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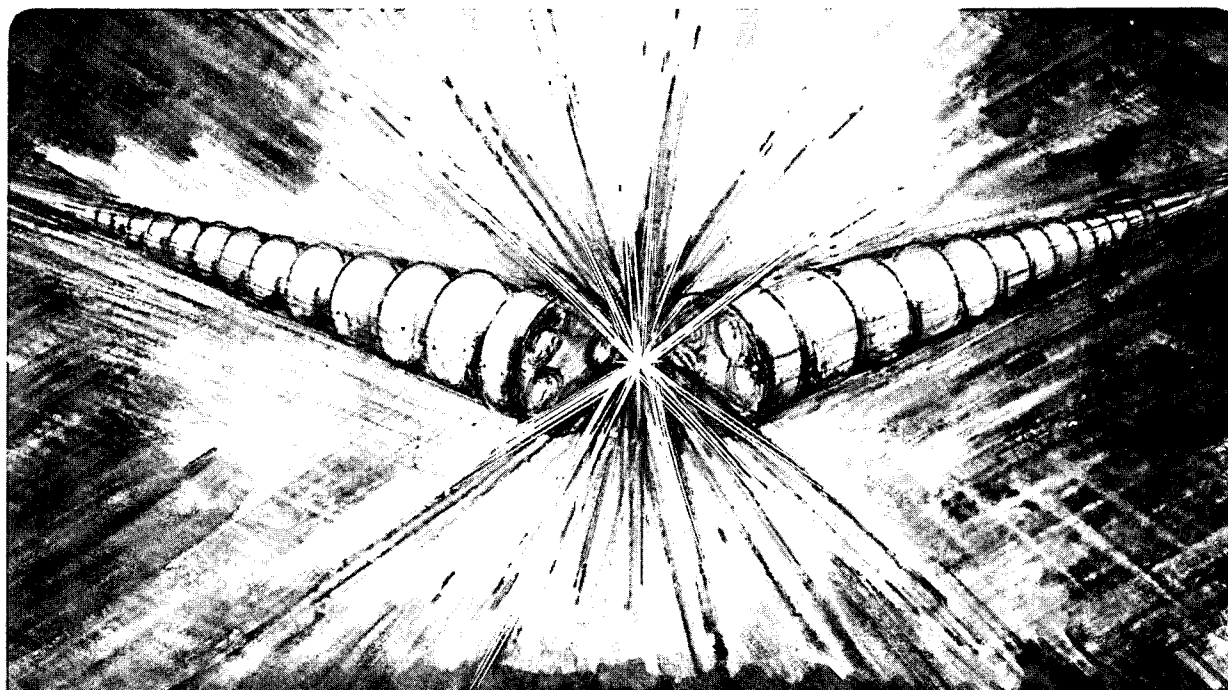
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**PERFORMANCE OF ADVANCED LIGHT
SOURCE PARTICLE BEAM DIAGNOSTICS**

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PERFORMANCE OF ADVANCED LIGHT SOURCE PARTICLE BEAM DIAGNOSTICS*

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Abstract

The Advanced Light Source (ALS), a third-generation synchrotron radiation facility, is complete. The particle beam diagnostics have been installed and tested. The beam injection systems have been running for two years. We have performance data on beam position monitors, beam intensity monitors, scintillators, beam collimators, a 50 Ω Faraday cup, and broad-band striplines and kickers used in the linac, transport lines, and the booster synchrotron. The single-turn monitoring capability of the booster beam position monitoring system has been particularly useful for studying beam dynamics. Beam diagnostics for the storage ring are being commissioned. In this paper we describe each instrument, show its performance, and outline how the instruments are controlled and their output data displayed.

I. INTRODUCTION

Recently, the commissioning performance goals of the ALS storage ring were met. Multi-bunch beam intensity has reached 460 mA. Single-bunch current has exceeded the 8 mA specification by a factor of three. Beam lifetime is dominated by vacuum chamber pressure and is increasing as synchrotron light scrubs the many photon stops. At 100 mA, the lifetime is about 1 hour. The commissioning process went very rapidly. Instrumentation played a critical role.

II. BEAM INTENSITY MONITORS

A. Wall Current Monitors

Two identical monitors are installed, one near the electron gun, and the other in the 1.5 GeV beam transport line connecting the booster and storage rings. The monitor near the electron gun is described. The function of this device is to measure the amplitude and duration of the RF-modulated beam emitted from the electron gun. Beam energy at this location is 120 keV. The gun emits from 1 to 20 beam bunches, 2 ns FWHM, spaced at 8 ns, at a 1 Hz repetition rate. Peak current is between 1 and 2 A.

The wall current monitor requires a gap in the beam pipe to intercept the beam image (wall) current. This is provided by a commercially available ceramic insulator fitted to 114 mm diameter flanges on a 64 mm diameter beam pipe. The ceramic insulator is approximately 25 mm long and is coated with a thin layer of chromium on the vacuum side. This coating protects the ceramic from the beam and somewhat damps wave guide modes (important only in the high-energy transport line beam monitor). The

resistance of the metalization is 60 Ω . Twenty, 39 Ω , low-inductance, leadless resistors are installed symmetrically around the outside of the ceramic gap. The resistors are soldered to soft copper rings, which are strapped to the metal beam pipe on each side of the gap. The total resistance across the gap is about 1.9 Ω .

With a single tap on the resistor belt we noticed undesirable beam position sensitivity during the early part of each bunch. By tapping the resistor belt at four equally spaced locations and summing the voltages in three, 180-degree hybrid combiners, the position sensitivity is considerably reduced. The summed output of the hybrids is displayed on an SCD1000 scan-converter oscilloscope via 60 feet of 0.25 inch Heliac cable. The ALS control system collects oscilloscope trace data over the General Purpose Interface Bus (GPIB) and displays the trace in the control room at 1 Hz. At the oscilloscope input the final sensitivity including cable and hybrid response is about 2.5 V/A.

