X-RAY, SOFT X-RAY, AND VUV BEAM POSITION MONITOR

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ABSTRACT

An x-ray beam position monitor has been developed and is currently operational at the NIST beamline X-24A of the National Synchrotron Light Source, Upton, NY. It was developed to accurately measure the vertical position of the synchrotron beam and to allow precise positioning of beamline optics. It is an area type monitor positioned 5.6 meters from the Tangent Point and precedes all beamline instrumentation. Vertical beam position is given by the differential photoemission current from two grids mounted on a Macor frame. The monitor also senses the total photon beam flux.

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Introduction

The development of high-brightness, dedicated synchrotron radiation storage rings has opened a new era in synchrotron radiation beam instrumentation. As beamline optics have become more sophisticated to fully exploit the ultimate capabilities presented by the new sources, their performance has also tended to become more sensitive to small errors and fluctuations of the electron beam position in the storage ring. The ideal solution of eliminating these orbit problems is not yet in hand. An alternative approach is to permit the beamline optics to adapt to the orbit position as changes occur. Another possibility is to carefully monitor and record these changes as data is collected for the purpose of applying corrections later during data analysis.

In any of the three proposed solutions to the electron beam motion problem, a necessary element is the ability to monitor the photon beam displacement and/or angle, preferably in real time. Various designs for x-ray beam position monitors have been previously described [1,2,3,4]. In this work we present a novel variation on previous designs that has several advantages, especially for low energy x-ray and VUV beamlines. The prototype monitor is operational at the NSLS on beamline X-24A [5] which operates in the energy range 500 - 5000 eV. The performance and characteristics of this monitor are presented.

Monitor Design

The basic principle for the X-24A beam position monitor employs two triangular photoemitting electrodes to provide a linear differential signal versus beam position. This principle has previously been utilized in the *jeu de jacket*, or "backgammon", position sensitive proportional counters [6] and in at least two other designs of x-ray beam position monitors [3,4]. It is necessary that the beam impinging on the electrodes cover the full width of the differential elements. The triangular shape of the differential elements assures detector linearity versus beam height. This design is shown in Figure 1.

One problem encountered with previous differential element beam position monitors is that of transmission. The x-ray scattering monitor of Siddons and Kraner [7] was entirely

opaque. It is advantageous to have a transparent monitor capable of sensing the portion of the photon beam used in experiments. In order to maximize throughput, a beam position monitor should not block a significant fraction of the available beam. The photoemitting differential element beam position monitor by Johnson and Oversluizen [¹] is transparent to hard x-rays, but due to the energy dependent photoabsorption cross section of graphite, its transmission function is unsatisfactory in the low energy x-ray and VUV photon energy ranges.

To overcome this limitation, we have substituted 70% transmissive molybdenum wire grids, which allow the throughput of the monitor to be independent of the photon energy. This is especially important for use on VUV, soft x-ray, and low energy x-ray beamlines. The grids are mechanically supported and electrically isolated from each other by a Macor [¹] frame. The photoemission electrodes are mounted within a UHV section of the beam transport tube. Electrical signals are extracted from the UHV enclosure via BNC feedthroughs. The monitor is mounted on a micrometer driven linear motion UHV thimble for calibration tests.

One concern was whether the use of wire mesh would produce fine structure in the position output. Care was taken to orient the wires in the meshes at an angle with respect to the sensed direction. Also, the mesh spacing was chosen to be small compared to the photon beam size. Since the dominant photoemission cross section for molybdenum occurs at approximately 200 eV, the photon beam is relatively large at this energy.

The photocurrent from the grids is converted to voltage by the resistor network shown in Figure 2. This voltage may be amplified to a reading in millimeters as demonstrated by Heald [²]. By summing the current, one obtains a signal (V_i) which is proportional to the beam current and x-ray beam intensity. The differential voltage (V_d) between the grids is proportional to beam displacement at a given current. By normalizing V_d by V_i the position output is rendered independent of ring current.

The high transmission of the monitor permits it to remain permanently in place so beam position can be monitored in real time without interfering with any experimental processes. This output can also be connected to a chart recorder to track beam drift or orbital changes. The

¹ Macor is a trademark of Corning Glass, Corning, NY USA. Identification is for completeness and does not imply an endorsement by the authors or their institutions.

grids intercept approximately 4.2% of the beam, so the total transmission is 95.8%. More importantly, this transmission percentage is constant for all wavelength photons because it is determined by the geometrical obstruction of part of the beam by the wires in the grid. Additionally, by placing the monitor as the first element of the beamline, its performance is rendered insensitive to the monochromator energy or other optical elements. We have chosen molybdenum wire as the grid material since the beam position monitor is placed in the white beam where radiative power densities are high. Molybdenum has proven impervious to the white beam at X-24A for over 2 1/2 years of operation.

