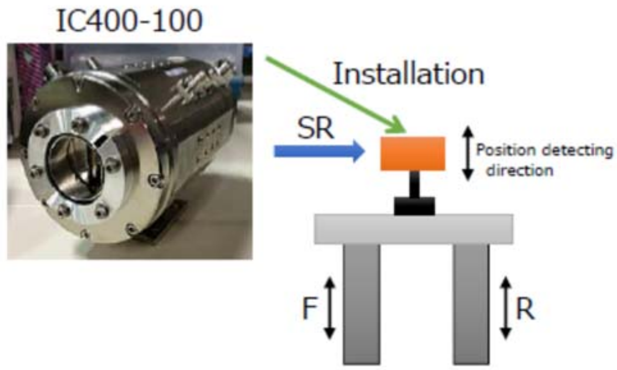
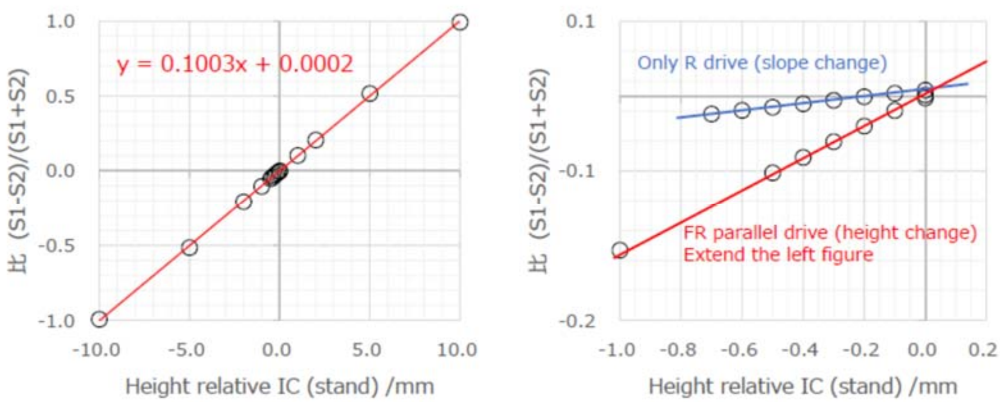


FIGURE 3. Kyushu University Beamline Test

Lifting mechanism (front and rear) with stand, using the IC400 precision Ion Chamber. The measured current while changing the height of the gantry to the position fixed beam.

In Figure 4 the movement shows a high linearity of the count changes to the amount of movement for the same parallel move. Accuracy of 10-50 microns was obtained. Considering error of 100-101 microns was generated in the driving accuracy of the stand, the Ion Chamber shows that sufficient accuracy is achieved.

Figure 4 (b) shows the accuracy can be measured sufficiently even the inclination of the IC relative to the beam when it is driven only R.



(a) (b)

FIGURE 4. Test results obtained from Kyushu University Beamline Test

Another similar test was conducted at Advanced Photon Source (APS) in Chicago using PNC-CAT, Pacific Northwest Consortium Collaborative Access Team. Results from this test are shown in Figures 5 and 6.

