J. Synchrotron Rad. (1998). **5**, 872–873

A new ion chamber with a movable photodiode monitor for absolute intensity measurements of soft X-rays

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(*Received 4 August 1997; accepted 1 December 1997*)

A new ion-chamber system with a movable monitor detector for the measurement of soft X-ray absolute intensity is introduced. The calibration results are also given.

Keywords: ion chambers; calibration; soft X-ray absolute intensity measurements.

1. Introduction

With the development and application of soft X-ray optics, the measurement of the absolute intensity of soft X-rays is becoming more and more important in many fields, such as soft X-ray microscopy, irradiation breeding of crops, calibration of detectors for diagnosis of tokamak plasma, irradiation of semiconductor materials *etc.* However, there is no metric standard in the soft X-ray region, especially in the range above 250 eV. The National Institute of Science and Technology (NIST) in the USA can only calibrate a detector in the range above 5 nm wavelength (National Institute of Science and Technology, 1997). In the other part of the soft X-ray region, there is no standard which is widely accepted. NIST were planning to upgrade their SURF II to expand the range of soft X-ray measurement to 3 nm (400 eV) in 1986 (Ott *et al.*, 1986), but this has yet to be completed.

There are two possibilities for a standard: a standard light source and a standard detector. Because there is no standard source in the region 250–3000 eV, a detector with high precision is the only choice for the measurement of absolute intensity. Its calibration can only be achieved by considering and analysing all possible errors carefully.

The gas-ionization chamber is the most plausible candidate due to its simplicity in principle and in configuration. Due to these advantages of the ionization chamber, it can also be used as a primary standard detector after calibration.

Usually ionization chambers are used in the hard X-ray region above 5 nm wavelength. Because of secondary and multiple ionization in the soft X-ray region, it becomes very complicated and difficult to analyse and correct the results. Therefore, in the soft X-ray region, the ionization process must be carefully considered.

We have designed a set of low-pressure ionization-chamber systems for the measurement of soft X-ray absolute intensity. The system will be used as a primary standard detector for calibration of other soft X-ray detectors at Beijing Synchrotron Radiation Facility.

2. Configuration of the system

The system consists of an ion chamber, a photodiode monitor and transferring system, a pressure controller and a low-current measurement system (Keithley 6517 electrometer). The ion chamber includes a cylindrical cavity for positive-bias voltage, an off-axis mounted wire and a thin Si_3N_4 window (300 nm), as shown in Fig. 1. The electrical field of the cross section between the anode and the collector is also calculated.

The wire includes four sections, two signal collectors and two guarding poles. The collectors can be used as single or double collectors by connecting or disconnecting the contact between the two collector sections. The guarding poles at the two ends keep the electrical field near the edges of the collectors uniform.

The photodiode monitor is fixed at the end of the cylindrical cavity. It can be moved along the axis of the cylinder for the whole length of the ion chamber. The transferring system gives an accuracy of movement of 0.05 mm. The monitor has three uses: firstly, it can be used to measure I_0 and *I in situ* to eliminate the effect of changing the light source; secondly, it can be used to calibrate the uniformity of the pressure at any point on the axis of the ion chamber; and thirdly, it can also be calibrated as an uncalibrated detector.

The pressure in the ion chamber can be controlled by a pressure-measuring apparatus and a mass-flow controller within a range of $1–10^{-3}$ torr. The ionization chamber is connected to the synchrotron radiation beamline. The vacuum match between the ion chamber and the upstream part of the beamline is achieved through a differential vacuum system or a thin window (Si_3N_4). There is a 1 mm-diameter hole in the light diaphragm. If a thin window is used, it is installed onto the diaphragm. With the thin window, the vacuum in front of it can reach 10^{-7} torr while that behind it is $1–10^{-3}$ torr.

The ion current is measured by a Keithley 6517 electrometer. The signal is fed into the electrometer through a low-noise cable from the ion collector.

