OPERATION AND PLANS ON THE ACCELERATOR COMPLEX IN KURCHATOV CENTER OF SYNCHROTRON RADIATION

V.Korchuganov (BINP, Novosibirsk; RRC Kurchatov Institute, Moscow), M.Blokhov, M.Kovalchuk, Yu.Krylov, V.Kvardakov, L.Moseiko, N.Moseiko, V.Novikov, S.Zheludeva, D.Odintsov, V.Rezvov, V.Ushkov, A.Valentinov, A.Vernov, L.Yudin, Yu.Yupinov (RRC Kurchatov Institute, Moscow)

Abstract

Kurchatov Synchrotron Radiation Source began the work as a first dedicated synchrotron radiation facility in Russia in 1999. The accelerator complex includes 80 MeV linac accelerator as an injector and two storage rings: 450 MeV SIBERIA-1 and 2.5 GeV SIBERIA-2, which are used for the experiments in the range of SR from VUV up to hard X-ray. Large progress was achieved in increasing SIBERIA-2 stored current during last year. The SR dose is rising fast and the lifetime is also grown. The report describes the current work and the plans on the accelerator facilities development.

INTRODUCTION

At present, the Kurchatov SR source operates close to the design parameters. Table 1 presents the main features of the acting optical structure of the storage rings Siberia-1 and Siberia-2.

Table 1: Main parameters of Siberia-1 and Siberia-2 rings

Parameter	**Siberia-2**	**Siberia-1**
Energy	2.5 GeV	0.45 GeV
Circumference	124.13 m	8.68 m
Optical structure	Modified DBA	FODO
Superperiods	6	1
Bet. tunes: ν_x, ν_y	7.772; 6.692	0.793; 0.895
Mom.compaction	0.0104	1.64
Damping *x ,y, s, ms*	3.04; 3.17; 1.49	7.15; 7.15; 3.57
Hor. emittance	78-98 nm-rad	880 nm-rad
RF harmonic	75	1
Energy spread	0.000953	0.00034
Dipole field: B_y	1.7 T	1.5 T
ID space	2x3m($\eta = 0$) 5x3.2m($\eta \neq 0$)	-
Bunch length: σ_s (without IDs)	1.84 cm	30 cm
SR pulse duration	0.14 ns FWHM	2.35 ns FWHM
SR pulse spacing	5.5-414 ns	28.9 ns
Current	100-150 mA (multibunch)	100-300 mA (single bunch)
Life time (100 mA, coupling 1%), hrs	10-14 (multibunch)	1.5 (single bunch)

WORK WITH ELECTRON BEAM

Electron storage

As rule the work on Siberia-2 SR goes in the multi-bunch regime with a current of 100-120 mA by filling of 1/2 to 1/3 of the ring (25 to 37 bunches).

The synchrotron oscillations collective modes appear after injection of first four or five bunches. Nevertheless we have realized that it is possible to store the electrons in all 75 bunches without specially made empty gap widely used to prevent ion trapping (see Fig.1a).

The energy ramping of the electrons with current in many bunches exceeding 150 mA is characterized by both big synchrotron motion in coherent modes and losses of the beam part. The losses depend on the number of bunches and modulate the particles numbers in bunches correspondingly with the synchrotron mode number (see Fig.1b).

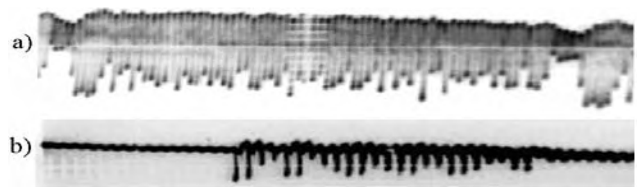

Figure 1a: The typical picture of the filling at the injection. Figure1b: The modulation due to collective mode instability losses during an energy ramping.

In single bunch mode the storage is accompanied by the bunch lengthening and microwave instability leading to the increasing of energy spread. In result the enlargement of the bunch was stopping the storage near 72 mA due to the losses of the particles as a consequence of the energy acceptance limitation. The maximum single bunch current accelerated up to 2.5 GeV was about 30-35 mA and was again limited by the coherent synchrotron oscillations, which are strong when ramping the energy within 0.45-1 GeV.

