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Present Status of the Pohang Light Source

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The Pohang Light Source (PLS), the first large-scale accelerator complex in Korea, is a national users facility for basic and applied science research using synchrotron radiation. It consists of a 2 GeV linac as a full-energy injector and a low-emittance storage ring. The PLS linac is 150 m long with eleven 80 MW klystrons for a high accelerating gradient; the storage ring has the TBA-lattice with 12 super-periods and a 280 m circumference. Since the accelerators were commissioned in December 1994, the annual operation time exceeded 4600 h in 1996, and the user service time is expected to reach 3500 h in 1997. The facility was opened to general users in 1995 with two beamlines. Six beamlines are now operating: white-beam, NIM for ARUPS and gas-phase, photoemission spectroscopy, EXAFS, X-ray diffraction and lithography. Our long-term plan is to construct three new beamlines every year.

Keywords: facility reports; Pohang Light Source; 2 GeV linacs; third-generation storage rings.

1. Introduction

The PLS is the first large-scale accelerator complex in Korea (Lee, 1993). It is a national synchrotron radiation users facility for basic and applied science research consisting of a 2 GeV linac as a full-energy injector and a low-emittance storage ring.

In 1988 the Pohang University of Science and Technology (POSTECH) initiated the PLS project with financial support from the Pohang Iron and Steel Company (POSCO). The Korean government joined the project in 1989. A brief history of the PLS construction project is listed in Table 1. When the accelerator construction was officially completed at the end of 1994, the total project cost was 144.7 billion won (about US $180 million). The facility was opened to users in September 1995, initially with two beamlines, with the number of beamlines increasing to six in 1996. One may note that a commercial company, LG-Semiconductor, built its own beamline for lithography research. Another beamline is being built by the Kwangju Korea Institute of Science and Technology (KJIST) with support from the Kumho Business Group.

Since the Pohang Accelerator Laboratory (PAL) is affiliated with POSTECH, a private university, we established a new format for operating this nationwide users facility. At the end of 1996, POSCO endowed PLS with an operating fund of 20 billion won. The Ministry of Science and Technology (MOST) will cover the rest of the annual operating budget. The PAL budget has increased from 12.7 billion won (US $15.8 million) in 1995 to 14.2 billion won (US $17.7 million) in 1996 and 17.7 billion won (US $22.1 million) in 1997. This funding level will be maintained for the next few years. It includes the construction cost of three new beamlines annually. One may expect 40 beamlines to be completed by 2008. In order to undertake this mission effectively, the laboratory organization changed from the accelerator construction phase to the beamline construction phase in November 1996.

2. Operation of PLS accelerators

The 2 GeV injector linac consists of a 100 MeV pre-injector and ten SLAC-type regular modules, with four accelerating sections fed by each klystron (Namkung *et al.*, 1996). Each module also has a SLAC-type pulse compressor with an average energy gain factor of 1.5. Because 80 MW class high-power klystrons are used, each regular module is able to provide a beam energy of 200 MeV with microwave power of 50 MW. The beam injection to the storage ring every 8 h usually takes 2–5 min with 10 Hz and 1.5 ns pulses. Table 2 shows the designed and achieved values for the PLS 2 GeV linac parameters. In order to improve the machine availability even when extended repair is needed, for example, in the case of klystron replacement, we propose an additional klystron with two accelerating sections using the reserved space in the beam switch yard.

The PLS storage ring has a TBA-lattice structure with 12 superperiods. The circumference is 280 m, and there are two straight sections allocated for the RF cavities and the injection system (Yoon *et al.*, 1996). Aluminium vacuum chambers are machined by an outside vendor and welded in-house. The vacuum chambers consist of two sectors of

Table 1
A brief history of the PLS construction.

Project started	1 April 1988
Site preparation completed	31 December 1990
Ground breaking	1 April 1991
Pre-injector completed	28 February 1992
2 GeV linac commissioned	30 June 1994
Storage ring commissioned	24 December 1994
User service started	1 September 1995

Table 2
Designed and achieved values for linac parameters.

	Designed	Achieved
Beam energy (GeV)	2.0	2.34
Acceleration gradient (MeV m^{-1})	15.5	18.1
Beam pulse length (ns)	2	<1, 2, 40
Energy spread (%)	<0.6	<0.5
Energy doubler gain factor	1.5	1.5–1.63
Injection current (mA)	200	800

10 and 7 m length in each period. The RF system uses four RF klystrons of 60 kW to support a beam current of 400 mA at 2.0 GeV and 250 mA at 2.5 GeV. We have demonstrated beam-energy ramping to 2.5 GeV from 2.0 GeV. We have also achieved a stored current of 373 mA, but the beam showed various instabilities in this high-current regime. The lifetime was normally more than 15 h at 100 mA in the first half of 1997. Table 3 shows the designed and achieved values for the PLS 2 GeV storage ring parameters.

