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NSRL Phase II Project (a Brief Introduction and Status)

Zuping Liu* and Xinyi Zhang

National Synchrotron Radiation Laboratory, University of Science and Technology of China, Hefei, Anhui 230029, People's Republic of China. E-mail: zpliu@mail.nsrl.ustc.edu.cn

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The Phase II Project is to be launched soon at NSRL, People's Republic of China. The main purpose of the project, an outline of its upgrade/expansion plans, and its present status are briefly described.

Keywords: NSRL.

1. Introduction

The National Synchrotron Radiation Laboratory (NSRL), the first dedicated synchrotron radiation facility in China, on the campus of the University of Science and Technology of China (USTC), Hefei, Anhui, has been in regular operation since 1992.

The facility principally consists of an 800 MeV electron storage ring, the Hefei Light Source (HLS), and a 200 MeV linac as an injector. So far, NSRL has equipped five beamlines for synchrotron radiation research. A new beamline will be brought into service in early 1998.

The proposal for a 'Phase II Project' at NSRL was first promoted in 1994, in order to make fuller use of HLS by adding eight more photon beamlines and experimental stations, inserting an undulator in the ring, and enhancing the quality, stability and long-term reliability of the light source. The main aim of the project (NSRL, 1996, 1997) is to meet the increasing requirements of Chinese scientific and technological development, especially at this historic moment, facing the new century.

The NSRL Phase II Project was chosen as an 'important scientific project' in the 'National 9th Five-Year Plan' by the State Council in 1996, and the proposal was formally approved by the National Planning Committee in April 1997. The project is to be launched late in 1997, with a total budget of about 120 million Chinese Yuan (roughly 14 million US dollars).

2. Machine upgrading

HLS, the 800 MeV storage ring of NSRL, has a 66.13 m-long circumference, divided into four quadrants by four 3 m-long straight sections. One of the sections is occupied by the injection system; the others are for the installation of insertion devices. There are 12 bending magnets, 32 quadrupoles powered in four or eight families, and 14 sextupoles of two families in the ring. Every three bends and eight quads make up a TBA-type cell.

The HLS lattice allows different configurations. The GPLS (general purpose light source) is the present operational configuration. The typical stored current is 150–180 mA. With a moderate emittance of 134 nm rad and a typical beam lifetime of 10 h, GPLS serves most users satisfactorily. On the other hand, the goal of upgrading to a high-brightness light source (HBLS) configuration is to provide stronger focusing and a much lower emittance of 27 nm rad, and to produce synchrotron radiation light of much higher brilliance, as shown in Fig. 1.

On the machine side, the goals of the Phase II Project upgrading plans are: (1) Regular operation of GPLS with 300 mA current in every fill, with more than 8 h lifetime. (2) Alternatively, HBLS operation of a 150 mA beam, with a 4 h lifetime. (3) Reduction of unscheduled breakdown time from ~10% to less than 7% of total operation hours and constraint of the 'injection plus machine tuning' time to ~10%. This is to ensure effective synchrotron radiation user time of no less than 70%, or usually greater than

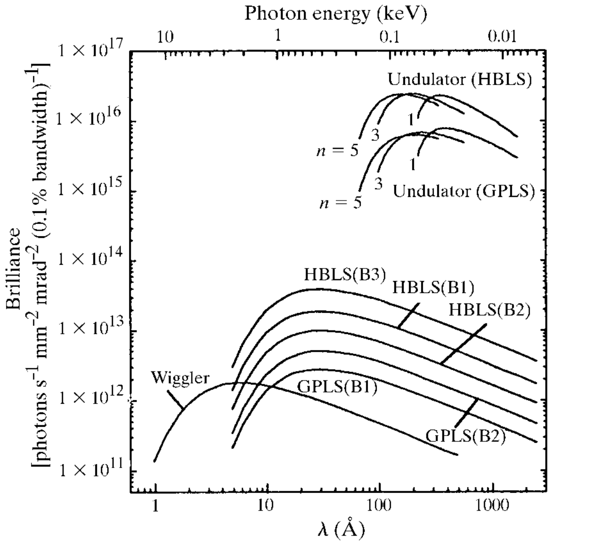

Figure 1
Brilliance curves of synchrotron radiation from HLS (after the Phase II Project).

