Submitted to the SRI-89 meeting at Berkeley, CA

August 7-10, 1989.

BNL--42941

DE91 007565

UHV Photoelectron X-Ray Beam Position Monitor*

Erik D. Johnson and Tom Oversluizen

Brookhaven National Laboratory

National Synchrotron Light Source

Upton NY 11973

As part of our research program to develop viable beam position monitors for both the X-ray and VUV beamlines at the NSLS, we have constructed vertical photon beam position monitors which are presently mounted in two front-ends in the X-ray ring. These area-type detectors are located before the safety shutters and are, therefore, able to monitor the beam position even during injection. The features of this type of monitor which contribute to its long-term stability, position sensitivity, and immunity to horizontal beam motion have been examined and will be discussed.

*Work supported by the United States Department of Energy under contract #DE-AC02-76CH00016

1. Introduction

In our previous work, we developed a monitor for use on an undulator beamline (1). This device incorporated opposed water cooled blades with an open gap through which the majority of the undulator radiation passes. While this type of geometry is often required for monitoring photon beam position on insertion devices, it has at least one disadvantage, in as much as its transfer function depends upon the K of the insertion device. In effect, the apparent deviation of the photon beam from the monitor centroid depends on what the opening angle or beam size is relative to the blade gap, and how the photo-yield of the blade material varies with photon energy. This is a general feature of gap type monitors which will be discussed elsewhere (2).

While this problem can be overcome to some extent by empirical calibration curves, operation over a large range in K will generally require physically moving the monitor to the center of the desired beam position and operating any feedback in a null seeking mode. This introduces additional mechanical complexity, which may be an acceptable price to pay for photon beam monitoring at insertion devices, but will limit the general applicability of gap-type monitors for other beamlines.

In our present work we seek to develop a device for monitoring the beam position at dedicated diagnostic ports on the NSLS x-ray ring. We demand that it have a sensitivity comparable to that of our other monitors (sub-micron) and long term stability. Further, the monitor should be insensitive to apertures which are upstream of it, and be independent of apparent source size. As there are many such potential positions, we impose the additional criterion that the monitor be inexpensive and that its complexity be reduced with an eye to enhancing reliability. The monitor we describe in this paper meets all of the above criteria and, in the process of its development, several extensions to other situations became obvious as we will discuss in the following sections.

2. Monitor Design

The device we present in this paper is a discrete element split diode, similar in geometry to those described by Siddons and Kraner (3) or Mitsuhashi, Haga, and Katsura (4). The principle advantage of this type of device is that its transfer function is only sensitive to the pitch angle of the blades with respect to the axis of motion being monitored, and not to the beam size. A photograph of the monitor stationed at X-14 is shown in figure 1 with a schematic representation of its placement given in figures 2 and 3.

The monitor is positioned behind a beryllium oxide filter which is mounted on a water-cooled aperture plate three meters from the source. The filter absorbs 95% of the beam power and dramatically reduces the flux of photons below 16 keV. The remaining radiation is at energies greater than three times the critical energy of the ring, which compresses the apparent source size in the vertical direction, and significantly reduces heat load problems. In fact, the power deposited in the detector is below 100 mW so the monitor itself needs no additional cooling. The compression of the apparent vertical source size is so significant that shadowing effects from the machine vacuum chamber slot and water-cooled aperture plate are eliminated. The filter then addresses both the heat load and shadowing problems simultaneously.

The active elements of this area-type detector are two triangular carbon (Grafoil) blades, 0.3 mm thick, which have a 1.2 um gold coating to generate the photo-current. The blades are oriented at normal incidence to the beam and are housed within a stainless steel box which has front and back windows made from the same carbon foil as the blades themselves. The carbon is transparent to photons at these high energies but is an effective barrier to stray electrons and ions. The shielding from background current sources provided by these windows is a significant contributor to the stability and low noise operation of the detector.

The water-cooled aperture has a 12 mm square hole for the dedicated detector port, so a 3 mm thick stainless steel aperture plate was added to the front of the detector which has a vertical slot 8 mm wide. This plate ensures that the monitor blades are uniformly illuminated horizontally, even for horizontal electron beam excursions of up to 30 mm. Such a deviation would be outside the dynamic aperture of the machine, so for all practical purposes the monitor is sensitive only to vertical position or angle changes.

