Status of the PLS 2 GeV Storage Ring*

Y. S. Kim, W. C. Choi, B. K. Kang, Y. M. Koo, B. H. Kwon, K. B. Lee,
S. C. Lee, J. E. Milburn, S. C. Won, M. Yoon and T. N. Lee
(presented by M. Yoon)
Pohang Accelerator Laboratory, POSTECH
San 31, Hyoja-Dong, Pohang, Korea 790-784

Abstract

In Pohang, Korea, a 2 GeV third-generation synchrotron light source project is underway. The accelerator facility consists of a full energy linear accelerator injector and a 2 GeV storage ring. The storage ring employs a Triple Bend Achromat (TBA) structure with 12 super-periods. Construction of the accelerator building was completed in September, 1993. Installation of the storage ring components started in March, 1993, when the first chamber and support girder assembly was moved into the storage ring tunnel. Installation will be completed in August, 1994 and commissioning will continue until the end of 1994. In this paper, we present the recent progress of the PLS storage ring installation and the status of beamline installation.

1 INTRODUCTION

The Pohang Light Source (PLS) project was launched in 1988. A budget of US $97M was approved by the Pohang Iron and Steel Company (POSCO), and later the Korean Ministry of Science and Technology (MOST) also gave its approval and the promise of support in raising the remaining required funds, about $79M.

The PLS site was chosen to be an area adjacent to the Pohang University of Science and Technology (POSTECH) campus in Pohang, which is about 400 km southeast of Seoul. For the site, an area of 110,000 m^2 was needed, but it was decided to acquire 650,000 m^2 of land for possible future expansion of the accelerator complex. Within the acquired land, a 75 m hill was leveled down to 50 m to provide the desired 110,000 m^2 site. The storage ring is situated on stable solid mud-stone. A ground-breaking ceremony was held on April 1, 1991 and construction of the accelerator building and utility buildings was completed in September, 1993. Commissioning is scheduled to start in September, 1994.

The storage ring is 280.56 m in circumference and consists of 12 super-periods. Each super-period contains two vacuum chamber/support girder assemblies; one 7 m long and the other 10 m long. The lattice employs a triple bend achromat structure, with 36 dipole magnets distributed around the ring. Details about the PLS storage ring components are described elsewhere [1]. In this presentation, we describe the progress of the storage ring components and installation.

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2 PROGRESS OF THE STORAGE RING COMPONENTS

2.1 Magnets

In the PLS storage ring, there are 298 magnets; 36 main dipoles, 144 quadrupoles, 48 sextupoles, and 70 combined horizontal and vertical correctors. Sextupoles have additional trim windings for horizontal and vertical orbit corrections, and for skew quadrupole. All magnets were fabricated by a local company, Hyundai Heavy Industries. All magnets are asymmetrical C-type to make fabrication easy and to allow easy extraction of photons. Such asymmetric magnets, however, can produce spurious magnetic multipole errors. Such errors have been controlled by appropriate core designs, and by shimming and/or rotating core pieces to introduce compensating perturbation errors. Prior to magnet installation, we have carried out a number of repeatability tests to ensure that the assembly and disassembly processes do not significantly modify the magnet multipoles and magnetic center. Our result indicates that multipoles are not changed more than 10% and magnetic center shift is within 5 μm *rms*.

Multipole, magnetic center, and fundamental field reproducibility measurements have been carried out for all magnets in our laboratory and the results in all cases are found to be within tolerance.

2.2 Vacuum System

To achieve sufficient lifetime of the circulating electron beam, an operating average pressure of 1 nano-torr is required. The storage ring vacuum system is pumped by non-evaporable getter (NEG) pumps and sputter ion pumps (SIP). Combination pumps, consisting of lumped NEG and SIP, are provided under each photon stop. Each super-period has two ante-chamber type sector vacuum chambers (7 m and 10 m long) and one long ante-chamber type straight section chamber. Aluminum alloy 5083-H321 has been chosen as the vacuum chamber material. The chambers were machined by a domestic company, with cleaning and welding done in the PLS vacuum laboratory. In-situ bake-out has been done for two super-periods. Mid 10^{-10} torr was achieved after bake-out. Further bake-out for the remaining ten super-periods is planned to be carried out after commissioning.

2.3 RF Power System

There are four 500 MHz RF cavities located in one of the dispersion-free straight sections. For each cavity, the shunt impedance is measured to be 8 MΩ. To provide an overall single-bunch lifetime of more than 5 hours, a voltage of 1.8 MV is required at a beam energy of 2 GeV. The total RF power requirement varies from 160 kW to 344 kW as the stored current is increased from 100 mA to 400 mA. For 2.5 GeV operation, which is one of the options in our future upgrade plan, the power requirement varies from 234 kW to 540 kW. Initially, for commissioning, only three cavities will be activated, with a maximum RF voltage 1.5 MV. With three cavities, the injection efficiency should not be deteriorated significantly. Also, Touchek lifetime reduction for single-bunch operation is not important during the initial period. The remaining cavity will be installed immediately after commissioning.

