NOV 15 1983

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ANL/ASD/CP-80718

104-1510204-10

CONFIGURATION AND TEST OF THE APS STORAGE RING BEAM POSITION MONITOR ELECTRONICS*

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Abstract

This paper will present the final tests of the APS storage ring BPM electronic system. The final configuration includes the filter-comparator installed in the accelerator tunnel and the signal conditioning and digitizing unit (SCDU) in a VXI configuration. The SCDU includes an AM/PM monopulse receiver at 352 MHz. Extensive testing was performed on the system. The key parameters measured were the null cancellation better than 45 db, dynamic range of better than 40 db, single bunch capability with 0.01 mA sensitivity, and a resolution better than 10 micron for 512 averaged turns. This last critical performance was tested using a moving wire to simulate the beam. This report will concentrate on the wire test results. Also, the actual production hardware will be presented.

Introduction.

The Advanced Photon Source (APS) at Argonne National Laboratory is a synchrotron radiation source based on a 7-GeV storage ring. It includes a positron storage ring with a circumference of 1104 meters. The accurate control of the particle beam is very critical to the ability of the system to direct the photon beam to the target. Therefore, we need 360 beam position monitors (BPM) around the ring, with a resolution of less than 10 micron in the ring and only few microns in the insertion devices. This level of resolution sensitivity was obtained by an electronic instrument whose design is described in reference 1. This instrument was designed and built with industry cooperation, and laboratory tests of the first production articles show that the required performance was achieved.

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*Work supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

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System Description.

The BPM uses an AM/PM technique and is capable of measuring the beam position on a single bunch. Since a detailed functional description of the BPM electronics is given in a separate paper¹, we will give only a brief description here. The system block diagram is shown in Figure 1.

The position information is derived from the signals detected by four "button" pickups inserted in the accelerator vacuum tube². The four impulses are fed into the filter-comparator (Figure 2), where they are stretched by low-pass filters. The four signals are then processed by 180-degree hybrids to create the SUM, Dx, and Dy. The outputs are filtered by 352-MHz band-pass filters to provide a Gaussian-shaped pulse 100 ns. wide. The filter-comparator is installed in close proximity to the buttons.

BEAM POSITION MONITOR

Fig. 1: BPM Block Diagram.

FILTER-COMPARATOR UNIT

Fig. 2: Filter-Comparator.

The filter-comparator outputs are fed into the monopulse receiver (Figure 3), which is an AM/PM conversion receiver where the main components are a 90-degree hybrid, two parallel rf limiter channels, one logarithmic channel, and a phase detector. The Δx and Δy signals time-share the same receiver channels. The 0/180-degree switch is used to cancel the limiter mismatch by inverting the sign and adding two consecutive position data. The output signals are the SUM (Σ) and the normalized $\Delta x/\Sigma$ and $\Delta y/\Sigma$. The monopulse receiver is installed on a VXI board, together with the signal conditioning and digitizing unit (SCDU).

MONOPULSE RECEIVER

Fig. 3: Monopulse Receiver.

The SCDU (Figure 4) is built as a VXI board. The first section includes analog processing circuits, a peak detector for S and a gated integrator for $\Delta x/S$ or $\Delta y/S$. The gated integrator is followed by a 4:1 programmable amplifier, which can improve resolution over limited excursion. The signals are digitized by 12-bit A/D converters and the digital intensity and position data is output on the VXI local bus. The data is then read by the memory/scanner, which can scan up to 9 SCDUs, average the data, and transfer it to the various users. The same data is recorded by a beam history card, for postmortem analysis.

SIGNAL CONDITIONING AND DIGITIZING UNIT

Fig. 4: SCDU.

Test Results.

The BPM electronics were tested using buttons installed on a test section of the APS storage ring vacuum chamber. The beam was simulated by a wire running through the center of the pipe, connected to a high voltage pulse generator. The wire in the pipe could be very accurately positioned by stepping motors controlled by a PC.

Linearity Tests.

a. Low Gain Test.

We moved the wire on the x and y axes, from -10 mm to +10 mm in steps of 0.2 mm. The output digital data was averaged 128 times, and the A/D count was recorded. The tests were done with a high voltage pulse generator, which can generate 2.5 kV/1 ns. pulses equivalent to a single bunch beam current of 0.35 mA. This is a low level, since the nominal bunch current in the storage ring is 5 mA. Figures 5 and 6

show the output in digital counts vs. the beam position for the x and y axes, respectively. Figures 7 and 8 show a zoom around the center.

Fig. 5

Fig. 6

Fig. 7

Fig. 8

The results show that the output is linear versus the position around the center, and starts to deviate from linearity toward the edge. Those nonlinearities, as well as the offset, will be calibrated by a polynomial approximation in the computer. The zoomed data was approximated by a linear regression, with a very good fit. For x and y the slope is 109.67 and 81.14 counts/mm, which means that the resolution capability around the center is about 9 and 12 microns/count, respectively.

b. High Gain Test.

We switched the system to high gain mode and moved the wire from -1 mm to +1 mm in steps of 0.02 mm, at 0.35 mA equivalent storage ring beam current. We averaged 128 data points at each position. Figures 9 and 10 show the output vs. position for x and y.

Fig. 9

Fig. 10

The linear regression indicates a slope of 444.55 and 327.22 counts/mm, or a resolution capability of 2.25 and 3 microns/count for x and y, respectively. The ability of the system to achieve this resolution depends upon the signal-to-noise ratio, which can be improved by more averaging at the expense of reduced data rate.

Resolution Test.

In order to directly evaluate the system's resolution performance, we moved the wire on the x axis from 0 to 50 microns every 5 microns, for both low and high gain. The averaging number was 512. Figures 11 and 12 show the results for low gain and high gain, respectively.

Fig. 11

Fig. 12

We can see that the system is sensitive to the small changes. The standard deviation of the residue from linearity was calculated to be 0.344 counts for low gain and 1.717 counts for high gain.

Stability test.

In order to prove the stability of the electronics, we injected a constant signal and averaged the output 256 times. The test was repeated 50 times. Figures 13 and 14 show the output of the x position for low and high gain.

Fig. 13

Fig. 14

We can see that the averaged output is very stable. The standard deviation of the measurements is 0.75 counts for low gain, and 2.56 counts for high gain.

Conclusion.

A BPM system was built and tested using a wire setup to simulate the beam. Although the generated signals correspond to low beam current, we could prove exceptional sensitivity and resolution well within the requirements. Since the geometrical size of the insertion device vacuum chamber is smaller, we expect further improvement of approximately 3:1 in resolution at this location. The performance over the full dynamic range of beam intensity could not be measured due to setup limitation, but laboratory tests showed a dynamic range in excess of 50 db.

References.

1. E. Kahana, "Design of Beam Position Monitor Electronics for the APS Diagnostics," Proceedings of the Third Annual Workshop on Accelerator Instrumentation, Newport News, VA, October 1991, pp. 235-240.
2. Y. Chung, "Theoretical Studies on the Beam Position Measurement with Button-type Pickups in APS," Proceedings of the IEEE Particle Accelerator Conference, San-Francisco, CA, May 1991, pp. 1121.

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