The prototype monitor has two additional features which would not necessarily be required for "production models". First, in addition to the blades, the enclosure which houses them is electrically isolated.

Experimentation thus far has shown this to be unnecessary. Second, for the purpose of testing and calibration, the detector was mounted on a simple linear motion described elsewhere in these proceedings (5). While this feature is convenient for development work, it is not utilized in routine operation for reasons discussed below.

[Note for editor/reviewer: These figures should appear in this section of the paper. Numbers are stamped on the back of the figures

figure 1 picture of monitor (w/o cover) (photo 3--849--89)

figure 2 schematic of arrangement in front end(photo 7--274--89)

figure 3 drawing of monitor being illuminated (photo 7--299-89)]

3. Experimental Results

The detector shown in figure 1 was installed in the X-14 front-end tank during a two day shutdown. The beryllia window was installed during the phase II shutdown of the NSLS and was already fully out-gassed. From installation to re-opening of the beamline to synchrotron radiation was only 30 hours. The position data presented here were recorded as photo-currents on each blade and, subsequently, the "position signal" was computed as the difference of the blade currents divided by the sum. Typical blade currents were the order of 300 nA for 100 mA of stored beam current at 2.5 GeV.

By rapidly translating the monitor and recording the blade currents, the calibration curve given in figure 4 was obtained. Note that these data are linear over the range of many millimeters, with the theoretical range of this 45 degree pitch monitor being 8 mm, as defined by its aperture plate width. The data clearly demonstrate that not only is the monitor sensitive at the sub-micron level, but that the same signal is obtained regardless of the bias placed on the monitor body. This must be due in part to the large photon energies and extremely low background currents (the order of a few pA) provided by the shielding arrangement. This level of performance has been obtained for stored beam currents ranging from over 200 mA to less than 2 mA.

To test the monitors immunity to horizontal motion, local bumps were utilized during machine studies which pushed the beam 8mm either-side of the nominal orbit in the horizontal, while maintaining the vertical position to ca. 30 microns as recorded by the pickup electrode system of the ring. The apparent vertical excursions measured by the photon beam position monitor were well within these limits, demonstrating a high degree of immunity to horizontal beam motion.

As the linear range of the monitor is so large, our practice during normal operations has been to roughly center the monitor on the nominal orbit and leave it in place. The position signal is provided by simple analog electronics previously described (1), with output displayed on a chart recorder for reference and machine diagnostic purposes. An automated data logging and error reporting system is currently being developed for use with multiple detectors.

[Note to editor/reviewer Figure 4 which is a plot should appear in this section of the paper]

4. Discussion

The combination of the beryllia filter and simple area monitor geometry provide a detection scheme which is both simple and relatively inexpensive. While it was developed for bending magnet radiation, adaptations of the design should be equally useful on wiggler-type insertion devices and high energy undulators. These possibilities can be envisioned by reducing the device to its essential elements and modifying them to suit different situations.

The monitor embodies two design concepts which suggest extensions to these other applications. First, the use of a filter to harden the spectrum observed by the monitor and compress the apparent beam size. This type of technique may be a valuable method for avoiding the shadowing effects of upstream apertures in many circumstances. The second concept is to select materials or a combination of materials which remove only the power needed from the beam to make the desired measurement. In this case the beryllia filter removes a substantial amount of the power, but the selection of graphite blades (which are transparent in this case) and only a thin coating of gold (which produces ample photo-current with very little absorbed power) simplifys the design by obviating additional external cooling mechanisms.

This same concept can be applied on a more typical x-ray beamline. Most of these lines at the NSLS have beryllium windows and are meant to utilize radiation above 8 keV. A monitor fabricated with just graphite blades has been tested on such a beamline and found to work quite well. Calculations show (6) that at 5 keV, only a factor of two in intensity is lost to this monitor, while at higher energies, essentially no intensity is removed from the beam. Such a monitor can be operated in parallel with a running experiment. This may be an important feature since these devices can only measure position of the beam at the monitor which may be a combination of angle and position movements of the electron beam in the machine. For crystal monochromators, the difference between these two can have a significant impact on resolution and/or position stability of the beam at the experiment.