2.4 Instrument and Control System

The storage ring control system consists of a host computer, an expandable set of console computers, and *VME-bus* based data acquisition and control systems (DACS). The UNIX-based Sun computer was chosen as a host computer. A total of four workstations are used as operator consoles, and an additional three color display monitors are planned for continuous display of information such as beam lifetime, vacuum status, and magnet power supply setting and monitor values. The DACS consists of subsystem control computers (SCC), machine interface units (MIU) and low level communication networks. MIUs are distributed around the ring to reduce the length of the signal cables from the machine components and also to reduce the electromagnetic noise problems on the cables. Each SCC is interconnected to multiple MIUs via a MIL-1553B network. The SCCs are also linked to the high level computers via Ethernet (TCP/IP).

Diagnostics of the PLS storage ring include 108 button-type beam position monitors (BPM), one direct current current transformer (DCCT), a strip-line kicker and a pickup for measuring betatron tunes, a beam scraper, and a photon beam monitoring system. Among the nine BPMs per super-period, one has the ability to make turn-by-turn measurement, which will be helpful during the commissioning period. In addition, there are five destructive beam profile monitors for monitoring first turn operation. Except the one in the injection straight, these profile monitors are not impedance matched, and therefore will be removed after commissioning.

2.5 Survey and Alignment

The *rms* positioning tolerances of the PLS storage ring magnets are: 0.5 mm for dipole magnets, 0.15 mm for quadrupole magnets, and 0.2 mm for sextupole magnets. To achieve these tolerances, ten geodetic control points are established, six inside the storage ring and linac buildings, and four in the hill area outside the buildings. A relative accuracy of better than 0.5 mm *rms* is expected. In addition to these geodetic points, a number of tunnel control points are installed to establish a tunnel network. To minimize centering error, 72 wall brackets are mounted on the inner and outer walls of the storage ring tunnel. In addition, there are 32 wall brackets in the beam transfer line tunnel. All the possible directions and distances, between control points are measured with electronic theodolites and EDMs. A relative accuracy of 0.2 mm *rms* is achieved.

There are four stages for alignment of the storage ring components; pre-alignment, rough setting, fine positioning and smoothing. The pre-alignment process involves aligning a vacuum chamber with respect to the girder coordinate system while in the assembly area. For this purpose, a number of fiducial marks are installed on the girder plate. A relative accuracy of 0.2 mm *rms* is achieved. The pre-aligned girder/chamber assembly is transported into the tunnel and positioned roughly on floor marks. All magnets are then mounted onto support struts on the girder. Because of the small gap between magnets and the vacuum chamber, an accuracy of ±1 mm is required for rough setting. The roughly positioned girder and magnets are adjusted to a relative accuracy of 0.2 mm with respect to the control points inside the ring tunnel, using the electronic theodolite. Several iterations of surveying and alignment are carried out at this stage. Finally smoothing involves a set of successive overlapping measurements of the local curvature using a metrological chain of triangles formed by the storage ring quadrupoles. The control points are no longer referenced at this stage. An accuracy of 0.15 mm *rms* is required, and expected to be achieved.

3 INSTALLATION PROCEDURE AND STATUS

The installation procedure of the PLS storage ring can be summarized as follows. Vacuum chambers are machined in the factory and delivered to the lab. Each piece is inspected and cleaned chemically, after which top and bottom pieces are welded together. Spool chambers and flanges are then attached and welded. The chamber is then mounted on the support girder. Beam position monitors are inserted and the whole assembly is baked and leak checked. After that, the chamber is aligned with respect to the girder coordinate system. The girder/chamber assembly is transported to the storage ring building. Inside the storage ring building an air-bearing system is used to move the assembly to its position inside the tunnel. Screw jacks are then mounted from the floor to the girder. The girder is aligned within ±1 mm, and magnets are installed. Finally, the magnets are fine aligned.

Each step of the above sequence takes three or four weeks depending on the vacuum status of the assembled chamber. Two or three steps can be performed simultaneously on different sectors. The installation of the chamber/girder assembly began in March 1993 and was completed in January 1994. In parallel, magnet power supplies (MPS), vacuum control racks and MIUs were placed in the shed, which is located on the inner radius of the storage ring tunnel. MPS, vacuum and control cables are then installed. Radiation-resistant HYPALON is used as an MPS cable insulation material. In each super-period, there are two trenches; one provides a path for cooling water and the other for cables.