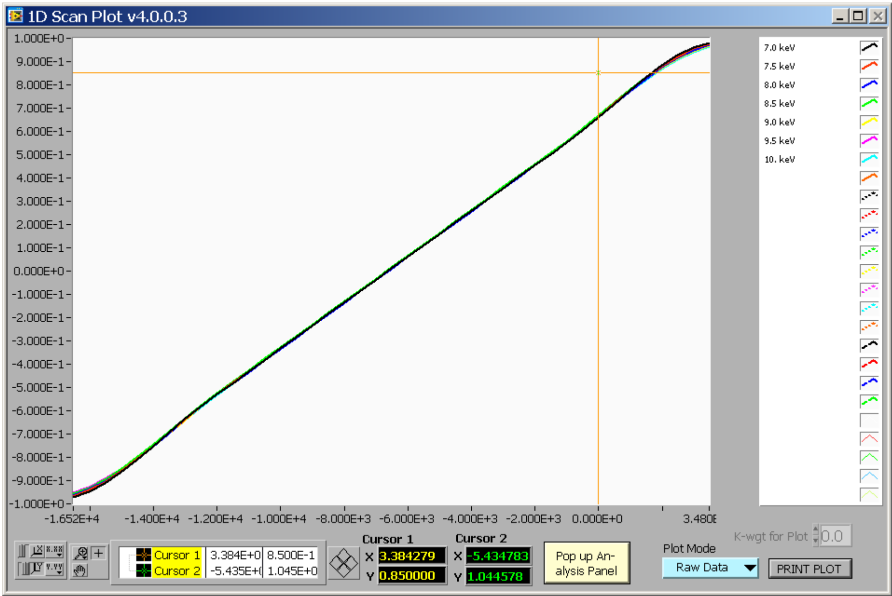


FIGURE 5. Normalized difference signal vs. vertical chamber position

Figure 5 shows normalized difference signal (i.e. (I1-I2)/(I1+I2)) vs. vertical chamber position at several different energies. The horizontal scale is in microns. The scan range was -10mm to +10mm from the starting position. At each energy the hutch table was adjusted to center the beam on the I0 slit.

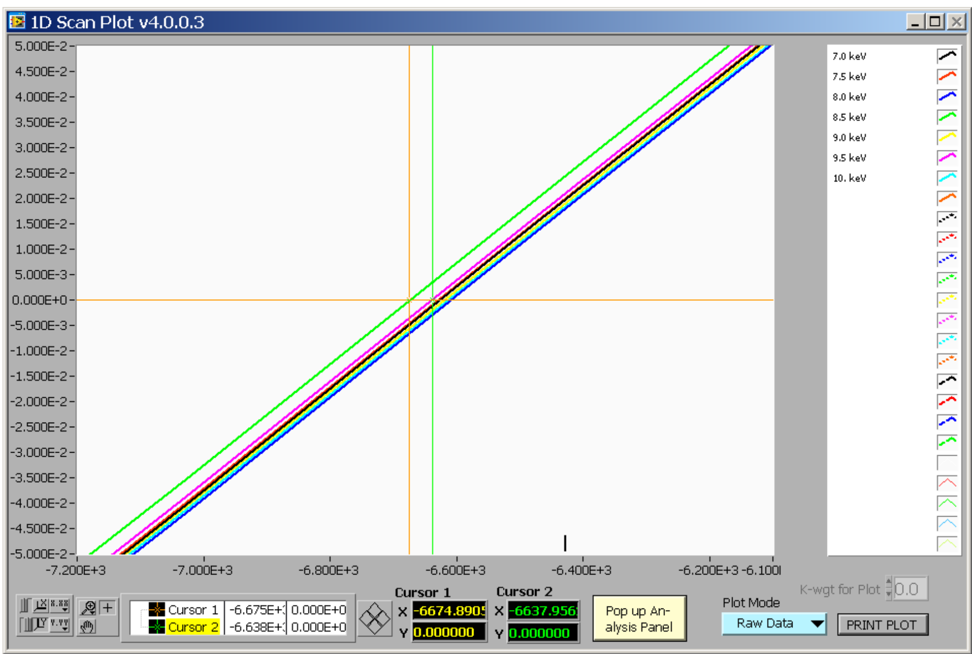


FIGURE 6. Zoomed in normalized difference signal vs. vertical chamber position

Figure 6 shows the same image as Figure 5 except zoomed in near the center. The cursor displays illustrate the displacement between the 8.5 keV plot and the next closest plot (9.5keV) at 0 difference signal. The measured difference in positions where the difference signal is 0 at the two energies is ~37 microns. The uncertainty in position for a given difference signal was most likely dominated by the uncertainty in centering the beam on the I0 slit, which was done by simply maximizing the I0 signal as we moved the hutch table vertically. We could no doubt get better precision by scanning the table to find the best position.