Another extension of this monitor would be the trivial addition of horizontal displacement measurement capability. By substituting split, electrically isolated elements for the front aperture plate, a gap type monitor in the horizontal direction is provided. We take advantage of the fact that for a dipole source, the apparent "size" of the beam or radiation fan is not determined by the machine energy or actual electron beam size. It is instead related to the size of the beam-defining aperture and the ratio of the distance from the source to the monitor, to that of the source to the beam-defining aperture.

It is hoped that this device and extensions of the design principles it embodies will help to provide a family of robust and reliable photon beam position monitors for machine diagnostics and feedback as well as a variety of applications in synchrotron radiation experimentation.

Acknowledgement

The authors wish to identify Jerry Hastings as the original contibutor of the idea to use the Beryllia filter, an essential element of this work. We would like to thank Dr. Yen-Fang Song for her able assistance in our preliminary experiments with this generation of monitor during her visit from the physics department of National Taiwan Normal University. We would also like to thank G. Ice and members of the Oak Ridge National Lab PRT at X-14 for allowing us to install our development monitor in their front-end tank. In addition, credit for the rapid installation and commissioning of the monitor is due to the diligent efforts of members of the NSLS vacuum group. This work is supported under the auspices of the United States Department of Energy, contract #DE-AC02-76CH00016.

References

1 E.D. Johnson and T. Oversluizen, Rev. Sci. Instrum. 60 (1989) 1947.

2 E.D. Johnson, T. Oversluizen and S. Sharma, to be published.

3 D.P. Siddons and H. Kraner, NSLS Workshop on Beam Position Monitors, unpublished (1986).

4 T. Mitsuhashi, K. Haga, and T. Katsura, Proc. of 1987 IEEE Particle Accelerator Conf. p538.

5 M. Iarocci and T. Oversluizen "Stepping Motor Adaptor for a Commercial UHV Linear Motion Feedthrough", pxxx these proceedings

