Nuclear Instruments and Methods in Physics Research A 391 (1997) 160–163

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

ELSEVIER

First results obtained for the KSRS design parameters

A. Filipchenko[a], E. Gorniker[a], A. Kalinin[a], V. Korchuganov[a], G. Kulipanov[a], G. Kurkin[a], E. Levichev[a], Yu. Matveev[a], V. Sajaev[a], V. Ushakov[a], A. Kadnikov[b], Yu. Krylov[b], D. Odintsov[b], S. Pesterev[b], V. Stankevich[b], V. Ushkov[b,*], A. Valentinov[b], Yu. Yupinov[b], A. Zabelin[b]

[a]*Budker Institute for Nuclear Physics, Novosibirsk, Russia*
[b]*RRC KI, KSRS, Moscow, Russia*

PACS: 29.27-a; 25.40 Ep
Keywords: Storage ring; Beam dimension; Synchrotron radiation

1. Introduction

At present a complex of SR sources is being commissioned at the Russian Research Center Kurchatov Institute, Moscow [1]. The facility is intended for synchrotron radiation (SR) experiments in the 0.1–2000 Å range of SR wavelengths and at an electron energy of 2.5 GeV.

The facility comprises the dedicated storage ring Siberia-2 with an energy of 2.5 GeV for the stored electrons and the Siberia-1 storage ring with 450 MeV electron energy. The injection part includes an 80 MeV linear accelerator [2] and two transport beam lines, TBL-1 and TBL-2.

In April 1996 storing was obtained in a single bunch mode operation at Siberia-2. At present one can work with electron bunches in single bunch and multibunch modes at 2.5 GeV. In April the first experiments of the LIGA-program were performed with an SR beam extracted from the bending magnet.

2. Siberia-1

The Siberia-1 storage ring is a 450 MeV booster for Siberia-2 and, in addition, an independent SR source in the VUV and soft X-ray ranges, with a characteristic radiation wavelength from the bending magnets of 61.3 Å [3]. At present the computer controlled process of electron acceleration from injection energy to 450 MeV lasts 20 s. Now the ramping time is limited by the maximum tuning time of the RF cavity during ramping. Both beam extraction and beam injection are done in the vertical plane. The periodicity of the electron beam extraction is 30 s at a current of 100–140 mA.

Typical cycles of current storage, energy ramping and extraction are shown in Fig. 1. The pulse duration of the extracted beam is $\sigma_s = 1$ ns, the natural horizontal and vertical emittances are 8.6×10^{-7} m rad and 8.6×10^{-9} m rad with a standard energy spread of 3.9×10^{-4}.

3. Siberia-2

3.1. Magnetic system

The magnetic lattice of Siberia-2 was optimized to obtain an intensive spectral flux and to reach a high spectral brightness of the radiation source in the wavelength region of 0.1–2000 Å [3,4]. The optical functions of the Siberia-2 lattice are shown in Fig. 2. The main parameters of the Sbieria-2 ring are listed in Table 1.

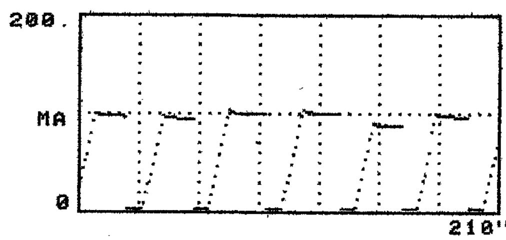

Fig. 1. Siberia-1 booster regime.

* Corresponding author. Tel.: +7 095 196 92 06, fax: +7 095 943 00 73, e-mail: ushkov@ksrs.msk.su.

PII S0168-9002(97)00275-1

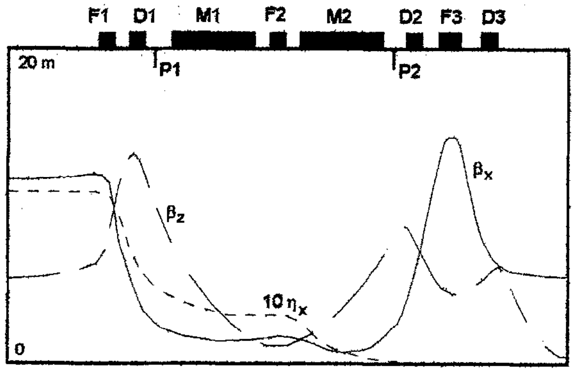

Fig. 2. Siberia-2 optical functions at one half of a cell.