Electrical Connection

In a typical ion chamber setup, shown in Figure 7, one of the electrodes is given a high voltage and as the beam goes through the chamber the gas ionizes and is collected on the low voltage collector plate. This collector plate signal is then increased by the current amplifier which outsputs to the voltage-to-frequency converter (VFC). This signal is then sent to the scaler (also called a counter) to be analized by the end user.

A position-sensitive ("split-") ionization chamber can 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. To accomplish beam monitoring in an ion chamber there must be nearly twice the amount of electronics are needed, shown in Figure 8.

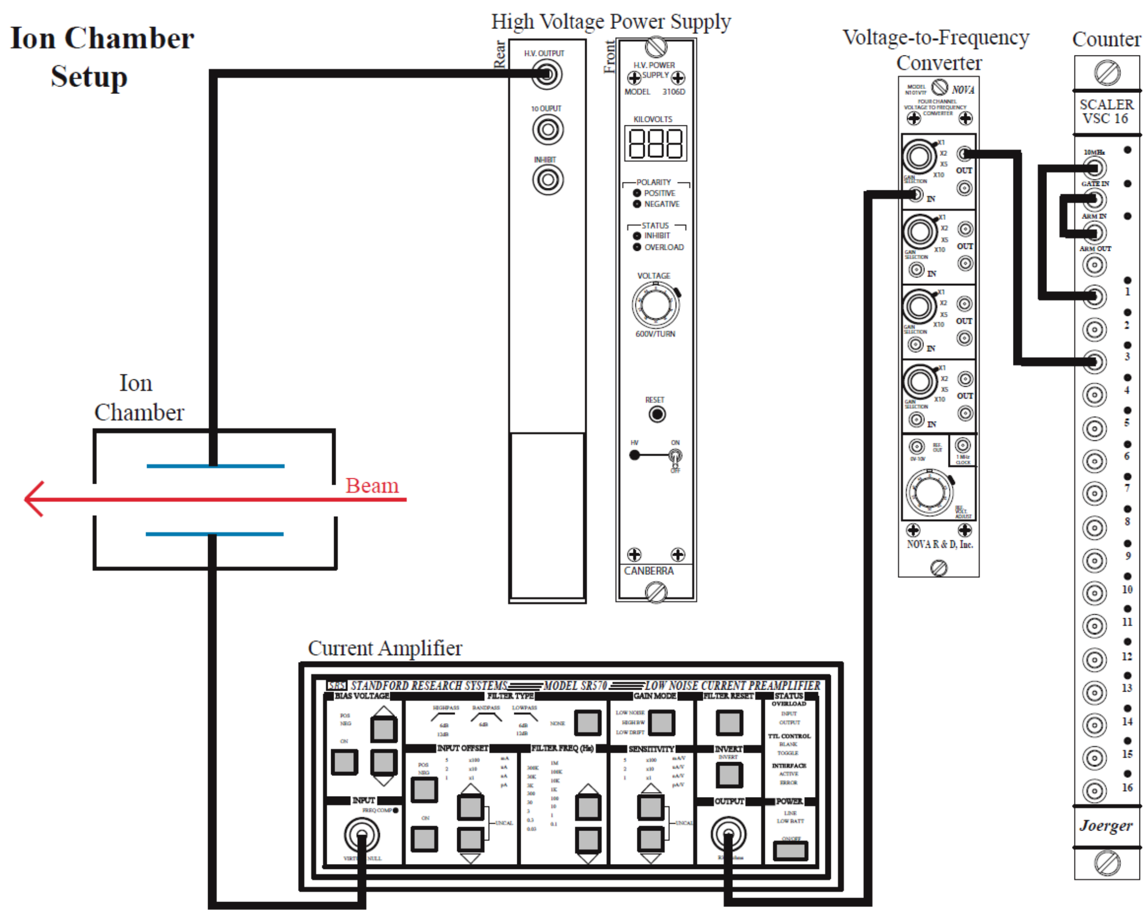
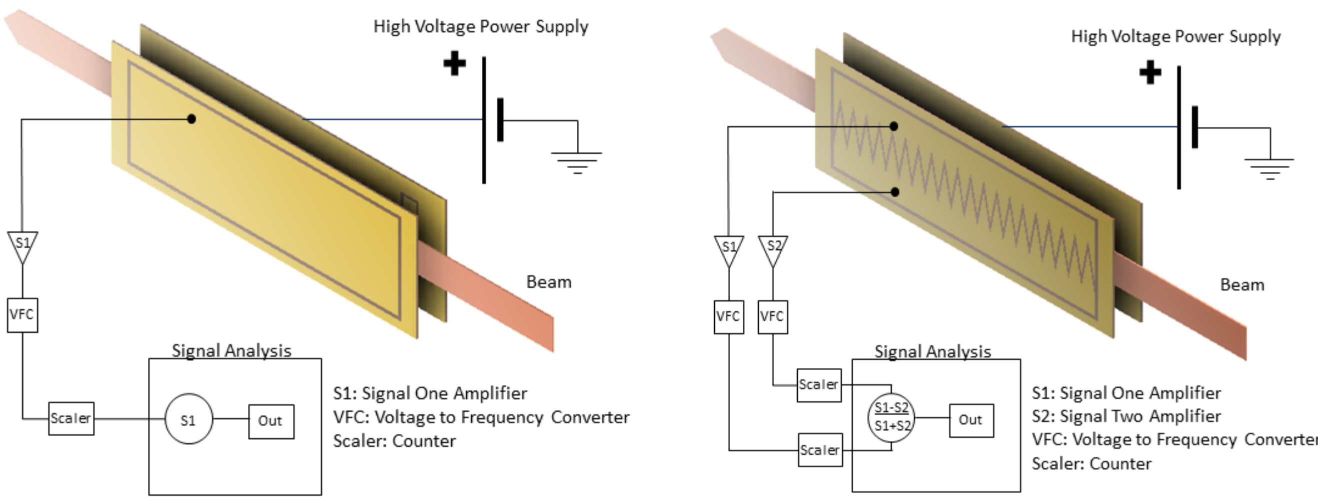


