7th International Conference on Mechanical Engineering Design of Synchrotron Radiation Equipment and Instrumentation 15-19 OCT. 2012, SHANGHAI, CHINA

Development of a Series Low Noise & Precise Ion Chambers Capable of Beam Position Monitoring

Eric Van Every, Alex Deyhim, Joe Kulesza
ADC Inc. Lansing, NY 14882, U.S.A

Abstract

This series is a second generation significantly improved compact Ion Chambers with Beam Position Monitoring shown in figure 1. These ion chambers were tested at the Advanced Photon Source (APS-USA) and are being used in all major synchrotron facilities around the world with excellent results.

In this paper ADC will discuss the design and shows the test results for IC-400 & IC-500 series ion chambers (figure 2 and 3) that are used for precise, low noise x-ray measurement. The device 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 can be determined. The system can be configured for air, vacuum, or ultrahigh vacuum operation through one of three interfaces.

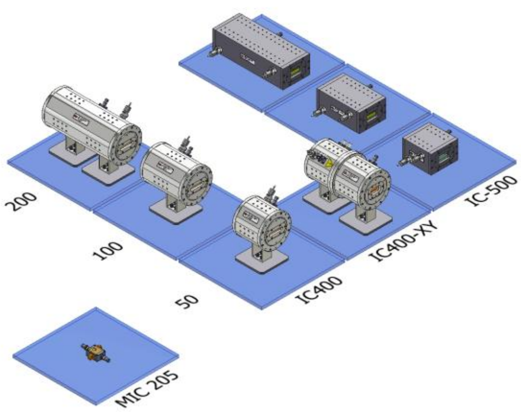

Figure 1: IC-400, 500, MIC-205

OVERVIEW

ADC's ion chambers are designed for precise, low noise x-ray intensity 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.

Figure 2: IC-500

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 20mm that, when the differential current is computed, allows the use as a beam position monitor as well as intensity monitor. A pair of ion chambers connected with a 90° relative rotation can be used for 2 axis position monitoring.

Figure 3: IC-400

ION CHAMBER ELECTRICAL DISCRIPTION

In a typical ion chamber setup 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, Figure 4, top. This collector plate signal is then increased by the current amplifier which outputs to the voltage-to-frequency converter (VFC), Figure 5. This signal is then sent to the scaler (also called a counter) to be analyzed 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, Figure 4, bottom. 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.

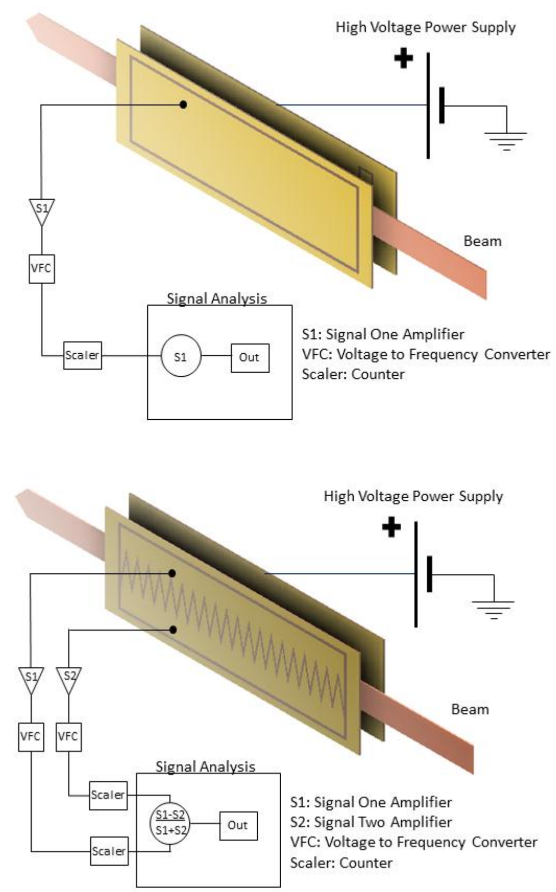

Figure 4: Single output ion chamber (top) & Position-sensitive ("split-") ionization chamber (bottom)