6 D. Chapman, N. Gmur, N. Lazarz and W. Thomlinson, Nucl. Instrum. and Meth. A266 (1988) 191

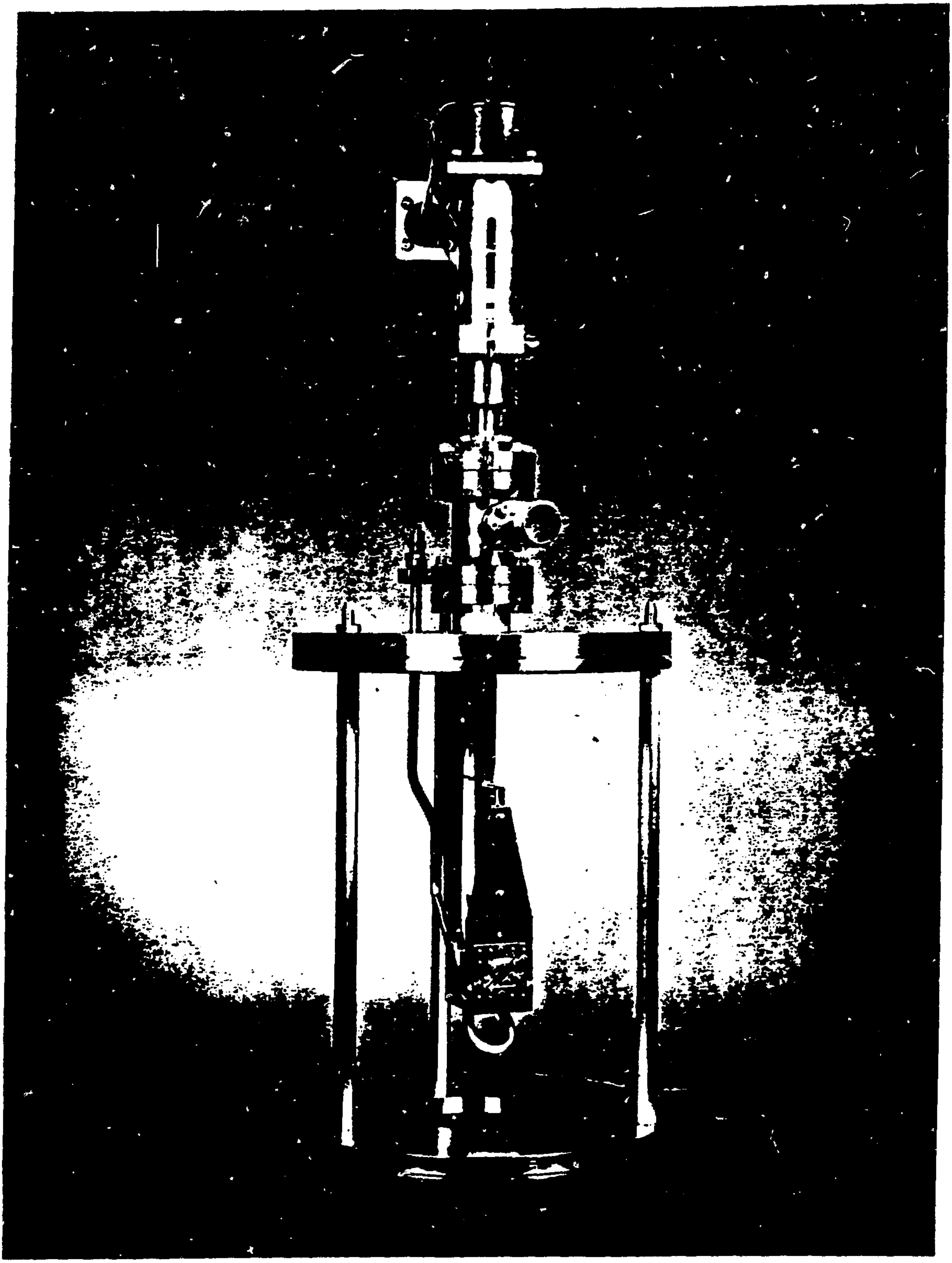
Figure Captions

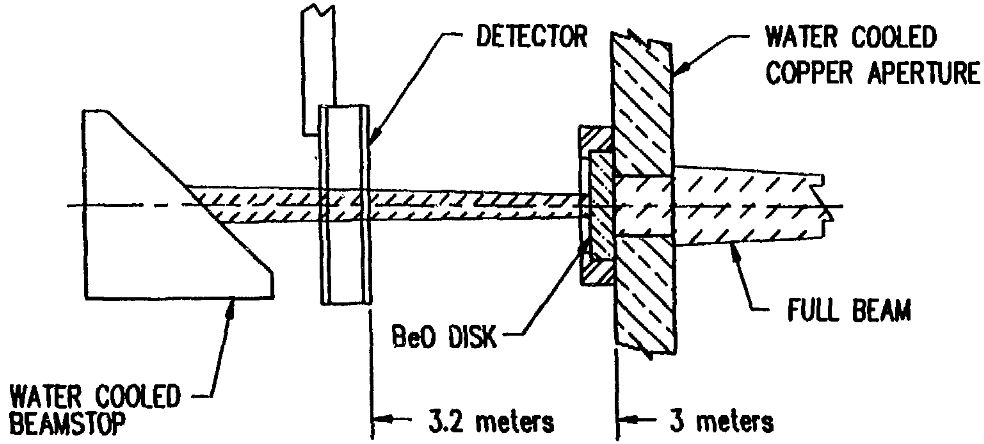
Figure 1 Photograph of the monitor installed on X-14. The flange on which it is mounted is also the support for the water-cooled beam stop. The linear translator is at the top of the photo with the electrical feedthru facing out. Note that the cover and front aperture have been removed to show the detector elements.

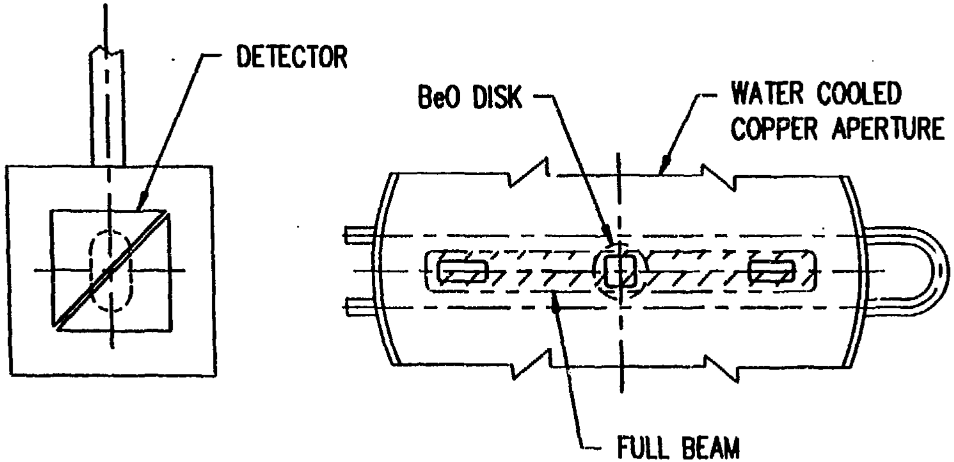
Figure 2 The top panel is a schematic representation of the layout of the monitor. The bottom panel shows the placement of the beryllia disk with respect to the beam-defining aperture for X-14. Also shown are the detector elements as they would appear from the beam-defining aperture.