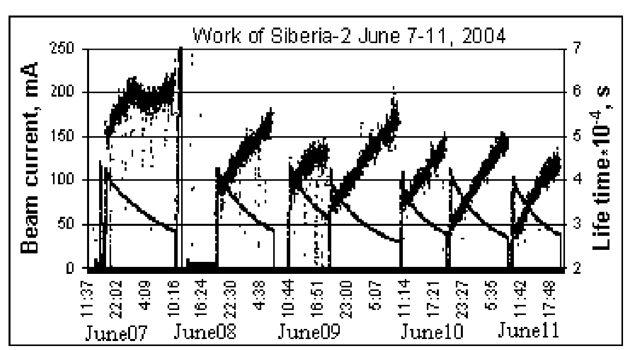

Figure 2: Work of Siberia-2 in June 7-11, 2004

During routine operation on SR experiments the electron storage and acceleration regimes are reproduced in a stable way. Figure 2 shows the dependence of the beam current and the lifetime versus the time at 2.5 GeV during the runs in June 07-11, 2004. Now the maximum currents achieved are: 300 mA (450 MeV) for Siberia-1 in a single bunch mode; 270 mA (450 MeV) and 150 mA (2.5 GeV) for Siberia-2 in multibunch mode.

Vacuum

During last year the vacuum system of Siberia-2 was opened twice. In May 27, 2003, aluminium vacuum chamber in one of the BMs was replaced on new one in order to remove a vertical cutting of the SR beam. Next opening was made in February 2004 in order to change the vacuum insulator of the inflector. In both cases the vacuum chamber was degassed with an SR beam during two week without warming it up.

With the increasing of the electron current the serious problem became. It was so called “hot” points arisen inside Siberia-2 vacuum tube due to SR parasite hit, which damaged the vacuum and the lifetime. Five such “hot” points with the sizes about 1-2 mm^2 were found and three of them were removed. As a result the vacuum condition was sharply improved and the lifetime was increased in a factor 2. After the spray of the titanium films in the magneto-discharge pumps around the ring the lifetime has exceeded 14 hours at 100 mA in the beginning of the week. But some degradation of the lifetime is observed to the end of the week run, perhaps due to both the gas loading from the working photon SR beam lines and some titanium films saturation (see Fig.2).

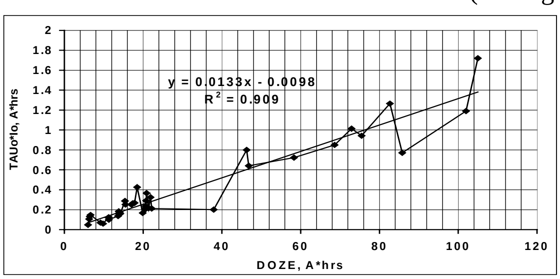

Figure 3: Dependence of the beam current and the lifetime product on the collected doze at 2.5 GeV

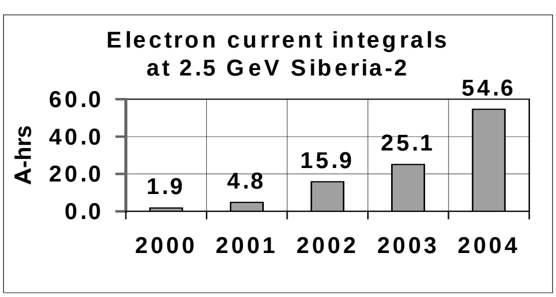

Figure 4: Annual dozes at Siberia-2

Till now the lifetime is generally defined by the SR stimulated gas desorption. In fact Fig. 3 represents near linear behaviour of the product of an electron beam current and a life time versus total SR doze collected by the vacuum chamber from the beginning of work. Intensity of works with SR increased in 2004. As a result a total integral of current overcame 100 A*h on June 8, 2004 and the doze of one half of 2004 is more than summarized doze of the 2000-2003 years (see Fig.4).