3.2. RF system

The RF system of Siberia-2 [5] includes two accelerating cavities, two waveguides and two RF generators operating at a frequency of 181.14 MHz. During 450 MeV electron injection the amplitude of the RF voltage is 60 kV. RF generators will provide a voltage of 1.8 MV at the cavities when working with the maximum stored current of 300 mA at 2.5 GeV energy. At present one RF generator and one RF cavity are in operation. The maximum voltage reached at the cavity is 1.4 MV. Routine work is done with 1.2–1.3 MV at 2.5 GeV. A synchronizing system provides the possibility to inject the electron bunch into each of the 75 RF separatrixes. The maximum RF generator power now limits the possible accelerated electron current to 50 mA. The second RF cavity is also tested and installed on the ring; an RF feeder will be connected to the generator later this year. A temperature instability of the cavity tune is observed when working at a high energy; this is caused by overheating of the cavity walls.

Table 1
Basic calculated parameters of Siberia-2

Energy	E	2.5 GeV
Circumference	C	124.13 m
Number of cells	N	6
Betatron tunes	ν_x, ν_z	7.77, 6.70
Horizontal emittance	ε_x	9.0×10^{-8} m · rad
Chromaticity	ξ_x, ξ_z	−16.7, −12.9
Momentum compaction factor	α	0.0104
Damping times	τ_x,	2.92 ms
	τ_z	3.04 ms
	τ_s	1.55 ms
RF harmonic number	q	75
RF frequency	f_{RF}	181.14 MHz
Maximum current, multibunch mode	I	300 mA
Lifetime	–	5 h

3.3. Magnetic lattice tuning

A nominal injection energy of 450 MeV was achieved on June 18, 1995 and the beam was transported from Siberia-1 to Siberia-2 with an efficiency better than 90%. At the beginning of operation with electron beams in Siberia-2 the decision was made not to try a "soft optics" mode but to start with the project lattice together with the chromatic sextupoles excluding a harmonic sextupole. The resulting charge efficiency was around 6%. The real revolution frequency was equal to 2.41541 MHz while the project one is 2.41519 MHz. The measured frequency range (100 Hz) was related to the horizontal aperture at the center of the achromat $X_m = \pm 4$ mm. The first measured tune point was $\nu_x = 7.573$, $\nu_z = 7.376$. Successive lattice tuning was performed by two quadrupole families located in the dispersion free sections.

With the tune point (7.685, 7.721) the charge injection efficiency was increased up to 15%, the revolution frequency was shifted close to the project value (2.41528 MHz) and the possible frequency detuning range became 800 Hz. After the chromaticity was compensated we had $\xi_x = -0.2$, $\xi_z = -0.58$.

Our attempts to improve a single capture in Siberia-2 led to the necessity of careful measurement of the dynamic aperture (DA). We measured the DA by means of a pulsed thyratron generator, exciting x- or z-oscillations. The DA was treated as an amplitude of oscillations when $\frac{1}{2}$ of beam current was lost. Moving probes were used for calibration of the deflection amplitude of the kicked beam. It was shown that existing orbit distortions and the revolution frequency defined the horizontal DA to be no more than ± 7 mm; in other words a horizontal acceptance $A_x = 4.0 \times 10^{-4}$ cm rad that was evidently small for injected beam with horizontal emittance $\varepsilon_x = 0.86 \times 10^{-4}$ and existing random errors in the input coordinates.

In April 1996 we decided to change the optics structure of Siberia-2 in order to get a new working point with tunes $\nu_x = 7.773$, $\nu_z = 6.701$, differing by $\Delta\nu_z = -1$ from the old one. This tune point with a larger theoretical DA was found earlier when we studied nonlinear dynamics in Siberia-2 [6]. The main parameters of the new structure are shown in Table 1.

DA measurements made at 450 MeV beam energy for the new magnetic structure gave the following values (all values are measured from equilibrium orbit at the septum azimuth):
- in the horizontal direction: $DA_x = 16.4$ mm;
- in the vertical direction: $DA_z = 8.4$ mm.

The horizontal acceptance for the new structure became $A_x = 2.17 \times 10^{-3}$ cm rad, in accordance with DA_x and $\beta_{x_0} = 12.4$ m.

Note that from the point of view of customer performances the new SR optical structure did not differ essentially from the old one but the natural chromaticity is considerably less ($\xi_x = -17$, $\xi_z = -13$).

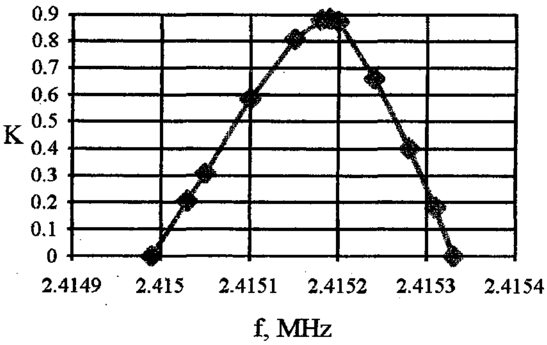

Fig. 3. Dependence of the injection efficiency K (≤ 1) of the electron charge on revolution frequency f. The basic value of the revolution frequency is 2.41519 MHz.