3. Calibration experiment

The calibration of the whole system was carried out on beamlines X8A and U3C at NSLS at Brookhaven National Laboratory. The ion chamber is operated as a single ion chamber and with a thin Si_3N_4 window. The energy range of the X-rays is 50–1600 eV. The

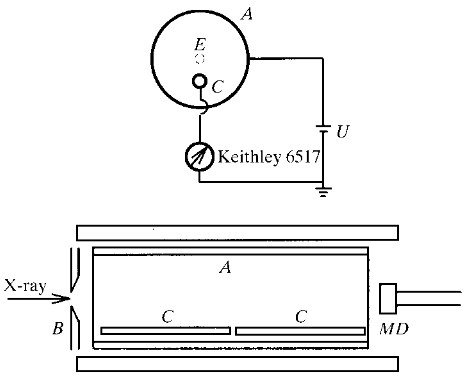

Figure 1
The measurement system for absolute intensity of soft X-rays. *A*, anode; *B*, diaphragm; *C*, collector; *U*, electrical source; *MD*, monitoring/uncalibrated detector; *E*, ionization area (the two guarding poles are not shown).

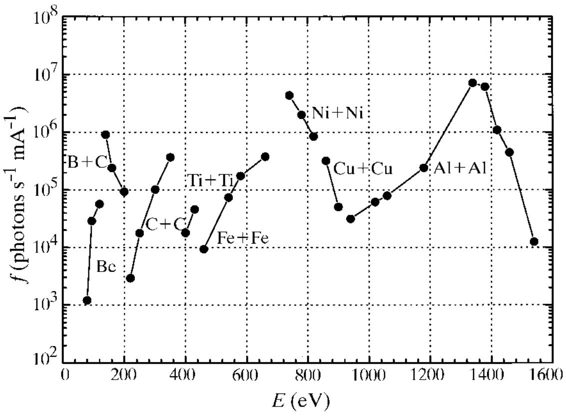

Figure 2
The photon flux measured by the soft X-ray absolute intensity measuring system. The flux is that received by the detector system after filters and the thin Si_3N_4 window. The elemental symbols in the figure indicate the filters. f, Photon flux; E, soft X-ray energy. This result was acquired on the U3C beamline.

pressure range is 1–200 Pa. The following measurements were made in the calibration.

(*a*) Measurement of the uniformity of the pressure at the axis of the ion chamber. The pressure of the ionizing area (near the axis of the ion chamber) is measured with the monitor detector and transferring system.

(*b*) Determination of the operating voltage of the ion chamber. The operating biased voltage is determined by measuring the saturation curves of the ion chamber at different X-ray energies and operating pressures.

(*c*) Measurement of the ionization chamber and monitor signals simultaneously while changing the X-ray energy and pressure. Argon and neon gas are used as the operating gases in the ion chamber.

(*d*) Measurement of the stability of the light source. The X-ray energy, pressure and biased voltage are kept constant while the ion chamber and monitor signals and the electron beam current are recorded.

A biased voltage of 60 V was chosen from the saturation curves at varying X-ray energies and pressures. At each X-ray energy, the relationship between signal and pressure was linearly extrapolated to zero pressure to eliminate the effect of secondary ionization. Then the result was corrected with multiple ionization data (Lightner *et al.*, 1971; Samson & Haddad, 1974*a*,*b*; Schmidt *et al.*, 1976). Other effects, such as that of the absorption due to the gas between the thin window and the front end of the collector *etc.*, were also eliminated.

4. Results

Some of the results are shown in Fig. 2. The uncertainties of the results considered include: the error of the electrometer and the pressure gauge, the pressure difference between the axis of the ion chamber and the site of the gauge, the non-uniformity of the pressure on the axis and the instability of the light source. The total uncertainty is 11%.

5. Conclusions

The whole system for the measurement of soft X-ray absolute intensities has been carefully designed and calibrated. After eliminating the effects of secondary and multiple ionization and considering all errors, this system can be used as a primary standard detector for measuring the intensity of soft X-rays.

The authors much appreciate the kind help of Dr Warren Towell, Dr Gong Pingpo and Dr Michael Sagurton.

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