Table 1
Details of the present NSRL beamlines.

Station	Beam number	Monochromator	Wavelength range	Light spot size (H × V)
Photoelectron spectroscopy	U20	SGM	10–1200 Å	3 × 1 mm
X-ray lithography	U1	White light	4–20 Å	30 × 30 mm (scanning)
Soft X-ray microscopy	U12A	Zone-plate linear monochromator	20–54 Å	Pinhole size
Time-resolved spectroscopy	U10B	Seya–Namioka	350–8000 Å	3 × 0.3 mm
Photochemistry	U10A	Seya–Namioka	350–6000 Å	3 × 1 mm

4000 h per year, and an annually integrated beam intensity of 600 A h, *i.e.* a doubling of the beam intensity available to the present users. (4) Maintenance of the vertical drift of the light source point for individual synchrotron radiation stations to within 30 μm.

To realize HBLS, which is technically more demanding, it is planned to reconstruct the injection system of the ring, *i.e.* using thyratron-type pulsed-current power supplies instead of the old gap-switch triggers, and to install four ferrite kickers in one long straight to produce a lattice-independent well shaped orbit bump. The removal of the air-coil kickers will give room for two additional sextupoles to save the superperiodicity and multiple symmetry of the sextupole configuration. As calculations have proved, such an improvement will enlarge the dynamic aperture of the ring significantly. The r.f. cavity also has to be rebuilt to provide a higher r.f. voltage for a sufficient Touschek lifetime.

An r.f. knock-out system was successfully tested in 1996, and is able to fill the ring in different bunch patterns. For example, the single-bunch-mode pattern extends the gaps between the electron bunches to better suit time-resolved synchrotron radiation experiments. With the r.f. knock-out system we can fill the ring unequally to overcome multi-bunch instabilities and achieve higher beam intensity. This system will be put into service. The new r.f. cavity, along with a circulator inserted in the coaxial feeding tubes, will also contribute to regular higher current operation, while new NEG pumps, added to the ring's vacuum system, will aid in lengthening the lifetime of the beam.

Other accelerator upgrading plans in the project involve mainly the power supplies of the magnets (which are now responsible for about a third of the failure time, while the r.f. system and the injection system are the next two largest sources of problems), the control system and the beam diagnostics system.

3. Insertion devices

NSRL will soon deliver synchrotron radiation light from two insertion devices: a wavelength shifter (WLS) and a transverse optical klystron (TOK).

The 6 T single-period superconducting WLS will produce synchrotron radiation with a characteristic wavelength down to 4.8 Å to expand the applicability of the facility for the benefit of hard X-ray users. The WLS has passed a series of off-line tests satisfactorily. It will be mounted in the ring (sharing a long straight section with the r.f. cavity) in the next winter shutdown.

The TOK permanent magnet was conceived for free-electron laser experiments. Its commissioning is underway. The radiation expected is coherent ultraviolet, a high harmonic of its firing YAG laser.

For the Phase II Project, a 29-period NdFeB permanent-magnet undulator is being designed. With the magnet gap adjusted from 96 to 36 mm and the K values varying from 0.5 to 3.9, the radiation from the undulator ranges spectrally from 210 to 1620 Å for the fundamental and from 100 to 540 Å for the third harmonic, with the brilliance about three orders of magnitude higher than that of bending-magnet-generated synchrotron radiation.

4. Expansion of beamlines

At present, five beamlines are available to users at NSRL, all derived from bending magnets. Their details are summarized in Table 1.

The newly built XAFS station and its beamline, U7C, have been manufactured, assembled and evacuated in the

