THE OPERATION STATUS OF HLS (HEFEI LIGHT SOURCE) *

Weimin Li, Hongliang Xu, Lin Wang, Guangyao Feng, Shancai Zhang, Zuping Liu, Junhua Wang, Baogen Sun, Ke Xuan, NSRL of USTC, P.R.China

Abstract

HLS (Hefei Light Source) is a dedicated synchrotron radiation research facility, spectrally strongest in VUV and soft X-ray, designed and constructed in 1980's, accepted to regular service in 1991. From 1999 to 2004, the National Synchrotron Radiation Laboratory carried out Phase II Project, in which quite a few sub-systems in HLS were upgraded and 8 new beamlines were constructed. After Phase II Project, the operation reliability and performance of HLS is improved considerably, for example, the operation beam current is above 250 mA, beam lifetime is longer than 8 hours, orbit stability met the requirement of users, and fault time of machine operation is much less than before. The capability of HLS to serve synchrotron radiation users is enhanced significantly. The main tasks of machine study in HLS are introduced briefly.

INTRODUCTION

HLS (Hefei Light Source) is a dedicated synchrotron radiation research facility, spectrally strongest in VUV and soft X-ray, designed and constructed in 1980's, accepted to regular service in 1991. From 1999 to the end of 2004, the Phase II Project was carried out, whose main purpose is to improve reliability and performance of HLS and to enhance its utilization efficiency. During the project, some sub-systems were upgraded and more photon beamlines were constructed. At present, two insertion devices are operational at HLS, one being a super conducting wavelength shifter and the other planar undulator, and 16 beamlines are service, with available photon energies ranging from Far Infrared to hard X-ray. In these two years, HLS provided hundreds of users, coming from China mainland and other countries or areas as well, with synchrotron radiation with good quality and stability, which is well above the requirements set by the goals of the Phase II Project. The goals are, for example, operation time per year more than 6000 hrs, user time per year more than 4000 hrs, fault time less than 420 hrs per year, beam current at each fill higher than 250mA, beam lifetime longer than 8 hrs, integrated beam intensity per year more than 600 A·hrs, and slow orbit drifts less than 100μm [1].

MAIN PARAMETERS

HLS is a second generation synchrotron radiation light source, whose operation energy is 800MeV. Due to financial limitation, low injection energy was adopted, and the injector of the ring is a 200MeV linac. For present, it became a main obstacle to higher stored beam current due to severe collective effects under low energy. The maximum achievable stored beam current in machine study shift is about 410mA, in regular operation, beam current is between 250 and 300mA. The emittance of current adopted optics is similar to these of other second generation light sources in the world, which is relatively large. To improve beam lifetime, transverse coupling of ring was increased to ~0.1 by two skew quadrupoles. Two insertion devices are used in the ring, i.e., a single period superconducting wavelength shifter with peak field 6T and a VUV undulator, while most users utilize dipole radiation. Table 1 gives main parameters of the linac at HLS, and table 2 gives main parameters of the storage ring, including characteristics of dipole radiation, undulator radiation, and wavelength shifter radiation.

Table 1: Main parameters of the linac

Maximum achieved energy	~220MeV
Length of macro pulse	0.2~1.0μs
Energy spread	~1%
Emittance	~0.5 π mm· mrad
Microwave frequency	2856MHz
Type of accelerating structure	Constant-impedance
Maximum electric field	~12MV/m
Total length of accelerating tube	~35m

Table2: Main parameters of the storage ring

Injection/operation energy	200/800MeV
Circumference	~66m
Focusing type	4×TBA
Emittance(horizontal/vertical)	~160/16nm·rad
Harmonic number	45
Radiation loss per turn	16.3keV
Radiation damping time	20/20/10ms
Betatron tunes	3.54/2.60
Operation beam current	250~300mA
Beam lifetime	>8 hrs
Critical wavelength of dipole radiation	2.4nm
Critical/Usable wavelength of WLS	0.48/0.1nm
Number of VUV undulator period	29
K range of VUV undulator	3.9~0.5
Period length of VUV undulator	0.092m
Wavelength of first harmonic	160~21nm

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#lwm@ustc.edu.cn

OPERATION STATUS

From regular service in 1992 up to the present, HLS has been operational for 15 years. Figure 1 gives the histogram of operation statistics in these years. It is clearly that, after phase II project, the operation time and user time are more than those in other years. In 2005 and 2006, operation time per year is about 7000 hrs, and the user time is about 5000 hrs. Effective operation time, including user time and machine study time, is approximately 90% of operation time. The operation efficiency is boosted by the improvement of hardware reliability.

