INITIAL DIAGNOSTICS COMMISSIONING RESULTS FOR THE ADVANCED PHOTON SOURCE (APS)*

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Abstract

Principal diagnostics systems have been installed and nearly all have been commissioned on the subsystems of the Advanced Photon Source (APS) facility. Data have been obtained on beam position, beam profile, current, beam loss rate, and synchrotron radiation monitors on both injector rings and most recently the main 7-GeV storage ring. Results for the 150- to 450-MeV electron beams in the accumulator ring, up to 7 GeV in the injector synchrotron, and 4.5 to 7 GeV in the SR will be presented.

I. INTRODUCTION

Significant progress has occurred in the last year at the Advanced Photon Source (APS) project including the beginning of commissioning of all the major subsystems. This process has of course included the commissioning of the primary diagnostics systems for each injector subsystem and the main storage ring. When completed in 1996, the APS will be a synchrotron radiation user facility with one of the world's brightest x-ray sources in the 10-keV to 100-keV regime [1]. Its 200-MeV electron linac, 450-MeV positron linac, positron accumulator ring (PAR), 7-GeV injector synchrotron (IS), 7-GeV storage ring (SR), and undulator test line provide the opportunity for development and demonstration of key particle beam characterization techniques over a wide range of parameter space. A description of the overall status with an emphasis on the diagnostic systems or techniques is provided. More detailed descriptions were provided at EPAC '94 [2,3], in BIW '94 proceedings [4-8], other meetings [9-12], and in proceedings of this conference. Initial measurements have been done with electrons at energies from 250 to 450 MeV and 50 to 400 pC per macrobunch. Operations in single-turn and stored-beam conditions were diagnosed on the PAR, IS, and SR. To date, energy ramping in the IS to 7 GeV has been attained, and beam has been stored at 4.5 GeV and 7 GeV in the SR. The installed diagnostics played a critical role in the early commissioning exercises.

II. EXPERIMENTAL 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 PAR. 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 shown in Fig. 1. All are installed except the diagnostic undulator in the SR. Our group's responsibilities now include the linac diagnostics as well as all other subsystems.

The main design features of the subsystems are listed in [11]. The 20-ns macropulse bunch length and the 200 to 400 pC per macropulse delivered by the linac into the low energy transport (LET) lines between the linac and PAR were measured by the fast current monitor. Macropulse repetition rates of 2 to 10 Hz have been provided with the ultimate design goal being 60 Hz. All experiments to date in the rings have used electrons. Recently a 450-MeV positron beam has been delivered into the LET1 line, and the 8-mA current was measured by the same fast current monitor. [12]

III. INITIAL DIAGNOSTIC RESULTS

The basic charged-particle beam parameters such as beam profile, position, current, beam loss, bunch length, and energy will be addressed. Initial reports have been provided at the 1994 EPAC conference [2] which focused on the early LET1 and PAR results, and the 1994 BIW which added the injector synchrotron results. In this report, samples from the different machines will be given with the most recent data coming from the SR.

A. Beam Profile Monitor

In the early stages of commissioning, one of the key diagnostic systems has been the beam profile monitor based on an Al_2O_3 (Cr) screen material and a standard charge-coupled device (CCD) video camera. Ten intercepting screens on pneumatic actuators are arrayed along the linac and three 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, five in the IS, and ten in the SR. 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