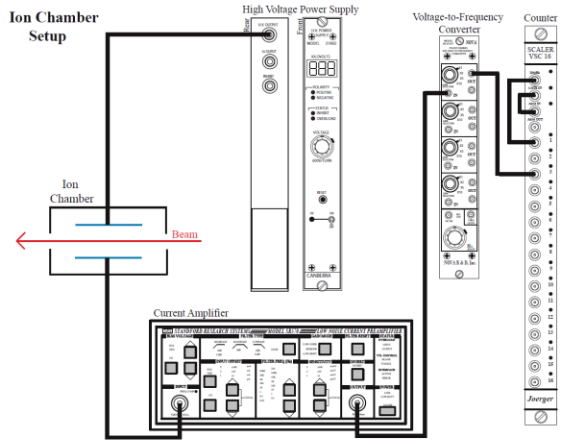

Figure 5: Typical ion chamber setup using a variety of off the shelf components

The amplifier for the low current of an IC is required to have ultrahigh open-loop gains to achieve the desired degree of linearity, together with ultra-low noise IC [2].

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

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

TEST RESULTS

These ion chambers were tested at the Advanced Photon Source (APS-USA). The following is a summary of the test results from APS shown in figure 6 and 7, on the following page.

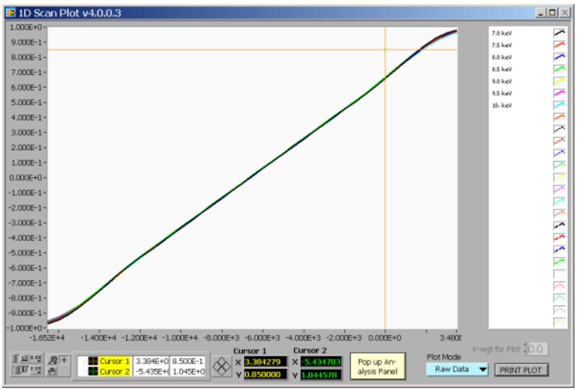

Figure 6: Normalized difference signal (I1-I2)/(I1+I2) vs. vertical chamber position at several different energies. Horizontal scale is in microns. Scan range was -10mm to +10mm from the starting position. At each energy (7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0 keV) the hutch table was adjusted to center the beam on the I0 slit.

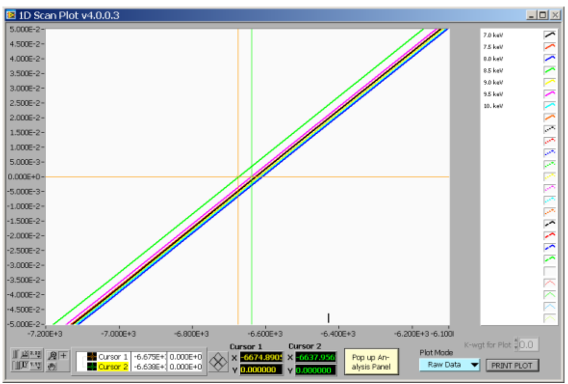

Figure 7: Same is Figure 4 except zoomed in near the center. The cursor displays illustrate the displacement between the 8.5 keV plot and the next closest plot (9.5keV) at 0 difference signal. The measured difference in positions where the difference signal is 0 at the two energies is ~37 microns. The uncertainty in position for a given difference signal is dominated by the uncertainty in centering the beam on the I0 slit

MICRO ION CHAMBER (MIC-205)

A small ionization chamber detector (figure 8) has been developed for monitoring the intensity of hard X-ray beam for synchrotron facilities. The small dimensions of the ionization chamber (20 mm along the beam direction and 30 mm perpendicular to it) make it possible to place it very close to the sample, or between other optical components.

The housing of the detector is made of stainless steel, nickel-plated copper electrodes, SHV and BNC electrical connectors, and gas connectors.

Sparking voltage is approximately 5500V under the atmospheric environment and leakage rate of gas is less than 2 torr/5 minutes under 10 torr vacuum environment.

Figure 8: Micro Ion Chamber (MIC-205)

REFERENCES

[1] High Precision Ionization Chamber for Relative Intensity Monitoring of Synchrotron Radiation. S.N. Ahmed (1), H.-J. Besch (2), A.H. Walenta (2), N. Pavel (2), W. Schenk (2) ((1)MPI for Physics, Munich, Germany. (2)Physics Dept., Siegen University, Germany) Instrumentation and Detectors (physics.ins-det) Nucl. Inst. and Meth. in Phy. Res. A449(2000) 248

[2] J. Gustafsson, P. Kotilainen, V. Hanninen, E. Liukkonen and K.Kaski, “K130 beam current measuremnt system”, Nucl. Inst. and Meth. Phy. Res. A 342 (1994) 552-557.