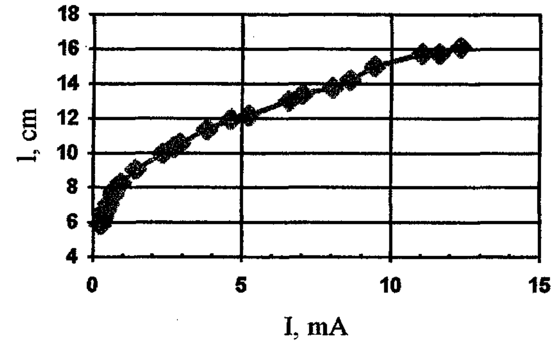

Fig. 5. Longitudinal beam size l at one half level vs bunch current I in Siberia-2.

After the new structure was installed we immediately obtained successive storing in one separatrix and a significantly increased injection efficiency (up to 90%). Fig. 3 shows the measured dependence of the injection efficiency on the revolution frequency.

The designed revolution frequency $f_0 = 2.41519$ MHz decreases the maximum correction (8 x steering magnets and 5 z steering magnets). The deviations of the closed orbit were $\langle x \rangle = -0.36$ mm, $\langle z \rangle = 0.2$ mm, $x_{rms} = 1.0$ mm, $z_{rms} = 0.8$ mm and $x_{max} = -1.9$ mm, $z_{max} = 1.5$ mm at the pickup azimuths. This gave the possibility to accumulate up to 25 mA in one separatrix. Note the good accordance between the designed and the measured parameters of the magnetic structure.

Fig. 4 shows the process of current storing vs time. One can see that with increasing current the lifetime rapidly decreases due to vacuum problems. Equilibrium between beam losses due to scattering at residual gases and growth after injection lies at 25–28 mA.

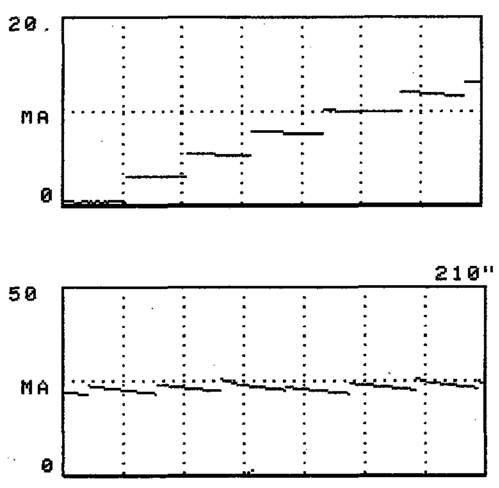

Fig. 4. Process of current storing versus time in the Siberia-2 storage ring. The full time scale is 210 s.

For natural chromaticity compensation we used only two families of sextupole lenses located inside the achromatic bend. The harmonic sextupoles were not switched on. Nowadays we work at $\xi_x = \xi_z = +0.72$.

3.4. Beam dimensions

Fig. 5 is a plot of the longitudinal beam size vs the bunch current. The curve is very similar to a power dependence $\propto I^{1/3}$. In our case it is interpolated by $I^{1/2.72}$. The curve was measured at an energy of 450 MeV and $U_{RF} = 60$ kV.

In fact, the real longitudinal size is larger than the natural cavity voltage (60 kV). A decreasing of the synchrotron frequency with the bunch current is observed. Perhaps this phenomenon is due to an interaction between the electron bunch and cavity that is switched off.

3.5. Betatron coupling

When crossing a coupling resonance $\nu_x - \nu_z = 1$ the vertical and horizontal betatron frequency difference was measured and so a coupling factor was achieved.

We believe that the main different resonance is excited by parasitic skew-quadrupole fields, vertical sextupoles displacements and vertical and horizontal CODs. A coupling factor measurement gives $K = 0.04$.

3.6. Lifetime

The lifetime is 1 hour at 5 mA and 2.5 GeV. We need to improve the vacuum conditions in the RF cavities and in several azimuths around the ring.

References

[1] V.V. Anashin et al., Nucl. Instr. and Meth. A 282 (1989) 369.
[2] V.N. Korchuganov et al., Proc. PAC, Washington, DC, May 17–20, 1993, vol. 1 (1993) 564; Proc. PAC, Berlin, March 24–28, 1992, vol. 1 (1992) 474.
[3] V.V. Anashin et al., Proc. 7th Nat. Particle Physics Conf., Dubna, 1980, vol. 1 (1980) 306.
[4] V.V. Anashin et al., Proc. 11th Nat. Particle Physics Conf., Dubna, 1988, vol. 2 (1988) 281.
[5] P.Yu. Abramskii et al., Proc. 11th Nat. Particle Physics Conf., Dubna, 1988, vol. 1 (1988) 227.
[6] V. Korchuganov, E. Levichev and V. Sajaev, Proc. PAC, Washington, DC, May 17–20, 1993, vol. 1 (1993) 230.