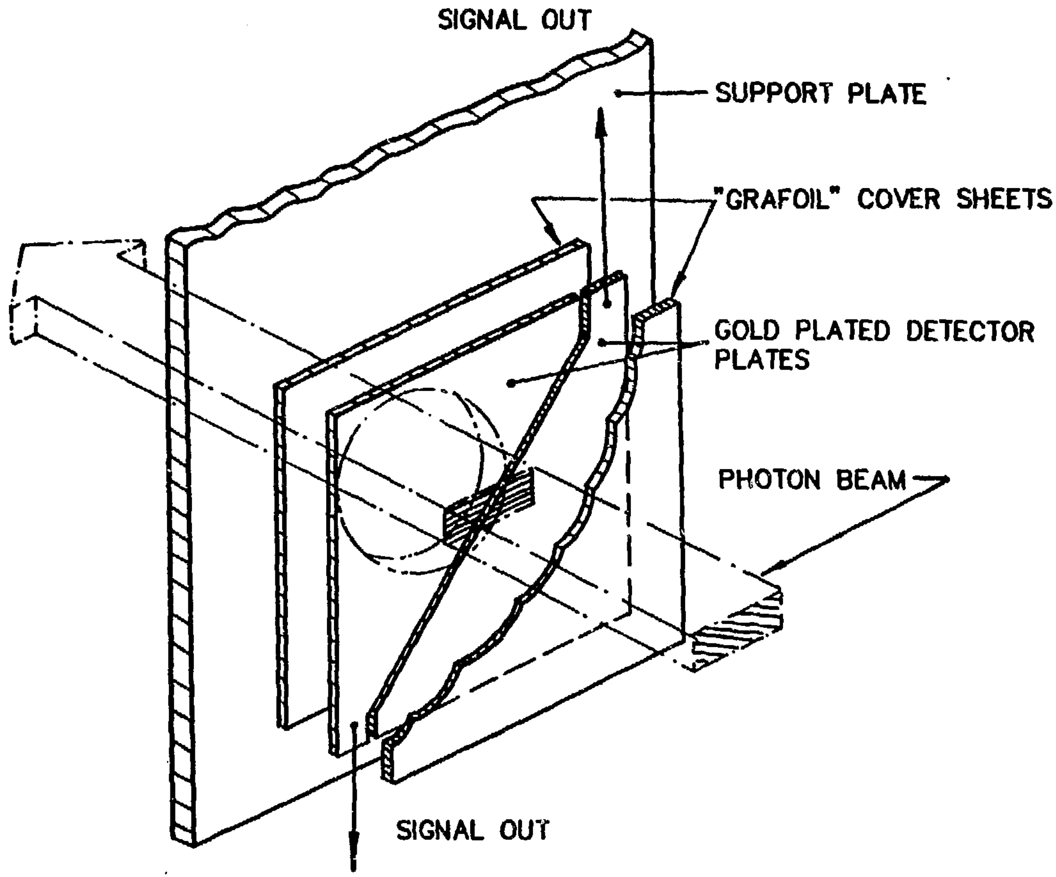
Figure 3 Phantom view of the monitor as it would be illuminated by synchrotron radiation.

Figure 4 Calibration curve of the monitor. Data recorded with 82 mA of stored beam at 2.5 GeV.

