Summary Test Results of the Particle-Beam Diagnostics for the Advanced Photon Source (APS) Subsystems*

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Abstract

During the first half of 1994, a number of the diagnostic systems for measurement of the charged-particle beam parameters throughout the subsystems of the Advanced Photon Source (APS) have been installed and tested. The particle beams eventually will involve 450-MeV to 7-GeV positrons and with different pulse formats. The first test and commissioning results for beam profiles, beam position monitors, loss rate monitors, current monitors, and synchrotron radiation photon monitors have been obtained using 200- to 350-MeV electron beams injected into the subsystems. Data presented are principally from the transport lines and the positron accumulator ring.

1. INTRODUCTION

The Advanced Photon Source (APS) is a third-generation synchrotron radiation user facility being constructed at Argonne National Laboratory [1]. The APS is a sister laboratory in scale to the recently commissioned European Synchrotron Radiation Facility (ESRF) in France and the SPring-8 facility under construction in Japan. The APS includes an injector system comprising a thermionic gun, a 200-MeV electron linac, an e^- to e^+ converter target, a 450-MeV positron linac, a 450-MeV positron accumulator ring (PAR), a 0.45-to-7-GeV injector synchrotron (IS), and the transport lines between the subsystems. These prepare the particle beam for the 7-GeV storage ring. The diagnostic systems for beam position, beam size, current, loss rate, and bunch length will be described briefly. In the spring of 1994, the first electron beams were injected into most of the injector accelerator subsystem. Early commissioning results using 200 to 350-MeV energy beams for the diagnostic systems are presented. More complete details of the diagnostic systems were given at the 1992 Accelerator Instrumentation Workshop [2-7] and the 1993 Particle Accelerator Conference [8].

2. BACKGROUND

Space precludes providing a complete description of the accelerator facilities for the APS but some background information is needed. The baseline electron source is a thermionic gun followed by a 200-MeV linac operating at an rf frequency of 2.8 GHz, and a maximum macropulse repetition rate of 60 Hz. The design goals include 14-ps-long micropulses, separated by 350 ps in a 30-ns macropulse with a total macropulse charge of 50 nC. The 200-MeV linac beam will be focused to a 3-mm spot at the positron-production target. The target yield is about 0.0083 positrons per incident electron with a solid angle of 0.15 sr and an energy range of 8 ±1.5 MeV. The positrons will then be focused by a pulsed solenoid and about 60% of them will be accelerated to 450 MeV. The 450-MeV positrons are injected into the horizontal phase space of the PAR at a 60-Hz rate. As many as 24 macropulses can be accumulated as a single bunch during each 0.5-s cycle of the injector synchrotron. The injector (or booster) synchrotron accelerates the positrons to 7 GeV at which energy they can be extracted and injected into the designated rf bucket of the storage ring. A schematic of the APS accelerators, which lists the number of diagnostic stations, is given in Ref. 2 and shown in Fig. 1.

Several features of the subsystems are provided in Table 1. The peak current, bunch length, and charge per pulse are given for the low energy transport (LET) lines between the linac and the PAR and the PAR and synchrotron, respectively. The high energy transport (HET) parameters are also provided. The revolution time, bunch length, and average currents are provided in Ref. 2 for the rings.

Table 1. APS Parameters for Beam Diagnostics

	LET 1	**LET 2**	**HET**
PEAK CURRENT	8 mA	11.9 A	28.9 A
BUNCH LENGTH	30 ns	0.29 ns	122 ps
INTENSITY PER PULSE	1.5×10^9 positrons	2.2×10^{10}	2.2×10^{10}
CHARGE PER PULSE	240 pC	3.5 nC	3.5 nC
PULSE RATE	60 Hz	2 Hz	2 Hz

3. INITIAL DIAGNOSTIC RESULTS

The basic charged-particle beam parameters such as beam position, profile, current, bunch length, energy, and beam loss are to be addressed. Both intercepting and nonintercepting techniques are used. Some of the systems had initial results from their prototypes on the APS linac test stand in the spring of 1992 as described previously [2,3,5,6,7]. Figure 1 shows a schematic of the diagnostic units assigned to each subsystem. The sample results will be from systems on LET1 or the accumulator ring. These tests are based on linac beams of 200- to 350-MeV energy and 50 to 400 pC per macrobunch.