Experimental Results

The X-24A beam monitor serves two purposes; it monitors the total x-ray intensity delivered to the beamline, and it determines the photon beam position. In the future it is intended to mount a second monitor so that photon beam angle can also be determined. Tests of the linearity of the monitor both as a flux monitor and as a beam position monitor have been performed.

The response of the electron emission current versus total flux was studied with a simplified monitor. In place of the complementary pair of triangular electrodes a single rectangular wire mesh was mounted in the beam monitor location.

Electron emission from the wire grid is due to both photoemission (including secondary emission) and thermionic emission due to beam heating of the grid. The photoemission component should be linear with photon flux. The secondary emission can be affected by charging of the electrodes, so it is important that the impedance of the read out electronics be conservative. The thermionic emission will be very non-linear. For weak fields, the Richardson-Dushman equation gives:

$$j_T \propto T^2 \exp(\Phi/kT),$$

where Φ is the thermionic work function for molybdenum ($\Phi=4.3$ eV). Since the primary heat loss mechanism for the fine wires in the photon beam will be radiative emission, the

temperature, T , will vary as the fourth-root of the photon flux. The situation is further complicated by the fact that the wire temperature will be non-uniform. Since the wire mesh is observed to glow white hot, the non-linear contribution of thermionic emission was tested experimentally. The output of the test monitor was compared over time with several other intensity monitors. The primary comparison was with an NSLS electron current sensor installed in the storage ring. The monitor signal was also compared to two detectors near the focal point of X-24A. One of these detectors was a photoemissive wire mesh, and the other was a PIN photovoltaic diode [7]. The two detectors near the focus intercept only the relatively low power monochromatic beam; they are therefore immune to thermal effects, except for those affecting the beamline optical components.

The grid current was periodically measured through the course of two fills of the NSLS x-ray ring. A comparison of the various signals versus time (and therefore ring current) showed deviations in linearity of less than 15%, with the deviations between the monitor and the ring sensor less than 5%. The ring current decayed from 223 mA to 110 mA over the course of these tests. The variation of 15% with respect to monitors at the beam focus suggests that the monitor does not provide satisfactory normalization for most experimental data. However, this signal does provide a reference for determining whether the beam is obstructed either in the front end or by misaligned beamline optics. It can also be used for studies of thermal effects on beamline optics.

The observed 5% nonlinearity compared to the ring current monitor is not significant for the above applications. Even had the total current from the electrodes shown significant non-linearity, the position response of the prototype monitor should be linear by virtue of the geometrical shape of the electrodes.

In order to test the linearity of the position readout, we simulated beam motion by moving the monitor vertically in 100 micron increments over a 4000 micron range during stable running conditions. Figure 3 shows a plot of the normalized differential current (V_d/V_0) versus vertical displacement for two different ring currents, 204 mA and 31 mA. As can be seen from this figure, the detector is linear with displacement for the two extreme beam currents at the NSLS. The parallel slopes for the two curves indicate that normalized sensitivity to displacement is unaffected by total flux. The offset of the two curves is evidently due to a real

displacement of the photon beam during the special ring operation at low current. Analysis reveals $X = 10640\mu\text{m}(V_d/V_0) \pm 20\mu\text{m}$. The integral linearity of the position readout is better than 4 %.

A second test was attempted involving actual beam height changes. During a template period the NSLS performed local beam bumps for X-24A in ~ 100 micron steps over a 7000 micron range. This data is plotted in Figure 4. Judging from the linearity of the detector as demonstrated in Figure 3, we may conclude that the beam movement is not linear with the strength of the bump.

Conclusion

We have demonstrated the utility of a simple beam position monitor which employs two triangular molybdenum grids for use in the x-ray, soft x-ray, and VUV regions of the spectra. The position readout of the detector is linear to better than 4 %, and it has a resolution of $20\mu\text{m}$. This detector is unique in that it blocks only $\sim 4\%$ of the synchrotron beam for all wavelength photons. In addition to monitoring beam position, the device measures total photon flux. Use of two such monitors for sensing photon beam angle should be straight forward.

Figure Descriptions

Figure 1 - Design of beam position monitor. The x-ray beam passes through the two wire mesh grids which are electrically isolated from each other by the Macor frame.

Figure 2 - Schematic of resistor circuit showing the differential and total output voltages.

Figure 3 - Calibration curve for the beam position monitor taken at two extreme ring currents.

Figure 4 - Beam position response to NSLS controlled beam bumps. The x axis is in units of significance to the NSLS x-ray ring operation. Evidently, they do not correspond linearity to beam displacement at beamline X-24A.

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Fig. 1

Figure 2

Beam Pos. Monitor Calibration Curve

Monitor Displacement (microns)

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Monitor Response Curve

NSLS Sector Beam Bumps

X-24A 7/28/90

Fig. 4

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