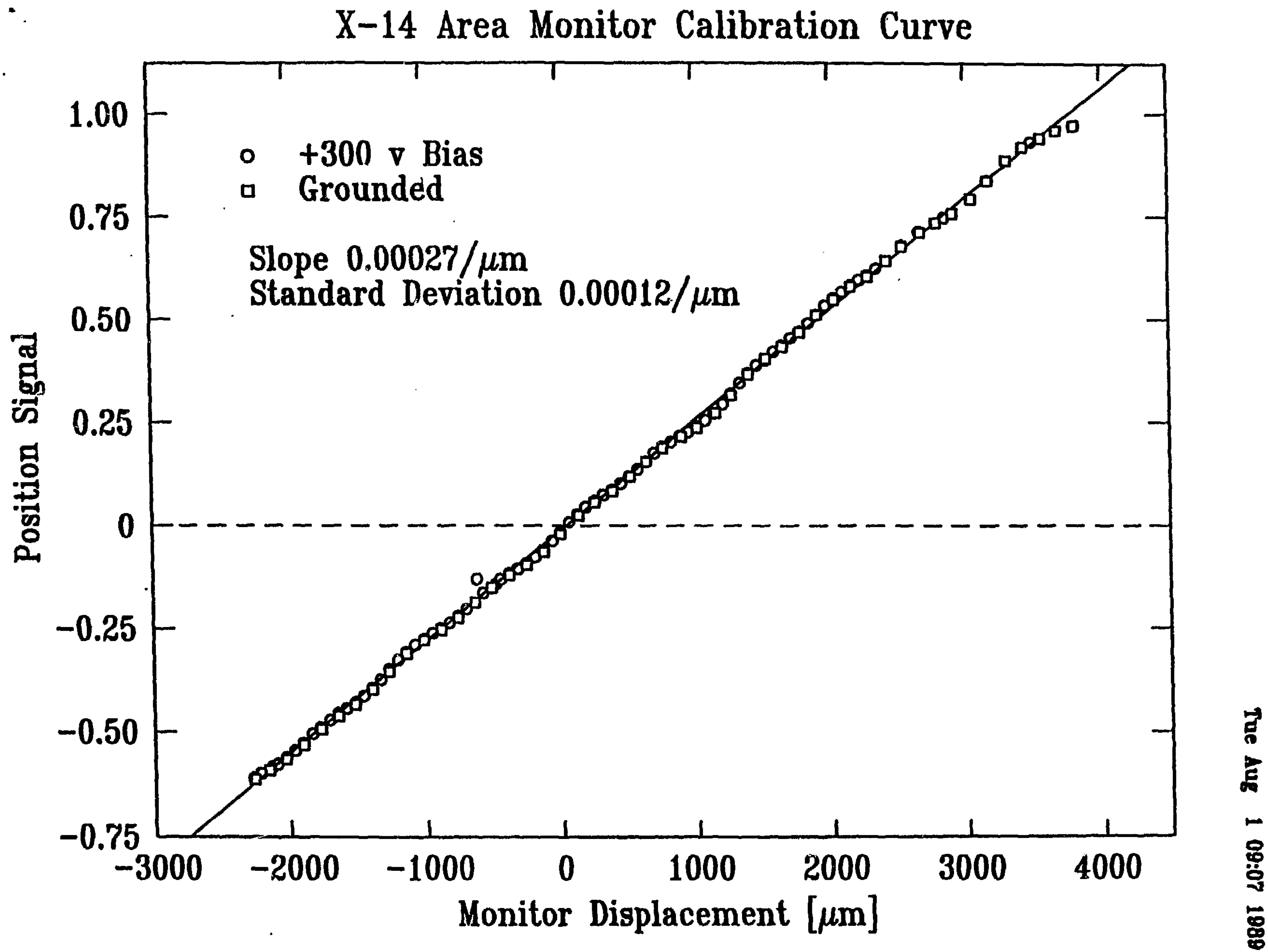



DETECTOR
WATER COOLED
COPPER APERTURE
FULL BEAM
BeO DISK
WATER COOLED
BEAMSTOP
3.2 meters
3 meters


DETECTOR
BeO DISK
WATER COOLED
COPPER APERTURE
FULL BEAM



X–RAY
BEAM POSITION MONITOR



X-14 Area Monitor Calibration Curve
+300 v Bias
Grounded
Slope 0.00027/μm
Standard Deviation 0.00012/μm
Position Signal
1.00
0.75
0.50
0.25
0
-0.25
-0.50
-0.75
-3000
-2000
-1000
0
1000
2000
3000
4000
Monitor Displacement [μm]
Tue Aug 1 09:07 1989