Progress of the APS high-heat-load x-ray beam position monitor development

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Introduction

The design requirements for Advanced Photon Source (APS) front-end x-ray beam position monitors (XBPMs) are such that they must withstand the high thermal load (up to 600 watts/mm^2) and be able to achieve submicron spatial resolution while maintaining their stability.

At the APS, each beamline front end has two XBPMs to monitor the x-ray beam position for both the vertical and horizontal directions. The XBPMs measure photoelectrons generated by the sensory blades and deduce the beam position by comparison of the relative signals from the blades. Both the first and second XBPMs are located upstream of the user photon shutter (PS2) so that they are functional whether the user shutter is open or closed [1]. The major advantage of the XBPM is its high positioning sensitivity. Additionally, when compared to the particle beam position monitors in the storage ring, the front-end XBPMs have much higher sensitivity to the x-ray beam angular motion simply because they are located far away from the source. Other design challenges for a conventional photoemmision-type XBPM are the bending magnet (BM) contamination of the signal and its sensitivity to the insertion device (ID) gap variations [2]. Problems are exacerbated for the XBPM when the IDs operate with different magnet gaps because the percentage level of the contamination will be a variable.

There are several novel design developments established for the APS ID XBPM to improve its performance:

- Optimized geometric configuration of the monitor's sensory blades.
- Smart XBPM (SBPM) system with an intelligent digital signal processor, which provides a self-learning and calibration function.
- Transmitting XBPM (TBPM) with prefiltering in the commissioning windows for the front end.

In this report, we summarize the recent progress on the XBPM development for the APS ID front ends in the mitigation of the problems explained in the Introduction.

The Front-end XBPM Structural Design

Both analytical and experimental results proved that CVD diamond is a good choice for the APS high-heat-load XBPM blade material because of its superior thermophysical properties (e.g., high thermal conductivity, low thermal expansion coefficient, and good mechanical strength and stiffness under heat). Submicron position sensitivity was also demonstrated by the APS XBPM prototype using CVD diamond blades during CHESS and NSLS tests [3].

Figure 1 shows the structure of the first (upstream) XBPM main assembly on the APS undulator beamline front end. In this design, four 150 µm-thick CVD-diamond blades were coated with 1 µm of gold. The blades are mounted vertically in pairs on the monitor body, which is made of oxygen-free copper (OFHC) and is cooled from the bottom by a water-cooled base. The vacuum chamber and the cooling base are designed for ultrahigh vacuum (UHV) condition.

To eliminate the blade shadowing problems, the second (downstream) XBPM has a different blade placement configuration. As shown in Figure 1b, the second XBPM has one pair of vertical blades and one pair of "tilted" horizontal blades. This configuration reduces the signal contamination level from the BM-emitted radiation.

The geometrical configuration of the APS XBPM provides a low-noise environment for photoelectron current output. The XBPM was sensitive enough to read out the photoemmission signal (about 0.6 nA) from a BM source while the APS storage ring had only a 24 µA electron beam stored at the first APS x-ray test on March 26, 1995.

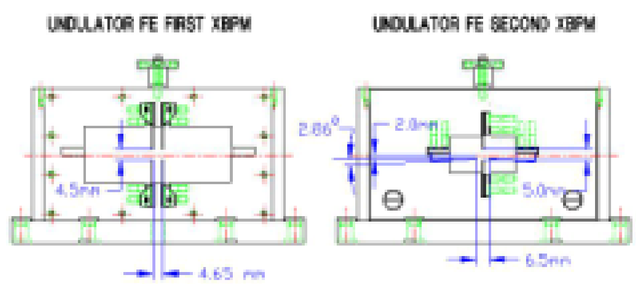

Figure 1: Structure of the XBPM main assembly for the APS undulator beamline front end (view a for first XBPM monitor body, view b for second XBPM monitor body).

Stability of the XBPM Supporting Stages

The XBPM main assembly is supported by a precision supporting stage, which is mounted on top of a mounting post. The post is made of steel, filled on the inside with sand, and thermally insulated on the outside by ceramic cloth. This post design is very resilient to short-term temperature fluctuations. The XBPM stage assembly consists of stepping-motor-driven vertical, horizontal, and rotational stages. Test measurements using a laser Doppler displacement meter (LDDM) prove that the vertical stage attained a resolution of < 0.2 µm with 1 µm repeatability under a 200 lb. load [4]. Preliminary *in situ* vibration tests show that the XBPM main assembly maintains less than 0.1 µm rms vibration displacement level with the cooling water on.