COD CORRECTION AT SIBERIA-2

Electron closed orbit distortion (COD) is measured by 24 pick-up stations with 10 micron accuracy at SIBERIA-2 storage ring. Correction system allows to achieve standard values of COD (at azimuths of BPMs) which are close to σ_z = 0.2 mm and σ_x = 0.7 mm. To find COD at the 72 quadrupole lenses azimuths we also use the method of their gradient changes with the correction coils existing on quadrupole lenses poles. From this method the transversal relative distances between neighboring BPMs and quadrupole lenses centers are found and taken into account to improve COD control.

PHOTON BEAMS STABILIZATION

The photon beams of Siberia-2 move vertically due to the temperature change of the magnets and supports with a time constant ~ 20 hrs. Total vertical displacement during 5-days operation at 2.5 GeV was reaching 2-3 mm at a distance 15-20 m. Oppositely the elements and the photon beams are coming back into initial positions after 2-days operation break. Now the feed-back system was made on two SR beam lines to correct SR beam position. It includes luminescent screens, TV-cameras, computer code with a space resolution of 2-3 mkm and the control of 3 magnetic correctors, which create the local electron orbit distortion in vertical plane. The turned-on feed-back demonstrates that SR beam drift is damped with a precision of ± 4-5 mkm during long time runs (see Fig.5).

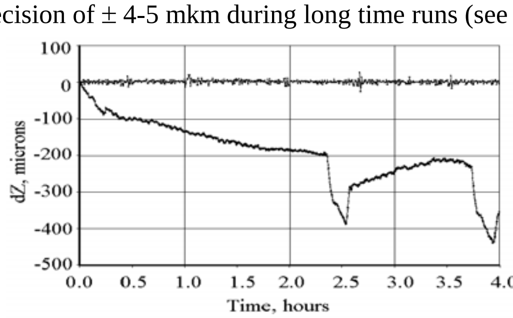

Figure 5: SR beam vertical position at X-ray station with feed-back system turned-on and turned-off

SR BEAMS

The Siberia-2 SR extraction scheme is the same for each of the superperiods [2]. There are 39 SR extraction channels in total. Those include: 24 channels with SR from the bending magnets with the characteristic wavelength λ_c = 1.75 Å and horizontal angles ± 5 mrad; 10 SR channels with λ_c = (0.25-0.4) Å from the two SCMP wigglers; 5 channels from multipole low field wigglers.

The works of SR stations at Siberia-2 are now performed with SR from the bending magnets over the photon energy range of 4 to 40 keV and with (10^{13}-10^{11}) phot/s/0.1%BW fluxes. Usually 7-8 12-hour shifts are scheduled each week for work with the SR beams. Figures 6, 7 shows diagrams of user time during last years dated on June 2004.

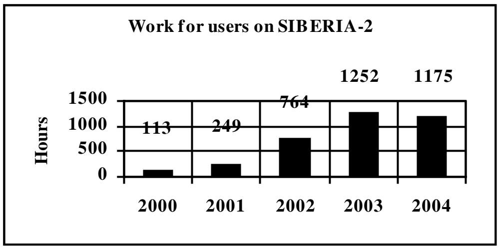

Figure 6: Siberia-2 as SR Source

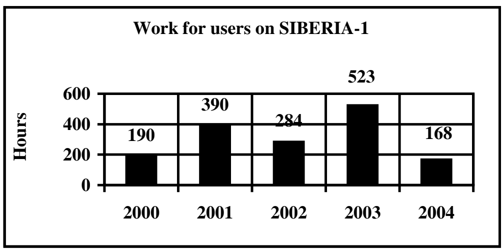

Figure 7: Siberia-1 as SR source

EXPERIMENTAL STATIONS

Nine experimental stations are in operation at the X-ray experimental hall of Siberia-2 [3], which are dedicated for: protein crystallography, precise X-ray optics, X-ray crystallography and material science, medical and industrial diagnostics, LIGA, EXAFS, small angle scattering, time-resolved small-angle diffraction, X-ray luminescence. Three experimental stations are in operation at the VUV experimental hall of Siberia-1 for: photoelectron spectroscopy, VUV luminescence and optical investigations of solids.