Inside the storage ring building, above the storage ring tunnel, there are a number of air handling units (AHU) to control the temperature. The storage ring tunnel and the experimental hall are maintained at 23 $\pm 1°$ C, and 23 $\pm 2°$ C, respectively. These AHUs are considered to be a significant source of vibration, which may deteriorate the quality of the photon beam. Therefore, a special double anti-vibration system has been installed for each AHU. A series of vibration measurement was carried out at various points in the storage ring tunnel. The results can be summarized as follows; 1) the double anti-vibration system damps the amplitude by a factor of 30 to 500; 2) during propagation of the seismic wave from the mezzanine floor to the storage ring tunnel floor, the amplitude is further damped by a factor of 30; 3) the main vibration source of the AHU is the fan and the motor whose characteristic frequencies are 23 Hz and 30 Hz, but the amplitudes at both frequencies are well below the tolerance, which is 0.1 μm; 4) cooling water flow does not cause any significant vibration of the magnets. After installation of the storage ring is complete, further measurements are planned to measure the effect of external vehicle traffic movement.

4 BEAMLINES

For each super-period, there are three source points, two at the middle dipole magnet, and one at the straight section, where insertion devices can be placed. Among the twelve straight sections, one is occupied by injection components and another by RF cavities. Thus, ten insertion devices can be installed in the PLS storage ring. Also, of the twelve middle dipole magnets, the one before the injection straight is not used for photon beam extraction. Thus, the total number of available bending source points are 22, and the total number of source points in the PLS are 32. However, each beamline can be split into multiple branches whenever needed.

Bending magnets produce photons of wide spectral range from infrared (IR) to hard X-rays. With a 1.058 T bending field for 2 GeV operation, the critical photon energy is 2.8 keV. Our domestic experimental advisory group recommended that there should be at least two beamlines delivering photons with an energy range of 2 $\sim$ 30 eV and 25 $\sim$ 250 eV. These beamlines are expected to be used very extensively by the large surface scientist community in Korea. Since there are many interesting phenomena which can be studied with photons in the energy range 250 $\sim$ 1000 eV, such as carbon K edge and water window, it was decided to build the first beamline delivering photons up to 1000 eV. There are demands for hard X-rays from various users. It is also apparent that there are many potential users who are using conventional X-ray sources at present but will be interested in synchrotron radiation after PLS begins to operate. Since photons of wavelength about 0.1 nm are so extensively utilized in condensed matter research, the hard X-ray beamline will be heavily occupied by on-campus users and outside users.

By the end of 1994, the PLS is planning to construct two bending magnet beamlines, one for VUV experiments and one for hard X-ray experiments with photons at energies below 10 keV. Since the radiation from bending magnets diverge uniformly in the horizontal direction, each beamline can be divided into several branches which have their own experimental station so that different experiments can be carried out simultaneously.

For the VUV beamline, two branches are attached to the exit beam port from a bending magnet, which has a horizontal divergence of 42 mrad. Of the two branches, one is a sherical grating monochromator (SGM) beamline for photoemission spectroscopy experiments and the other is a normal incidence monochromator (NIM) beamline for gas-phase experiments. The SGM will accept 10 mrad of white photon beam and provide photons between 13 and 1230 eV. Another 13.5 mrad of white beam can be used for the optics of NIM for 5 - 30 eV photons. However, only the SGM beamline is under construction during the PLS construction period. The branch for the NIM beamline will be used for diagnostic of the stored electron beam until the dedicated diagnostic beamline is ready.

For the bending magnet X-ray beamline, there will be two experimental stations, each for X-ray scattering and XAFS, respectively. Each experimental station will be located inside a hutch for radiation shielding. X-ray scattering beamline will accept a 3mrad wide X-ray beam from bending magnet. The X-ray photons will be focussed by a dynamically bent cylindrical Pt-coated sillicon mirror in front of a double crystal monochromator which monochromatize x-rays between 4-12 keV. The monochromator is being assembled and is planned to be tested with a conventional sealed-tube X-ray source. XAFS beamline is in the design phase and will be constructed after the completion of the PLS storage ring.

5 SUMMARY

Installation of the PLS storage ring is nearly complete. After installation of vacuum chambers, adjacent chambers are connected by a flex-band, which is a new type of shielded bellows developed by PLS. Vacuum pumps are then activated. Low 10^{-8} torr pressures were achieved without baking, which is considered to be good enough for commissioning. Injection bump magnets are to be installed in July and will be tested till the end of August. The whole system will be commissioned beginning in September, 1994

6 REFERENCES

[1] Pohang Light Source Design Report, January, 1991.