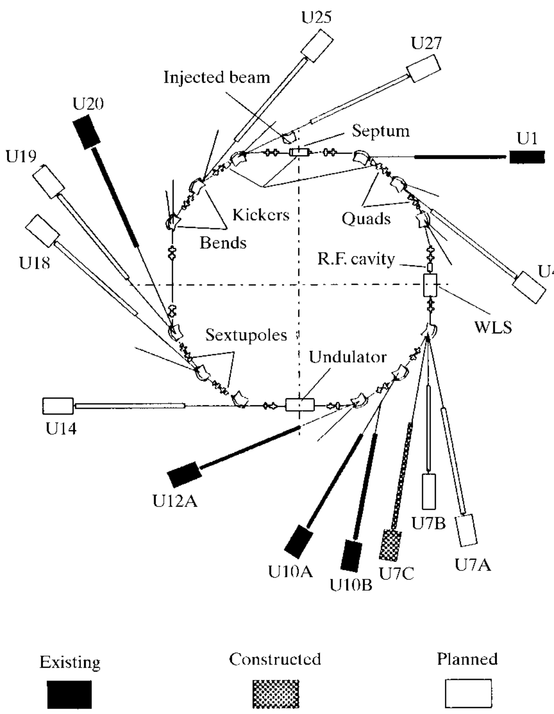

Figure 2
Beamlines and insertion devices at NSRL.

Table 2
Details of the planned NSRL beamlines.

Station	Beam number	Monochromator	Wavelength range	Light spot size (H × V)	Description
Surface physics	U19	PGM	60–1200 Å	3 × 1 mm	Emphasis on angle-resolved photoemission. *In situ* sample preparation, electronic structure study and atomic structure study on the same contamination-free surface.
X-ray diffraction and scattering	U7B	DCM	1–3 Å	1 × 0.5 mm	Uses X-rays from the WLS. High-resolution X-ray powder diffraction, multiwavelength anomalous scattering and single-crystal diffraction, including biological macromolecular crystallography.
LIGA	U7A	White light	2–7 Å	40 × 30 mm scanning	With the WLS radiation, patterning of submicrometer-deep X-ray etching in thick resist layers to obtain microstructure products, made of resist material, nickel or gold. Supported by mask fabrication, electric casting and mold replication.
Atomic and molecular physics	U14	SGM	100–1600 Å	1.5 × 0.5 mm	Illuminated by brilliant synchrotron radiation from the undulator. Studies on ionization and other processes of atoms, molecules, radicals and clusters.
Photoacoustic and photothermal spectroscopy	U25	NIM	1100–3000 Å	3 × 1 mm	Extension of photoacoustic and photothermal spectroscopy to vacuum ultraviolet, to study non-radiative transition processes of various materials.
Infrared and far-infrared spectroscopy	U4	IR FT	1–1000 μm	∅ ~25 mm	Following the new trend of synchrotron radiation applications in infrared. Efforts towards discoveries of spectral structures and designs of functional devices.
Soft X-ray magnetic circular dichroism	U18	VLSG	12–120 Å	3 × 1 mm	Extending the magneto-optic Faraday and Kerr effects to soft X-ray studies on the magnetic properties of ultra-thin films and multilayers.
Metrology and spectral radiation standard	U27	SGM/Seya	50–6000 Å	5 × 1 mm	Setting the national radiation standard, which covers a wide spectral band, from the visible all the way down to soft X-rays. Capability of authoritative measurements or calibrations for light sources, detectors, optical devices and materials.

ring hall, waiting for the WLS to start its service. Eight new beamlines and stations will be ready for synchrotron radiation users as the Phase II Project is fulfilled. The layout of the HLS ring and all the beamlines, either existing, constructed or being planned, is shown in Fig. 2. Brief descriptions of the eight new beamlines are given in Table 2.

5. Organization and status

The NSRL Phase II Project is the responsibility of its ‘headquarters’ team, led by the Project Director, Professor Zuping Liu, and the Vice Director, Professor Xinyi Zhang, under the supervision of the Chinese Academy of Sciences (CAS). Professor X. Zhang is also the Director of NSRL and a vice president of USTC.

Other members of the headquarters team include: Professors Weimin Li and Liusi Sheng, who are coordinating machine upgrading and experimental station construction, respectively; Professor Qiuping Wang, in charge of beamline construction; and Professor Shengsheng Hu, responsible for financial and administrative affairs.

According to China’s regulations for large-scale projects, NSRL has just submitted a detailed Feasibility Study Report to the National Planning Committee. The next step is a review of all the design work during autumn 1997, after which the funding will become available.

NSRL scientists and engineers are now making and examining designs of the machine upgrades, new stations and beamlines, as well as improvements in conventional utilities, and discussing them with worldwide experts. Prototype tests and machine studies are being carried out. Cooperation with other scientific institutes is ongoing as an essential factor towards the success of the project.

As scheduled, NSRL Phase II Project will be completed by the end of the year 2000.

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