STATUS OF KSRS

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1 INTRODUCTION

Kurchatov Synchrotron Radiation Source (KSRS) is a first dedicated synchrotron radiation facility in Russia. It was designed by Budker Institute of Nuclear Physics (BINP) [1]. The facility includes two storage rings: 450 MeV SIBERIA-1 and 2.5 GeV SIBERIA-2 and is intended for experiments in the 0.1-2000 Å range of SR wavelengths.

Large progress was achieved in increasing SIBERIA-2 stored current during last year. Now maximum current at injection energy is 129 mA in multi-bunch mode and 59 mA in single-bunch mode. Maximum current at 2.5 GeV is 72 mA, it is restricted by RF power available now. Outgassing of vaccuum chamber by SR is going on in order to increase beam lifetime.

First part of SR beamline from bending magnet was installed outside biological shielding in reconstructed experimental hall. We plan to install four beamlines and start regular experiments with hard X-rays at the beginning of the next year. SIBERIA-1 also has experimental hall with three beamlines and three experimental stations ready for experiments.

2 SIBERIA-1

2.1 Machine operation

The SIBERIA-1 storage ring is possible to provide 30 second cycle of injection to SIBERIA-2 with 120 - 140 mA current (circumference of the ring is 8.68 m). During last year we reduced ramping time in SIBERIA-1 from 20 sec down to 7 sec. This fact gave a possibility to make injection process more fast and stable. Ramping time is limited by the maximum tuning speed of RF cavity. Both beam extraction and beam injection are done in the vertical plane. The rms pulse duration of the extracted beam is σ_S = 1 nsec, natural horizontal and vertical emittances are $8.6\cdot10^{-7}$ m·rad and $8.6\cdot10^{-9}$ m·rad with rms energy spread of $3.9\cdot10^{-4}$. SIBERIA-1 operates only in single-bunch mode. Maximum stored current is 230 mA at injection energy 75-80 MeV, ramped current achieved 210 mA. Relatively short beam lifetime is a problem now.

2.2 Experimental stations

SIBERIA-1 has separate 300 m^2 experimental hall. Three beamlines are available to transfer synchrotron radiation with critical energy 200 eV from bending magnet to experimental stations. All stations are in last stage of commissioning and were tested by SR beam. List of experimental stations one can see in Table 1.

Table 1: SIBERIA-1 experimental stations

Experimental station	**Institution**
Photoelectron spectroscopy	Institute of Superconductivity and Solid State Physics (ISSSP), Moscow
VUV luminescense spectrometer	Moscow State University
Universal VUV spectrometer	KSRS; St.Peterburg State University

3 SIBERIA-2

3.1 Magnetic structure

SIBERIA-2 has magnetic structure of modified DBA type. It is optimized to obtain intensive spectral flux and to reach high spectral brightness of SR from radiation points situated both in bending magnets and in insertion devices. Optical functions of SIBERIA-2 lattice are shown in Fig. 1. Basic parameters one can find in [1, 2].

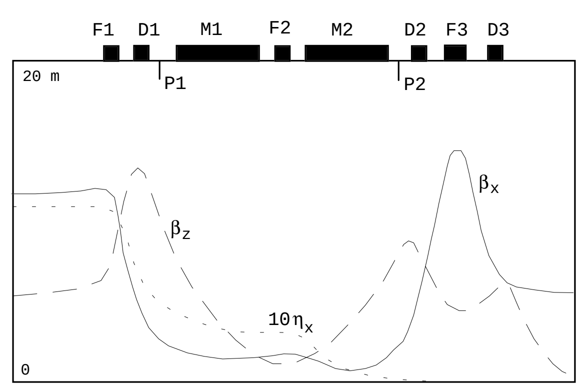

Figure 1. SIBERIA-2 optical functions at one half of cell.

Normally SIBERIA-2 operates with betatron tunes Q_x=7.775 and Q_z=6.695. Nearest dangerous resonances in this case are sum resonances of 4th order: $2Q_x+2Q_z$= 29 and $3Q_x+Q_z=30$. To keep the initial values of betatron tunes after long stop or after high energy run we use special magnetization loop of main magnetic elements [3].