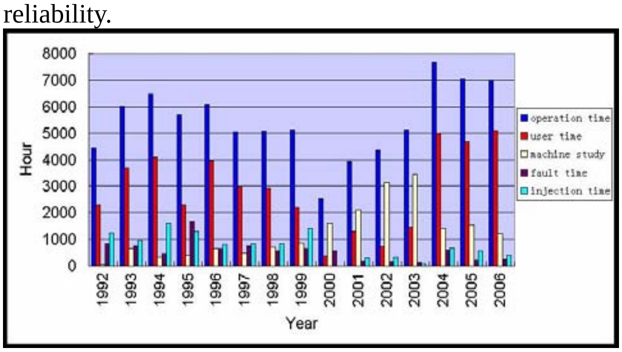

Figure 1: Histogram of operation status.

The reasons resulting in operation failure were recorded and summarized. Figure 2 gives the statistics of failure cases in 2005 and 2006. The fault time in 2006 is more than that in 2005. It is obvious that, some systems with high power, such as power supplies of main magnets, RF generator, klystrons and modulators, were main sources of machine failure. It was felt that, reliable standby hardware is important to stable and efficient operation.

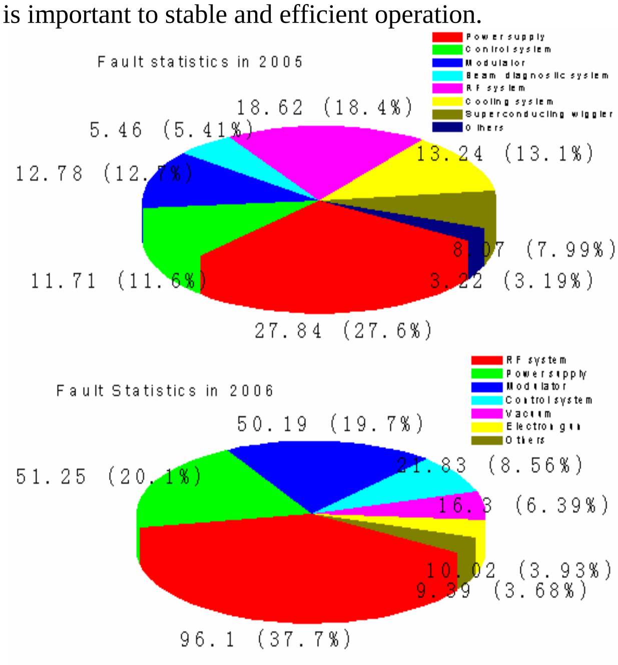

Figure 2: PIE graph of fault statistics in 2005 and 2006.

In normal operation, stored beam current is dependent on performance of the linac and RF system, including RF cavity temperature and low-level circuit. Usually, stored beam current at each shift is between 250 and 300 mA. Figure 3 gives typical beam current and lifetime curves in the operation log during two weeks.

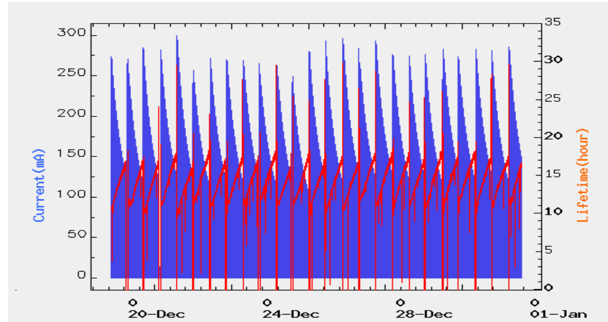

Figure 3: Beam current and lifetime curves in operation.

The requirement on orbit stability in phase II project is that the stability is not larger than 100μm. In 2006, slow orbit feedback system was employed and vertical slow orbit shifts were reduced within 25μm. In the place of insertion devices, horizontal orbit shifts were also smaller than 0.1 σ_x. Most synchrotron radiation users at HLS are satisfied with the orbit stability. Figure 4 gives typical vertical orbit shifts in operation log during two weeks.

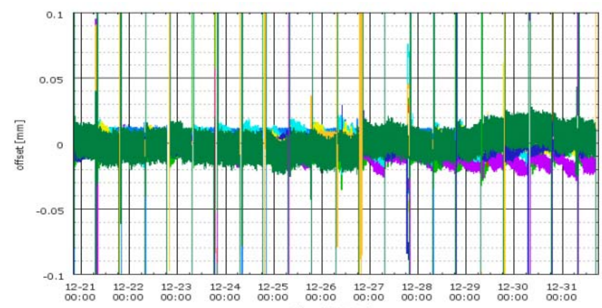

Figure 4: Vertical orbits at BPM during two weeks.

Table 3: Performance parameters of HLS

	2005	2006
Operation time (hr)	7039.53	6983.90
User time (hr)	4688.14	5092.72
Fault time (hr)	215.40	255.08
Beam current (mA)	~ 250	~ 250
Beam lifetime (hrs)	> 8	> 8
Integral current (A·hrs)	792.86	882.48
Orbit stability(μm)	~ 100	~25

With efforts from the operation group and machine maintenance personnel, injection time in operation was decreased. Due to aging of some hardware, machine fault time in 2006 is more than those in 2005, but still at an acceptable level. Table 3 shows the main performance of HLS in 2005 and 2006. In 2006, user time and integrated beam current are more than those in 2005. After upgrade of phase II project, the operation status, reliability and performance of HLS are improved considerably, and more beamlines are opened to users than before.