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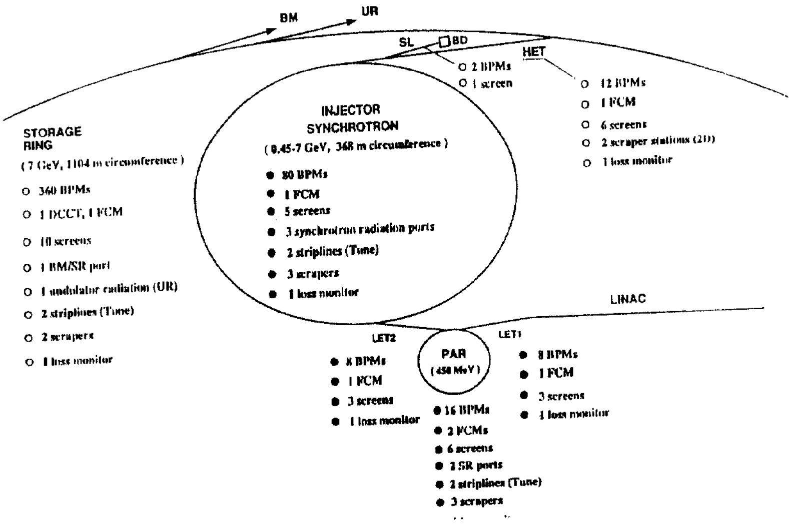


Fig. 1. A schematic showing the diagnostic systems assigned to the APS subsystems.

3.1. Beam Profile Monitor

In the early stages of commissioning, one of the key diagnostic systems was the beam profile monitor based on an Al_2O_3 (Cr) screen material and a standard CCD-video camera. Three intercepting screens on pneumatic actuators are arrayed along the transport line z-axis between the linac and the accumulator ring. There are an additional six viewing screens/cameras in the PAR itself for single-turn tuning, three in the transport line to the IS, and five in the IS. The system images beam as low as 10 to 30 pC in a macrobunch from the linac. The images are displayed at standard 30-Hz rates on a monitor or digitized by a VME-architecture-based video digitizing system linked to a Sun workstation. Figure 2 shows the pseudo-3D representation of one of the first electron beam bunches injected into the LET1 line. Since the screen is at 45° to the vertical, the ellipticity of the beam is exaggerated in this uncorrected image. The beam size is a few mm (FWHM) in the vertical dimension. During commissioning, beam was readily transported through both the transport lines, the PAR, and even the 368-m circumference IS using the observed image shapes and positions.

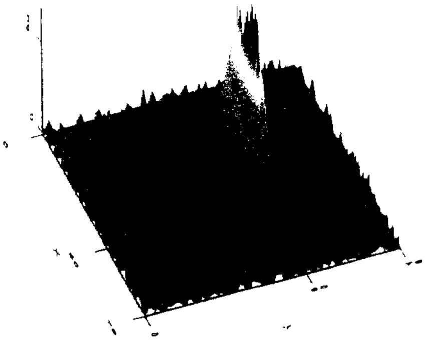


Fig. 2. A pseudo-3D representation of a beam image from the transport line to the accumulator ring.

3.2. Beam Loss Rate Monitor

The loss rate monitor (LRM) which will cover the entire extent of beamlines and accelerator is operational on all but the HET and the storage ring now. A gas-filled coaxial cable acting as an ionization chamber was installed along the length of the transport lines and around the circumference of the PAR and IS. The gas mixture is 95% Ar and 5% CO_2, and the voltage across the center conductor to ground is 500 V. Figure 3 shows the clear effect in loss rate when one beam profile screen in the PAR is removed and its adjacent LRM cable is monitored in a strip-chart-mode on the workstation. Time flows to the left, so the drop from about 0.3 nA to 0.1 nA is clearly evident with <100 pC in the beam bunch. If the arrival time of the signals is viewed on a scope, few-meter axial resolution for losses can be determined.