The main directions of the scientific program include the structure diagnostics of an atomic level space resolution of organic and inorganic objects; protein crystallography and biotechnology, nanotechnology and nanodiagnostics; material science, X-ray optics, new methods for medical diagnostics, industrial nondestructive control; deep X-ray lithography et cetera.

PLANS ON SIBERIA-2

The main task of future efforts is to increase intensity and lifetime of SR beams in Siberia-2 as well as to decrease the electron beams emittances as a result of work with new magnetic optics of the ring in order to augment SR brightness [2].

Optics with 66 nm-rad Horizontal Emittance

This optics keeps DBA structure. But it has a changed betatron frequencies: ν_x=7.85 ν_y=3.79**.** The natural chromaticities stay relatively small: ζ_x=–15.4, ζ_y=–11.7, the calculated dynamical apertures are as such as –20 mm < DA_x < 29 mm, -24 mm < DA_y < 24 mm. The structure "66nm-rad"do not require a special modification of the "iron".

Optics with a 18 nm-rad Horizontal Emittance

The case of non-zero dispersion in all sections of Siberia-2, a structure with 18 nm-rad horizontal emittance at 2.5 GeV seems to be quite achievable at the present variability of parameters of magnetic elements. It has the betatron tunes ν_x=9.708, ν_y=5.623, the chromaticities ζ_x=–21.4, ζ_y=–19.7 and the DAs -19 mm < Δx < 25mm, –12mm < Δy < 12 mm. Such optics makes it possible to obtain a diffraction-limited radiation in vertical plane with rather shot wavelength of λ_{fund}=6Å at E=1.33 GeV. But the "18 nm-rad" structure implies a modernization of the injection system and an optimization of the sextupole magnets positions on the Siberia-2 ring.

Installation of Wigglers

Activity in the protein crystallography and in material science is linked with an installation of the multipole superconducting wiggler. Now we begin to make 7.5 T wiggler with the 19 poles, the space period of 164 mm, photon flux up to (10^{14}-10^{12}) phot./s/0.1%BW and photon energies up to 200 keV.

Booster Synchrotron for Siberia-2

The 80-2500 MeV synchrotron (Figure 8a) will support 1 Hz top up energy injection of the electrons in Siberia-2, the work with small DAs in new Siberia-2 optics, periodical injection and constant intensity of SR ("infinite" lifetime), stability of photon beams. Booster has a 12-fold symmetry DBA optics (Figure 8b) with ε_x=52 nm-rad, a circumference of 110.9 m.

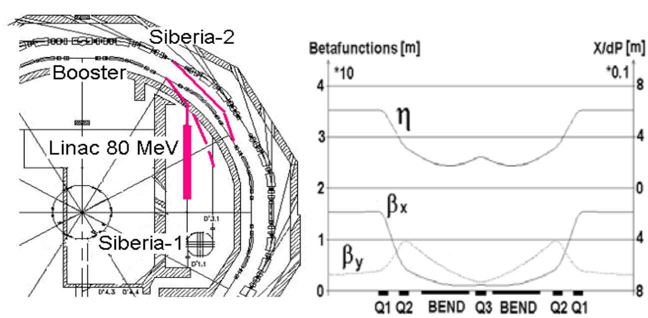

Figure 8: Booster installation in the tunnel of Siberia-2 and the amplitude functions of one booster superperiod

REFERENCES

[1] V.V.Anashin et al., NIM, A282, p.369-374,(1989).
[2] S.T.Belyaev, V.N.Korchuganov, M.V.Kovalchuk et al., "Status of Kurchatov SR Source", Proc. RUPAC2002, Obninsk, Russia .
[3] M.V.Kovalchuk, V.V.Kvardakov et al., "Kurchatov Synchrotron Radiation Center", The 5-th Asian SR Forum, March 16-17 2004, Japan, Ext. Abstract, p. 77-80.