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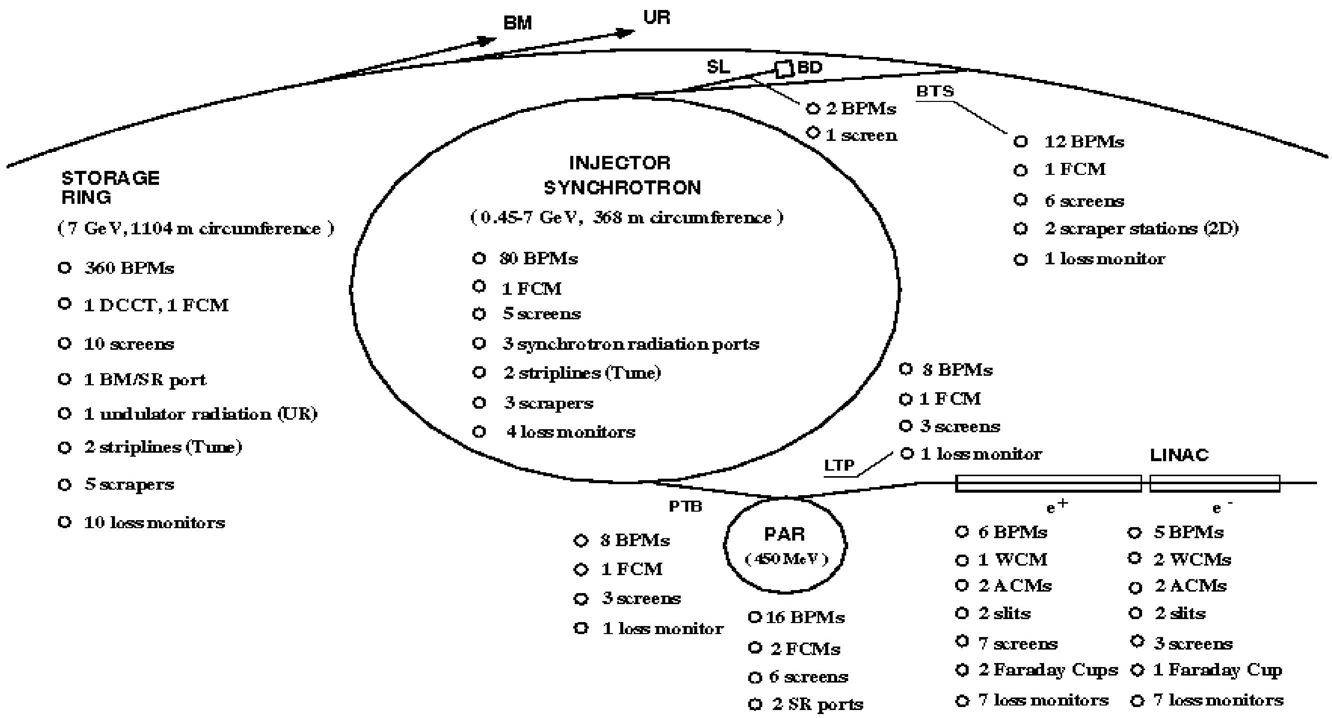

Figure 1: A schematic of the diagnostics system installed or planned for each APS subsystem. Almost all systems are now installed and functional except the undulator system in the SR.

or digitized by a VME-architecture-based video digitizing system linked to a Sun workstation. Figure 2 of [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 the uncorrected image. The beam size was a few mm (FWHM) in the vertical dimension. During commissioning, beam was readily transported through both the transport lines, the PAR, the 368-m-circumference IS, and the 1104-m-circumference SR using the observed image shapes and positions.

B. Beam Position Monitors

Beam position monitors (BPMs) are installed throughout the accelerators and transport lines. A series of stripline pickup devices are used in the linac, PAR, and the transport lines between the three rings. The processing electronics are designed to provide single macrobunch detection on the linac and transport lines, but require beam to be stored in the PAR. These are addressed in [7,8] and references therein.

In the injector synchrotron, 80 rf BPM stations are composed of 10-mm-diameter pickup buttons in sets of four and storage-ring-like electronics [8]. In early injector synchrotron runs, the initial 400-MeV orbit was closed and corrected as shown in Fig. 4 of [4]. The rms orbit error was corrected from 2 mm to about 0.5 mm using the singular value decomposition (SVD) technique. The booster has now been ramped to 7 GeV. In the SR all 360 rf BPM stations are installed and almost all are responding to beam. The electronics systems have been recently tested on the SR at ESRF and a resolution of 0.06 µm per $(Hz)^{1/2}$ has been indicated by scaling from the ESRF to APS standard chamber geometry. An additional factor of three in sensitivity from the reduced gap of the insertion device (ID) chamber is expected [8]. The electronics also have single turn capability through the AM/PM monopulse receiver so that an early two-sector test at 7-GeV was documented by the beam trajectory measured by the first 18 BPMs.

