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Tests for the Advanced Photon Source (APS)*

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Results of Prototype Particle-Beam Diagnostics Tests for the Advanced Photon Source (APS)*

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Abstract

The Advanced Photon Source (APS) will be a third-generation synchrotron radiation source (hard x-rays) based on 7-GeV positrons circulating in a 1104-m circumference storage ring. In the past year a number of the diagnostic prototypes for the measurement of the charged-particle beam parameters throughout the subsystems of the facility (ranging from 450-MeV to 7-GeV positrons and with different pulse formats) have been built and tested. Results are summarized for the beam position monitor (BPM), current monitor (CM), loss monitor (LM), and imaging systems (ISYS). The test facilities ranged from the 40-MeV APS linac test stand to the existing storage rings at SSRL and NSLS.

I. INTRODUCTION

The Advanced Photon Source (APS) will be a third-generation 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 lines (UTL) will also provide the opportunity for development and demonstration of key particle beam characterization techniques over a wide range of parameter space. Some of these values overlap or approach those projected for fourth generation light sources as described at a recent workshop [2]. The Accelerator Systems Division (ASD) Diagnostics Group is responsible for the design, procurement, testing, and operation of all the diagnostic systems on the injector rings, their transport lines, the storage ring, and the undulator test lines. Descriptions of these plans using electrical conversion and optical conversion techniques and initial results from some prototype diagnostics tested on the linac test stands operating at 20 and 45 MeV, and the storage rings at SSRL and NSLS are presented briefly. These are supplemented by more detailed reports given at the 1992 Accelerator Instrumentation Workshop [3-8] and elsewhere at this conference. A brief outline of the undulator test line parameters and diagnostics is also presented.

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II. 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 base injector (gun, bunchers, and 45-MeV accelerating structure) was operated April through June 1992 as the injector linac test stand [9]. 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. Commissioning of these two linacs is to be completed by December 1993. 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. 3.

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

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	1.5×10^8 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

transport (HET) parameters are also provided. The revolution time, bunch length, and average currents are provided in Ref. 3 for the rings. Due to the low emittance of the beam, the BPM resolution in the SR and the number (360) of units is a challenge.

III. Prototype 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 [3,6,7]. Other tests have been performed on the ANL Chemistry Department linac at 20 MeV, the Los Alamos APEX facility at 40 MeV, and the storage rings at SSRL and NSLS in the year prior to this conference.

A. Beam Position Monitors

The major component of the beam position monitor (BPM) plans involves rf BPM pickup elements and their associated electronics. The button feedthrough for the storage ring main chamber (~10-mm-diameter button) and the insertion device chamber (~4-mm-diameter button) have been designed. Over 1800 standard buttons have been received and tested mechanically and electrically. A number of them are installed in the first set of vacuum chambers in a staging area. In addition to these, there will be intercepting beam profile screens and the use of synchrotron radiation from at least one bending magnet in each of the rings.

The BPM electronics have been designed for single turn capability in the storage ring and injector synchrotron. For these two rings the prototypes of the rf front end and the monopulse receiver that uses the AM/PM conversion technique have been tested in the laboratory and with input from BPMs at SSRL. Figure 1 shows the results of data obtained in a 20-bunch mode and using the signals from the SSRL striplines. The observed linearity and the resolution were scaled to APS conditions satisfactorily [4].

Figure 1 BPM Prototype Electronics Test at SSRL.

Another extensive program involves our orbit feedback design developments. Both AC global and local feedback aspects are involved. Results of a DC test at NSLS of the singular value decomposition (SVD) algorithm for global feedback were encouraging. A noticeable improvement in the rms orbit error relative to the reference orbit was obtained, a reduction from 137 μm to 61 μm . This is described in more detail in a separate paper at this conference [10].

B. Beam Current Monitor

Monitoring of the current/charge in the transport lines and rings will generally be based on use of fast current transformers manufactured by Bergoz and in-house electronics. Because the pulse structure of the electron linac will be representative of beam in the linac-to-PAR transport line, or LET1, the prototype current monitor (CM) was tested on the APS linac test stand as reported previously [6]. More recently, the integrating current monitor (ICM) was tested on the ANL Chemistry Department linac. Measurement capability of the charge (5 nc) in a 25-ps FWHM bunch was demonstrated successfully. Sum signals in the BPMs will also provide relative beam intensity measurements.

C. Beam Loss Monitor

The loss monitor (LM) system which will cover the entire extent of beamlines and accelerators was tested as a prototype. A gas-filled coaxial cable acting as an ionization chamber was installed along the length of the APS linac test stand. Results from tests at 25-40 MeV were reported elsewhere [7]. More recently the system was installed in the first 30 m of the SSRL storage ring after the injection point. Initial data were obtained under purposely poor injection efficiency conditions. The trace showed losses as negative-going pulses on the first few passes around the ring. DC tests were also performed and compared successfully to the SSRL DCCT under various stored beam lifetime conditions.

D. Imaging System

The beam imaging system (ISYS) can be applied to several aspects of the beam profile tasks. These can relate to beam spatial profiles, energy, or bunch length depending on the location in the beam transport (dispersive or nondispersive) or the nature of the imaging system (standard camera, gated camera, or streak camera). Initial tests included use of a VME-architecture-based video digitizing system linked to a Sun workstation. We have recently had the Los Alamos GTA video system adapted to the APS EPICS environment [11]. Sample data from the use of a demo, gated camera at SSRL (collaboration with Jim Sebek and Bob Hettel) show the ability to image a single bunch from a single pass in the storage ring. A

short gate, ~ 30 ns, was used and the gate delay was adjusted to step the active window off the back edge of the beam bunch pattern. The signal levels for $N = 0$, 1, and 2 bunches were clearly evident (Fig. 2).

Figure 2 Gated camera results show observation of single bunch ($N=1$) possible.

IV. UNDULATOR TEST LINES

The undulator test lines are being considered at 650 MeV and 7 GeV. In the first case, the tungsten positron conversion target will be retracted and the 450-MeV linac rephased to accelerate the electrons to 650 MeV. A key point here would be the switch to the rf thermionic gun which is projected to provide normalized, edge emittance of about 10π mm rad, a few orders of magnitude colder than the standard thermionic gun [12]. This gun also may allow micropulse bunch lengths of less than 1 ps to be attained via filtering and magnetic compression techniques. The emittance at 200 to 650 MeV will be measured in a straight 10-m-long section that bypasses the PAR. Cross-comparison of several techniques, including three-screen, two-screen, optical transition radiation (OTR) interferometry [13], and quadrupole field scan, is planned. Bunch length will be determined by a streak camera using either OTR [8] or some other prompt mechanism. Many of the critical beam parameters identified in the 4th Generation Light Source Workshop [2] will be approached by the proposed undulator test line electron beam.

V. 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 and most prototypes have now been tested. In the rings, of course, the nonintercepting techniques are dominant. Additionally, the undulator test line

initiative will address measurement of high brightness beams, their emittance-preserving transport, and their interactions with undulators in a parameter space which will be of interest to the designers of the next generation of light sources.

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