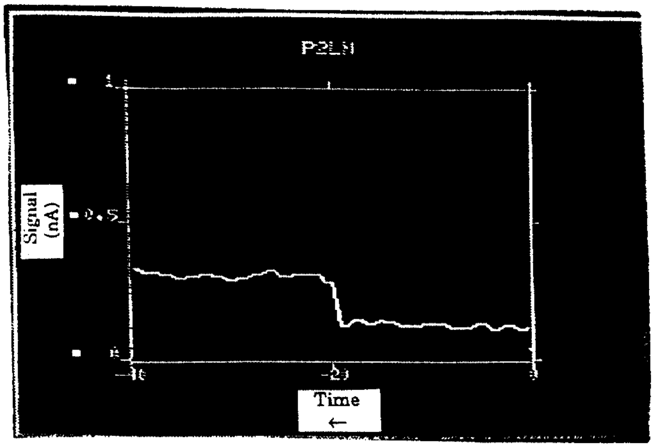
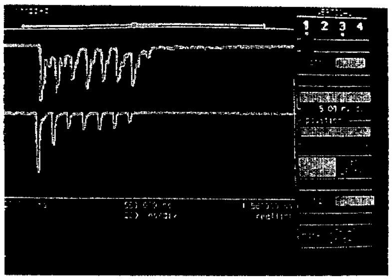


Fig. 3. Sample display of loss rate versus time in the PAR. The reduction is due to removing an intercepting screen.

3.3. Beam Current Monitor

Monitoring of the current/charge in the transport lines and rings is based on use of fast current transformers manufactured by Bergoz and in-house electronics. The current transformer signals are processed through a gated integrator and the output digitized to provide readouts on the workstation. During commissioning, transported electron beams from the linac were measured from 50 to 400 pC per macrobunch. Figure 4 shows the signals from multiple turns around the PAR (102-ns revolution time) from both the fast current transformer (FCT) and a nearby photomultiplier tube (PMT) that monitors the synchrotron radiation from a bending magnet.



- Photomultiplier tube (top trace - 5V/Div)

- Fast Current Monitor (lower trace - 5 mV/Div)

- 12:25 a.m.

Kicker off

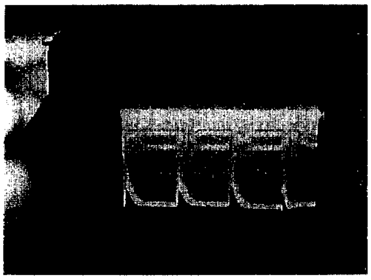
RF off

Time (200 ns/Div)

Fig. 4. Early multiple turn data in the PAR using the FCT and the PMT.

3.4. Photon Monitors

In the rings at APS at least one bending magnet's synchrotron radiation is viewed by photon detectors. Detection of this radiation can be used to count beam turns and provide measurement of tune, beam size, and bunch length. Figure 5 shows a scope trace of the PMT output covering the 2-Hz injection, damping, and stored beam features. The injected beam at 250 MeV damped in around 80 to 100 ms. The signal intensity is then steady for another 400 ms until the next pulse of the magnet field. Images of the transverse damping are shown in a separate paper at this conference [9].



20 mV/Div

200 ms/Div

Fig. 5. Photomultiplier tube data showing the stored beam intensity versus time. Injection is at 500 ms intervals.

3.5. Beam Position Monitor

Beam position monitors (BPMs) utilize a series of stripline pickup devices installed in the transport lines and the PAR. The processing electronics are designed to provide single macrobunch detection in the first transport line and require beam to be stored in the PAR. Position resolution of about 100 μm has been demonstrated.

4. SUMMARY

In summary, key charged particle beam parameter characterizations are being addressed at the APS. Due to the diverse parameter space involved, a number of complementary intercepting and nonintercepting beam techniques are being employed. Most of the diagnostic systems in the first part of the injector have been commissioned and are supporting the accelerator system commissioning.

5. ACKNOWLEDGMENTS

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