MAIN TASKS OF MACHINE STUDIES

In these two years, some machine studies were carried out at HLS for improving performance of the light source or testing new systems and techniques.

A special photon beam line for machine study was constructed. Three functions are being realized in this beam line. First, dipole radiation was transferred to a streak camera for studying beam dynamics. Second, SR was transferred to Photon Beam Position Monitor to observe beam orbit stability. Finally, at the end-station, SR desorption properties of various vacuum materials will be studied.

A turn-by-turn and a bunch-by-bunch beam diagnostic system were both established and some experiments were fulfilled. The turn-by-turn system was used in commissioning of injection system. Also, the horizontal damping process was measured by this system. Figure 5 gives the measurement results, which showed that, horizontal damping in the ring is quicker than pure radiation damping, thanks to horizontal tune spread. Lacking of vertical kicker, the vertical damping process was not measured yet. The bunch-by-bunch beam position monitor system would provide information of beam motion for a multi-bunch transverse feedback system, which is under testing. In the preliminary experiments, horizontal beam oscillation was suppressed by the feedback system, and better working conditions should be found for increasing stored beam current. Table 4 gives main parameters of the transverse feedback system.

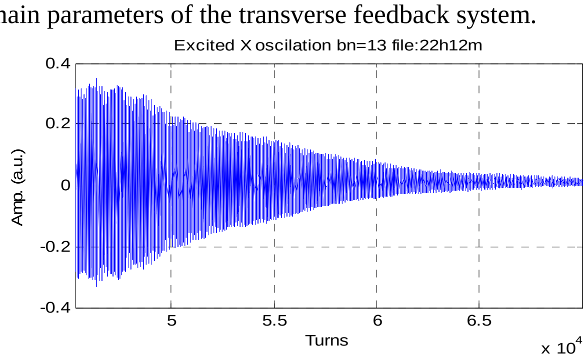

Figure 5: Horizontal damping process in HLS.

Table 4: Parameters of the transverse feedback system

Work frequency	612MHz
System bandwidth	102MHz
Adjustable precision in time	10ps
Adjustable precision/ range in phase	0.09°/≥ 360°
Dynamic range	≥ 35dB
Local oscillator	≥ 7dBm
Feedback power	≤ 100W
Feedback damping time	≤ 44μs

The LOCO [2] method developed by SLAC was employed to calibrate linear focusing model of ring and optics correction was made according to the fitting results. Figure 6 gives the calculated betatron functions based on the fitting quadrupole strengths.

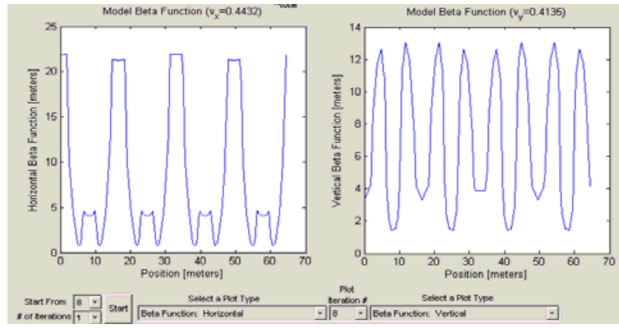

Figure 6: β functions of current operation mode of HLS.

To enhance light source brilliance, more efforts have been made to decrease beam emittance. Considering beam lifetime requirements from users, a lattice with medium emittance was tested. To overcome difficulty of injection, the betatron tunes of the new lattice are same with those of current operation mode. So the quadrupole strengths can be tuned to new values smoothly after beam energy ramping. The emittance of the new lattice is about 80nm·rad. Figure 7 describes the tentative operation of the new lattice in one machine study shift. The differential beam lifetime at 250mA is about 6hrs, which met the requirements of users. After orbit correction, orbit is close to the so called golden orbit. This lattice would be helpful to enhance brilliance of dipole radiation and will be put into regular operation in the near future.

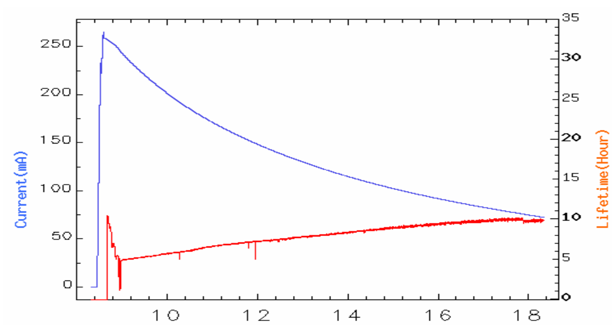

Figure 7: Beam current and lifetime curves of new mode.

We are grateful to the operation group for their work to keep stable operation of HLS.

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