There are three modes of accelerator operation: user service, machine study and beam alignment. Table 4 shows the number of hours of total machine operation and of the user service mode. For example, we operated the storage ring for 4680 h in 1996, out of which machine study and alignment took about 1400 h. In order to align newly built beamlines, one should provide stable synchrotron radiation for an extended period of time. Machine operation time in the user service mode was allocated 3200 h in 1996 and 1824 h in the first half of 1997. With reduced failures, the availability improved from 89.6% in 1995 to 95.9% in the first half of 1997.

The machine fault statistics are shown in Fig. 1 for both the injector linac and the storage ring. The most frequent failures in the injector linac were the modulators; in the storage ring the most frequent failure was the injection

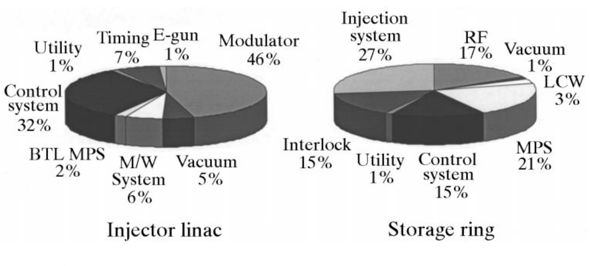

Figure 1
System failures in 1996.

Table 3
Designed and achieved values for storage ring parameters.

	Designed	Achieved
Beam energy (GeV)	2.0	2.5
Beam current (mA)		
Multi-bunch	400	373
Single bunch	7	26
Beam lifetime (h) at 100 mA	10	15–30
Tunes (v_x/v_y)	14.28/8.18	14.28/8.18
Emittance	12.1	N/A

Table 4
Statistics for total machine operation and user service mode.

	1995 (second half)	1996	1997 (first half)
Operation records			
Linac (h)	1870	4810	2970
Storage ring (h)	1820	4680	2710
User service mode			
Plan (h)	1275	3236	1824
Failure (h)	132.6	202	75.5
Availability	89.6%	93.8%	95.9%

system. We have experienced various beam instabilities, especially coupled-bunch instability in high-current operations. Therefore, we are going to improve the precision temperature-control system of the RF cavities and install transverse and longitudinal feedback control systems in 1998. The longitudinal feedback system is being developed in collaboration with SLAC.

3. Beamlines and insertion devices

There are 32 beamports in PLS, 22 for bending magnets and ten for insertion devices. We started initially with two beamlines: photoemission (VUV) and X-ray scattering. In

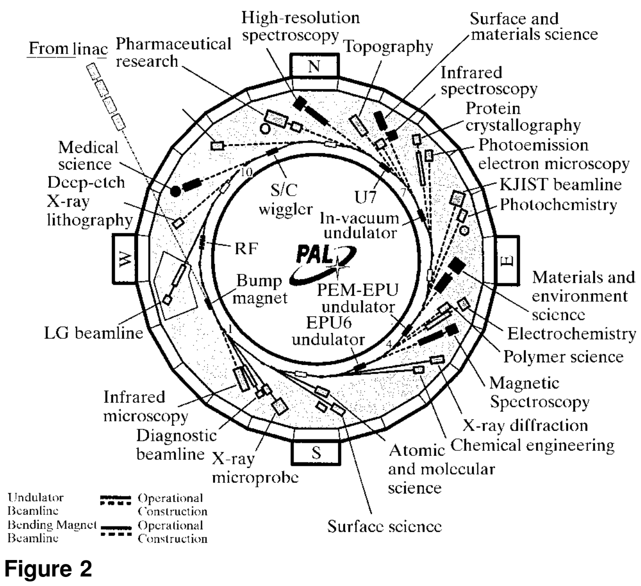

Figure 2
PLS beamlines during 1994–2002.

Table 5
PLS beamlines (operational).

Year	Beamline	Energy range	Beam size	Monochromator	Experiment
1995	Photoemission spectroscopy	12–1230 eV	1.5–1.8 mm	SGM	ESCA, XPS, UPS, ARUPS (EDC, CIS, CFS mode support)
	X-ray scattering	4–12 keV	1 × 1 mm	Si(111) DCM	Powder X-ray diffractometry, high-resolution X-ray diffraction, double-crystal X-ray diffraction, thin-film surfaces
1996	White beam	4–12 keV, 12.5 keV	0.6 μm^2	KB optics multilayer mirror, Si(111) crystal	X-ray fluorescence microprobe, phase-contrast imaging, LIGA *etc.*
	Lithography [LG-semiconductor]	1–2 keV	50 × 25 mm	–	X-ray lithography, LIGA
	NIM	5–30 eV	4 × 1 mm	3m NIM	ARUPS, UPS, mass analysis of photoion
	EXAFS	4–14 keV	10 × 1 mm	Si(111) DCM, fixed exit	Transmission EXAFS, fluorescence EXAFS, electron yield EXAFS

Table 6
PLS beamlines (under construction).