C. Beam Loss Rate Monitors

The loss rate monitors (LRMs), which cover the entire extent of beamlines and accelerators, are now operational on all subsystems including the SR. 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, IS, and SR. The gas mixture is 95% Ar and 5% CO_2, and the voltage across the center conductor to ground is 500 V. A clear effect in loss rate occurs 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. A signal change of 0.2 nA was observed with less than 100 pC in the beam [6]. If the arrival time of the signals is viewed on a scope, few-meter axial resolution for losses can be determined. Reference 6 provides more details. Recent data for the SR on 7-GeV beam losses indicate a calculated sensitivity of 13 pC collected charge per pC loss. The minimum observable loss is about 4 pC for this case.

D. Beam Current Monitor

Monitoring of the current/charge in the transport lines and rings is based on the use of fast current transformers manufactured by Bergoz and in-house electronics. The electronics are described in detail by Wang [5]. 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 and positron beams from the linac were measured from 50 to 400 pC per macrobunch. In the PAR, both a fast current transformer (FCT) and integrating current transformer (ICT) were used to assess single-turn and stored-beam conditions. Kicker electrical noise interfered with using the FCT raw signal as a turns counter in the early commissioning so a photomultiplier tube (PMT) was used [4]. In the IS, the ICT signal was used to track the charge intensity during the 230-ms ramping cycle to verify ramp performance. In the SR initial data from the ICT and DC current transformer (DCCT) have been obtained. On March 25, 1995, 50 μA of 4.5-GeV beam was stored, and on April 15, 1995, 100 μA of 7-GeV beam was stored.

E. Photon Monitors

In each of the three 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 or provide a measurement for tune, beam size, and bunch length [13]. A full complement of photon detectors and cameras was planned for radiation analysis. However, initial commissioning involved either a standard, CCD-based video camera and/or a photomultiplier tube (PMT). In the case of the PAR, an early commissioning issue was the large amount of electrical noise in the FCT signal from the nearby kicker magnet system. The PMT also showed noise, but the 300-mV signal from a single bunch/turn was much larger than the noise. The change from six turns in the PAR to thousands occurred in less than an hour with the PMT diagnostic after several shifts of fighting the kicker noise.

For PAR operations at 250 MeV, the lower energy resulted in a transverse damping time which corresponds to 80 to 100 ms. Our standard photon monitor camera easily tracked the progress of such damping in a series of six to eight frames taken 60 ms apart, as reported at EPAC 94 [3]. As a side note, the synchrotron radiation imaging has been very useful during early commissioning, even at low charge (~100 pC). We have routinely monitored the beam size in the nonintercepting mode for PAR and IS and recently recorded an image of the first beam stored in the storage ring at 4.5 GeV and at 7 GeV. Figure 2 shows the 7-GeV image which is sub-mm in extent for the horizontal and vertical FWHM. The orbit had not yet been fully corrected. The stored beam current was 100 μA.

IV. SUMMARY

In summary, key charged-particle beam parameter characterizations are well underway on the APS subsystems. Most of the diagnostic systems are now commissioned and are supporting the injector accelerators and SR commissioning. The formidable tasks of instrumenting the third-generation main storage ring are complete for the primary diagnostics, and the installation of the orbit feedback system, damper systems, and x-ray-based emittance measurements are expected in the coming year.

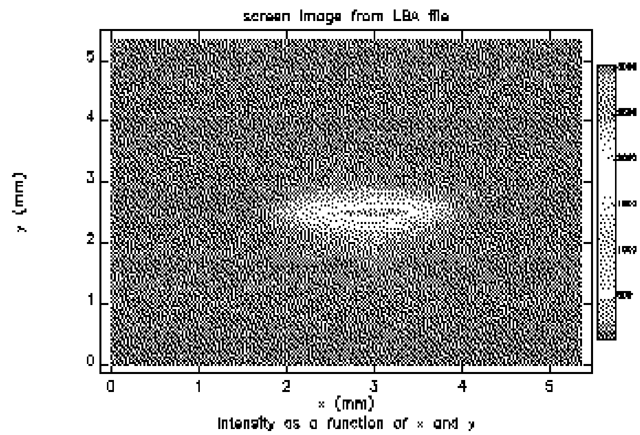

Figure 2: Image via OSR of first stored beam at 7 GeV in the main ring of APS on April 15, 1995. The scales should be multiplied by a factor of two.

V. ACKNOWLEDGMENTS

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