3.2 Injection

Electrons are injected to SIBERIA-2 in horizontal plane during one turn. Injection system includes two fast kickers and one septum magnet. Septum is situated in straight section with non-zero dispersion, kickers are introduced inside vacuum chamber of F2 lens (see Figure 1). DBA lattice provides 180^0 phase advance between kickers, so they create 1 cm compensated orbit bump near the septum. RF harmonic number is equal to 75, and only one of 75 separatrix can be filled during one injection cycle. Typically 5-6 mA is added to SIBERIA-2 current after each cycle of injection. Injection efficiency, that is number of stored electrons divided by number of extracted ones from SIBERIA-1, depends on RF voltage. It equals 90% when U_{rf} is below 70 kV and slowly decreases with U_{rf} growing. Such a behavior corresponds to energy aperture of approximately 1%. Kicker pulse duration is more than 15 nsec at half-level, minimum distance between bunches is 5.5 nsec. In spite of this fact injection to neighbouring bunches with high efficiency is possible because of high stability of kicker pulses in time (rms deviations are near to 1 nsec). It was found that maximum current in multi-bunch and single-bunch modes is not restricted by injection system operation.

3.3 Single-bunch mode

We achieved 59 mA in single-bunch mode at injection energy. Above 40 mA longitudinal instability was observed by phase dissector. This instability leads to lifetime shortening and saturation of stored current. Maximum current value depends on RF generator tuning. We also observed strong lengthening of bunch with current (see Figure 2).

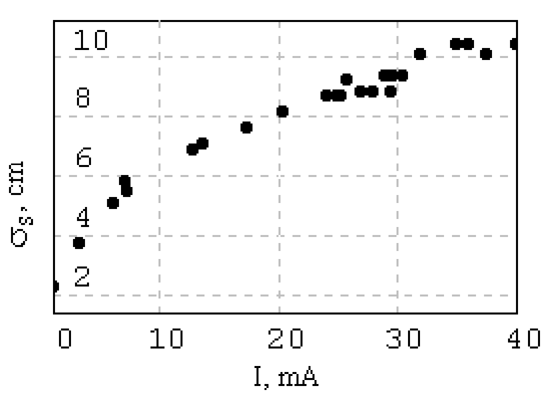

Figure 2. Dependence of longitudinal rms beam size on electron current in single-bunch mode.

The behavior of bunch length corresponds to longitudinal coupling impedance of vacuum chamber walls equal to approximately 10 Ohm. It may be caused by imperfections of vacuum chamber.

3.4 Multi-bunch mode

Maximum current stored in multi-bunch mode now equals to 129 mA. Every bunch contains 5-6 mA, number of bunches can reach 30 - 40. At present it takes near 20 minutes to store 125 mA, so first bunches have a time to lose 40 - 50 % of electrons. Maximum current is limited by coherent longitudinal instabilities of many bunches observed by dissector. A threshold of instability appearing depends on RF voltage. For example, we can store 60 - 70 mA with U_{rf} = 100 kV, but 120 mA needs 190 -200 kV. Below 100 mA appeared instability can be damped by raising U_{rf}. Above 100 mA the instability can lead to increasing of beam size and finally to sharp beam losses.

3.5 Energy ramping

A time duration of energy ramping was reduced from 6 minutes down to 2 minutes 40 seconds during last year. Now maximum ramping speed is 22 MeV/sec. Ramping procedure is rather complicated and includes 9 intermediate levels of energy that can be tuned separately [3]. The main problem is to keep betatron tune shifts under acceptable values during ramping. Nearest betatron resonances (see Section 3.1) are very dangerous below 0.9 GeV and can cause beam losses. There is no any losses due to this reason above 1 GeV. Betatron tunes are measured by resonance excitation of beam by special coil. Typical betatron tune shifts during ramping are shown in Figure 3.

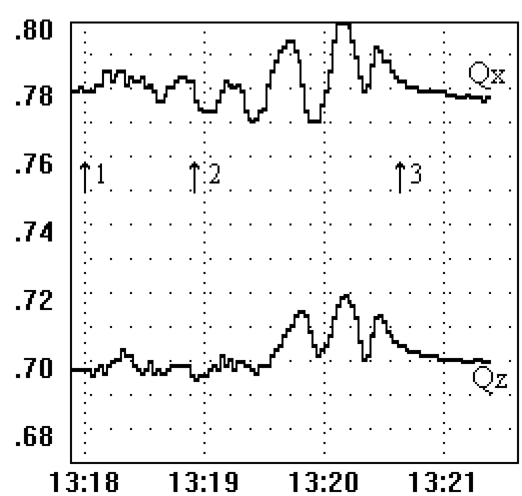

Figure 3. Typical betatron tune shifts during energy ramping. 1 - start at 0.45 GeV, 2 - 1 GeV, 3 - finish at 2.5 GeV.