Smart XBPM System (SBPM)

The optimized geometric design of the blades helps reduce the BM contamination. For instance, on the first APS 1-ID front end XBPM, the BM contamination has been determined to be approximately 10% of the signal from the 2.4 m undulator A with a 15.8 mm magnet gap. The contamination level will be much higher, however, when the undulator gap is opened more. The regular XBPM calibration process can only provide signal correction for one set of conditions. During normal operations, the insertion devices function at varying storage ring current, particle orbit, and a variety of ID gaps. In addition, because of the expected imperfections in the ID magnetic field distribution, each ID and its location on the storage ring has its own "personality."

To offset the XBPM sensitivity to such operational variables, a SBPM system has been designed and a prototype built and tested for the APS [5]. The system configuration includes 1) a pair of photoelectron emission-style BPMs using CVD diamond blades for undulator beamline front ends, 2) a set of photoelectron current preamplifiers, 3) a preamplifier autoranging controller and digitizer [6], 4) a digital signal processor (DSP) TMS320c40 (Texas Instruments, Inc.[7]) with EEPROM data base and ID source input interface for normalization [8], and 5) a system controller with motor driver and encoder interface for XBPM calibration processes. During the calibration mode, the system controller initializes a series of automatic scan motions for the XBPM with different ID setup information and records them into the EEPROM database array.

In the operating mode, the DSP gets the XBPM signal data from the preamplifier/digitizer through one of the communication ports and groups them into an input buffer array. The DSP then calculates the data under the control of a signal normalization program, which is using the external EEPROM database for reference. After a step-by-step approach process, the final beam position data (a pair for the beam positions at the first XBPM location and a pair for the beam angular displacement) is transmitted to a signal output buffer. There are two types of output data format available for users: 24-bit digital parallel output and 4–20 mA current loop for analog output.

Transmitting XBPM for the Front-end Commissioning Windows (TBPM)

During the beamline and front-end commissioning activities, the final fine tuning of the storage ring and/or final adjustment of the front-end components is attempted. Based on the measurement data for the beam position in two locations in an experimental station and in comparison with the calibration scan data from the front-end x-ray BPMs, a new zero position is set after the synchrotron radiation beam commissioning.

A CVD-diamond filter, which is a 25.4 mm-diameter disk mounted on the downstream side of the fixed mask, is also designed as a TBPM for the APS commissioning window system [9]. The basic concept of the TBPM is to mount the monitor blade perpendicular to the synchrotron radiation beam and design the blade and its low-Z metal coating thickness in such a way that most of the x-ray beam is transmitted through the blade (just like a filter or window). In this design, the 160 µm-thick CVD-diamond disk is coated with four electronically isolated aluminum quadrant patterns. The thickness of the aluminum coating is about 0.2 µm. The photoelectron emission signal is collected by a terminal interface disk, which is made from thin alumina and is coated with silver. This design concept provides the possibility of integrating the filter with TBPM functions. The beam position information from the TBPM in the commissioning window is very valuable to the front end commissioning and SBPM system initial calibration.

Discussion

To date, three SBPM systems have been installed on APS ID front ends, and they are operational [10]. On-line preliminary tests began in August 1996. Figure 2 shows a typical test result at the APS undulator beamline 1-ID front end. The rest of the 20 insertion-device front ends at the APS are expected to be furnished with SBPM systems within a year. Based on the experience from the prototype operation, we will determine the time duration of the calibration period and optimize the database structure. Automatic calibration is necessary if the particle beam orbit changes frequently. If needed, the beam position at the neighboring BM front end may also be used as another database reference input.

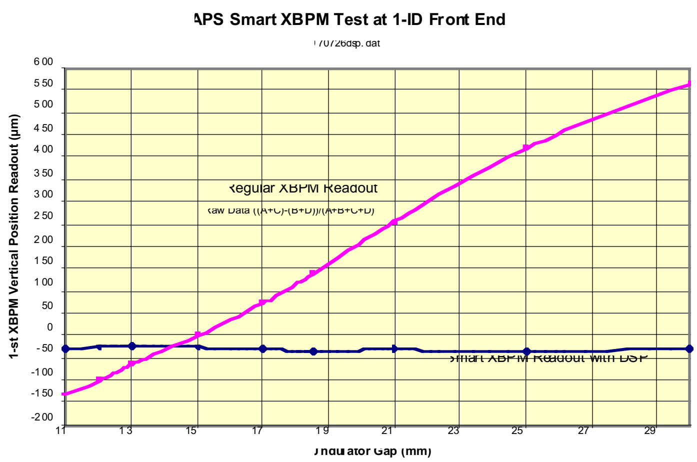

Figure 2: A typical SBPM test result at the APS undulator beamline 1-ID front end.

Acknowledgments

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