FIGURE 7. Typical ion chamber setup using a variety of off the shelf components (Drawing taken from Advanced Photon Source Sector 9)



(a) (b)

FIGURE 8. (a) Single output ion chamber (b) Position-sensitive ("split-") ionization chamber

Preamplifier

Current range	0.1pA to 0.1mA
Integration time	1s to 10μs
Input bias current	100fA at 25°C
Input current noise	f=0.1 to 10Hz 10fA p to p
Input offset voltage	5μV/°C max 1μV/°C typical
Input/output imp.	1012Ω/50Ω
Voltage output	0-10V

The SR570 is a low-noise current preamplifier capable of current gains as large as 1 pA/V. High gain and bandwidth, low noise, and many convenient features make the SR570 ideal for a variety of photonic, low-temperature and other measurements.

Voltage to frequency convertor

Frequency output	10KHz to 1MHz
Linearity error	0.1% typical (100Hz to 1MHz)
Output impedance	50 Ω short circuit protected

High Voltage supply

Adjustable range	0-3000V in 10V steps
Noise	5mV p to p
Max. output current	1.2mA
Temperature drift	20 ppm/°C typical

The CANBERRA Model 3102D High Voltage Power Supply is a single-width NIM module designed primarily for use with photomultiplier and electron multiplier tubes. But it can be used with any detector requiring a bias voltage up to 2000 V and a current level of 1 mA or less. The 3102D allows the user to select from two continuously adjustable outputs, one ranging from ±15 to ±2000 V dc and the other from ±1.5 to ±200 V dc. The output voltage is measured and displayed by a three-digit voltmeter. In addition, this unit allows the user to select the output voltage polarity with an internal control.

CONCLUSIONS

We have confirmed that the position of an X-ray beam can be measured by using the ADC's Ion Chamber Experimentally utilizing 2 different Synchrotron facilities. Position sensitive ionization chamber may provide us with more detail information for systematic research of X-ray beam stabilization. Measuring the intensity change of the focused beam proved that the current of the chamber follows linearly the intensity change.

ACKNOWLEDGMENTS

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