High frequency response of the wall current monitor is dominated by the gap resistance and shunt capacitance of 20 pf. In our monitor the response is reduced by 3 dB at 4.2 GHz. The beam bunch spectra at the electron gun do not extend beyond about 1 GHz. The upper limit of the hybrid response is 2 GHz. The oscilloscope response is down 3 dB at 1 GHz. There is sufficient high frequency response in the system to show relevant beam bunch structure.

Low frequency response of the wall current monitor is dominated by system inductance. The beam pipe is grounded in many locations, creating a low-frequency short circuit across the gap. The limited inductance in these short circuits causes a noticeable baseline tilt in the oscilloscope response when we observe many bunches at 8 ns intervals. The calculated total inductance across the gap resistance is 130 nH. We intend to improve low-frequency response with external frequency compensation circuits.

B. Faraday Cup

This device is used to measure total beam charge in the 50 MeV transport line between the linac and booster. A passive, impedance matched RC network integrates the cup voltage for presentation on a remote digitizing oscilloscope. The wave form is displayed in the control room. We hoped the cup's 50 Ω construction would yield frequency response high enough to resolve adjacent S-band beam bunches. Our aim was to make a straightforward sub-harmonic buncher tuning aid. A rise time of 100 ps or less in a single-shot system was necessary. The best cup rise time we have observed is about 300 ps due to the lumped capacitance of a ceramic gap on the end of the cup. See Figure 2. Although the cup does not have the frequency response we desire, it does accurately quantize total beam charge. One interesting

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magnet repair was performed, and beam circulated with little tuning.

The BPMs require internal measurement of differential gain and offsets in order to make repeatable measurements to the required 30 mm. For reasons discovered just recently the storage ring BPMs would not perform an internal calibration sequence. Even so, the averaged beam position readings with stored beam made closed orbit corrections possible to 0.5 mm rms. With BPM calibration working we expect better than 0.1 mm performance.

IV. SCINTILLATORS AND TV

Throughout most of the ALS project we use scintillators made of high-purity alumina doped with chrome. They are referred to as Chromox 6 fluorescent screens and are produced by Morgan Matroc Ltd. in the U.K. The scintillators are UHV compatible and, in over three years of service, we have seen no signs of beam damage. Two zinc oxide scintillators are installed near the electron gun. We found the Chromox 6 scintillators were not usable in this location. Apparently, lack of a conducting substrate caused the scintillators to charge as they stopped the low-energy beam. A distorted image and some flashing resulted.

Early on, with weak beams, we had difficulty obtaining enough light from Chromox 6 for our CCD TV cameras. This was due to camera optics, number of electron bunches, and rather diffuse beams. TV image frame-grabbing and image enhancement helped. At the suggestion of a visiting colleague [5] we removed the infrared filter from the CCDs and obtained a huge increase in camera response. The scintillators produce strong infrared with a long response tail. The CCDs are quite sensitive at those long wavelengths.

Our efforts have been to commission the accelerator, and consequently, there has been little attention paid to improving the TV systems. We intend to study scintillator response and determine ways to optimize the scintillator and TV systems for best performance.

V. BROAD BAND STRIPLINES

Two broad band stripline pickups [6] are installed in the booster synchrotron. They are referred to as traveling wave electrodes (TWE). They were intended to be part of a fractional tune measurement system. The pickups have good frequency response and adequate coupling to the beam. The kicker however does not have sufficient coupling. We have been unable to excite detectable betatron motion in booster beam with as much as 70 W driving the kicker. We feel this is due to a rather large tune spread. The booster sextupoles that would reduce the tune spread are not needed for satisfactory beam acceleration. Our plan is to run the sextupoles and attempt more tune measurements. If we are unsuccessful, we will install a more robust kicker.

It is worth noting that booster fractional tune measurements are easily done with the BPM single-turn response and multi-turn data storage. At injection we determine fractional tune by performing an FFT on 1024 sequential turns. At higher energies, when the beam is damped, we excite it with the extraction kicker at low fields and again use the BPM data to determine tune.

We have no striplines, TWEs, or transverse kickers installed in the storage ring at this time. Consequently, accurate fractional tune measurements have been difficult to obtain when we have a stable, damped beam. We have had some limited success tickling the beam horizontally using one of three arrays of LEP BPM buttons, a 100 W power amplifier, and a tracking generator/spectrum analyzer combination. These buttons are not meant to be kickers. They will be used as pickups for transverse and longitudinal damping systems. We are able to use the single-turn capability of the BPMs to determine tune to 0.01 when the beam is unstable (at injection and at high current). A Tektronix 3052 fast spectrum analyzer displaying BPM spectra or an FFT performed 1024 turns of BPM data show similar results. We plan to install the transverse damping system kickers this year and will use them to excite a damped beam in the future. We expect we will achieve 0.001 tune resolution then.

VI. BEAM COLLIMATORS

Adjustable two-jaw beam collimators are installed in the low-energy diagnostics line off the linac and in the line between the linac and booster. A single collimator is used in the diagnostics line and defines a vertical slit. Two collimators in the booster line define a beam aperture. The 50 MeV beam is stopped with 0.5 inch tantalum plates. Stepper motors position the plates with 10 μ m resolution. Absolute position encoders read position to a few microns.

VII. CONCLUSION

The diagnostics are working well enough to commission and run the accelerators. Some improvements are needed. BPM resident software will be changed to take advantage of the device's ability to calibrate offsets and correct detector nonlinearity. We currently have no way of measuring total beam charge at the exit of the booster. We plan to install an integrating current transformer there. More work will be done on the wide band linac bunch monitor.

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