Ramping efficiency is usually equal to 85-90%. Most part of losses is caused by short beam lifetime at the energies below 1 GeV. Maximum current registered at 2.5 GeV was 72 mA in multi-bunch mode starting from 83 mA at injection energy. Efficiency of ramping depends of bunch behavior. If longitudinal instability (see above) takes place the efficiency is decreased rapidly. For example, we could not accelerate more than 20 mA in single-bunch mode due to this fact.

Maximum value of accelerated current is restricted by RF power available now. The RF system of SIBERIA-2 includes two accelerating cavities, two waveguides and two RF generators operating at 181.14 MHz. At present one RF generator and one RF cavity are in operation. Routine work is done with 1.2 MV at 2.5 GeV. The second RF cavity is also tested and installed on the ring. Commissioning of second RF generator is planned during July 1998. We hope to achieve 100 mA before the end of 1998 and then design value of 300 mA after tuning of RF system.

3.6 Lifetime

Electron beam lifetime depends mainly on vacuum conditions. Vacuum level is equal to 10^{-9} Torr with 1 mA beam, but it increases by almost two order of magnitude with 50-60 mA beam. We need to continue outgassing of vacuum chamber by SR beam in order to improve vacuum conditions and lifetime. We achieved 3.4 A·hours of current integral at 2.5 GeV up to now. Lifetime reached 1 hour at 50 mA and 2.5 hours at 10 mA with equal number of bunches.

At injection energy lifetime is much less and depends on bunch-to-bunch interaction. For example, one 5 mA bunch has lifetime of 35 minutes, but for more than 5 bunches lifetime is almost independent on current and equals to 22-25 minutes.

Calculations of Touchek lifetime show that it should have a minimum at 0.7-0.8 GeV. We observed it during energy ramping.

3.7 Closed orbit and chromaticity

Operation at designed revolution frequency f_0 = 2.41519 MHz provides maximum injection efficiency and decreases a number of correction magnets (8 - x steering magnets and 5- z ones) used for closed orbit correction. Maximum CODs are equal to 2 mm in horizontal direction and 1 mm in vertical direction at injection energy. These figures are slightly more at 2.5 GeV. Usual linear methods are available to correct closed orbit (LSQ, MICADO, SVD). Only calculated response matrix for correctors was used.

Coupling factor measurement after vertical orbit correction gave K = 0.02.

For natural chromaticity compensation we used two families of sextupole lenses located inside achromatic bend. Harmonic sextupoles were not switched on. In recent time we work at $\xi_x = \xi_z = +0.7$. We observed strong second order chromaticity in both horizontal and vertical planes of electron motion.

3.8 Beamlines and experimental stations

First experiments using SR with critical energy 7 keV from SIBERIA-2 were started in 1996. They were produced at short test beamline inside biological shielding. Now SIBERIA-2 has almost furnished 1200 m^2 experimental hall. It is a possibility to install experimental stations in it. Four beamlines are already produced and their installing was started. Two front-ends are installed and tested by SR beam at 2.5 GeV. SR beam was transmitted to new experimental hall for the first time in spring 1998. Five experimental stations are ready to be placed to experimental hall and to start their work immediately after installing appropriate beamlines. We plan to install four beamlines with five experimental stations (see Table 2) and start test experiments at the beginning of 1999.

Table 2: SIBERIA-2 experimental stations

Experimental station	**Institution**
X-ray emission line chemical shifts	KSRS, Institute of Physics, Czech Academy of Science
X-ray photoelectron diffraction spectrometer	Institute of Cristallography, Moscow
Medical station	KSRS; ISSSP; INR
Deep X-ray lithography station	KSRS, Institute of Microtechnology, Mainz
EXAFS spectrometer	JINR, Dubna, Russia

4 REFERENCES

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[2] V.N.Korchuganov et al. The EPAC’96 Proceedings, Sitges, Spain, 1996. Vol.1., p.608.

[3] V.N.Korhuganov et al., The EPAC’96 Proceedings, Sitges, Spain, 1996, Vol.2, p.1426.