Year	Beamline	Energy range	Beam size	Monochromator	Experiment
1997	Diagnostics	Visible	–	None	–
	X-ray diffraction [Kumho-KJIST]	4–12 keV	1 × 1 mm	Si(111) DCM	Powder X-ray diffractometry, high-resolution X-ray diffraction, double-crystal X-ray diffraction, thin-film surfaces
	SAXS	4–12 keV	1 × 1 mm	Si(111) DCM	Static and time-resolved SAXS, time-resolved X-ray scattering with varying temperature
1998	High-resolution PES [U7 undulator]	20–2000 eV	1 × 0.05 mm	VIA PGM	High-resolution photoemission spectroscopy
	Protein crystallography	4–20 keV	0.3 × 0.3 mm	Si(111) DCM	MAD
	Slitless photoemission/MCD	200–1000 eV	1 × 0.5 mm	VLS PGM	PEEM, MDC

1996, we added four beamlines: NIM for gas-phase and photoemission, EXAFS, microprobe and LG-lithography. The characteristics of operational beamlines are listed in Table 5 and those of the beamlines under construction in Table 6. We will complete two more in 1997: SAXS and Kumho-KJIST X-ray scattering. There will then be a total of eight beamlines by the end of 1997. We also initiated the protein and slitless beamlines this year. There will be 11 beamlines including the U7 beamline by the end of 1998.

We recently decided to construct three beamlines every year so that we will have 40 beamlines by 2008. The tentative arrangement in the experimental hall for the period 1994–2002 is shown in Fig. 2.

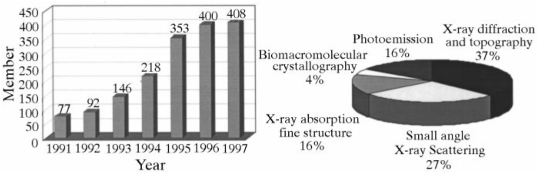

Figure 3
Number of members in the Korean Synchrotron Users Association.

We have prepared two insertion devices: a U7 undulator and a superconducting wiggler. The U7 undulator was constructed in-house with help from a domestic company. It has 59 periods, which are 4.3 m long, and a photon energy of 40–2000 eV. We installed the U7 undulator during the summer shutdown period in July 1997, and we expect to complete the U7 beamline by the end of 1998. The parameters for the U7 undulator are listed in Table 7. The superconducting wiggler of 7.5 T was constructed in collaboration with the Budker Institute of Nuclear Physics (BINP), Russia. We are now constructing an elliptically polarized undulator with a 6 cm period.

4. Experiments and user community

Users are becoming familiar with experimental techniques and instrumentation, and we have had some encouraging initial results, such as the magnetic moment measurement of gadolinium on the Gd/Fe superlattice and the lithography of a 0.13 μm linewidth. There were 18 experiments

Table 7
Parameters for U7 undulator.

Period length (cm)	7
Number of periods	59
Overall length (m)	4.3
Peak magnetic field (T)	1.01
Minimum magnetic gap (mm)	16
Peak power density (kW mrad^{-2})	4.27
Total weight (ton)	20
Status	Installed in position

conducted in 1995 and 64 in 1996 with two beamlines. More than 100 experiments are expected in 1997. Table 8 shows the statistics for the experimental proposals. The number of members in the Korean Synchrotron Users Association has increased from 77 in 1991 to 408 in 1997, as shown in Fig. 3. We have already experienced increased competition to obtain beamtime for certain beamlines. As more beamlines become available yearly, we expect a rapid increase of users and more foreign collaboration.

5. Summary

The Pohang Light Source was constructed during 1988–1994 with joint support from POSCO and the Korean government. It was opened to users in September 1995 and is now under normal operation with a total of 4600 h, of which 3500 h were allocated to users in 1997. The machine availability to users is about 95%. There are machine shutdowns twice a year, in the winter and the summer, for preventive maintenance and beamline installation. Six beamlines are completed and five are now under construction. The number of users and beamlines is increasing rapidly, and one may expect 40 beamlines and more than 1500 users in ten years.

Table 8
Research proposals for experiments.

	1995 (second half)	1996	1997 (first half)
Proposals applied	58	124	88
Proposals approved	53	93	64
Experiments performed	28	69	60

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