SIBERIA-2: WORK IN PROGRESS

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1 INTRODUCTION

At present a complex of SR sources in the Russian Research Center Kurchatov Institute, Moscow is commissioning [1]. The facility is intended for SR experiments in the 0.1-2000 Å range of SR wavelengths and a 2.5 GeV electron energy.

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

In April 1996 the storing was obtained in a single bunch mode operation at Siberia-2. At present there is a possibility to work with the electron bunches in a single bunch and multibunch modes at 2.5 GeV. In April the first LIGA-program experiment were performed with SR beam extracted from 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 61.3Å [3]. At present a computer controlled process of electron acceleration from injection energy to 450 MeV takes 20 s. Now the ramping time is limited by the maximum tuning time of RF cavity during ramping. Both beam extraction and beam injection are done in the vertical plane. A periodicity of the electron beam extraction is 30 s at the current 100-140 mA.

Typical cycles of current storage, energy ramping and extraction are shown in Fig. 1.

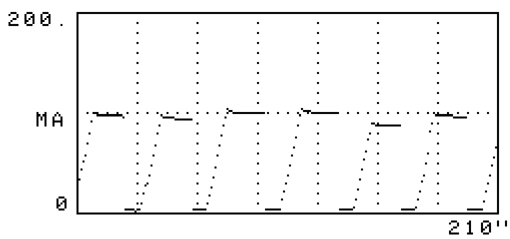

Figure 1. SIBERIA-1 booster regime.

The pulse duration of the extracted beam is $\sigma_s = 1$ ns, natural horizontal and vertical emittances are $8.6 \cdot 10^{-7}$ m·rad and $8.6 \cdot 10^{-9}$ m·rad with standard energy spread of $3.9 \cdot 10^{-4}$.

3 SIBERIA-2

3.1 Magnetic system

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

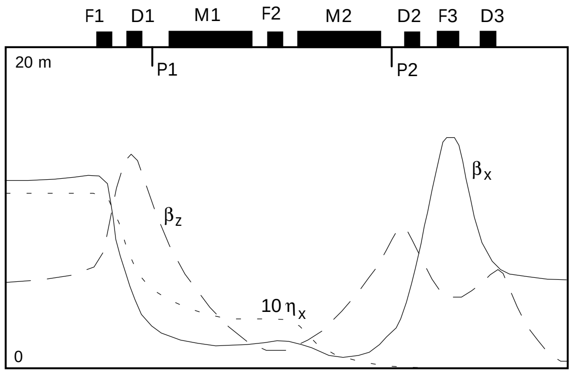

Figure 2. SIBERIA-2 optical functions at one half of cell.

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	$9.0 \cdot 10^{-8}$ m·rad
Chromaticity	ξ_x, ξ_z	-16.7, -12.9
Momentum compaction factor	α	0.0104
Damping times	τ_x, τ_z, τ_s	2.92 ms, 3.04 ms, 1.55 ms
RF harmonic number	q	75
RF frequency	f_{RF}	181.14 MHz

Maximum current, multibunch mode	*I*	300 mA
Lifetime	τ	5 hrs

3.2 RF system

The RF system of SIBERIA-2 [5] includes two accelerating cavities, two waveguides and two RF generators operating at 181.14 MHz frequency. During 450 MeV electron injection the amplitude RF voltage is 60 kV. RF generators will provide 1.8 MV voltage 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 RF separatrix of 75 ones. The maximum RF generator power limits now the possible accelerated electron current by the value of 50 mA. The second RF cavity is also tested and installed on the ring but RF feeder will be connected to the generator later this year. It is observed a temperature instability of cavity tune when working at a high energy, caused by overheating of the cavity walls.

3.3 Magnetic lattice tuning

The nominal injection energy of 450 MeV was achieved on June 18, 1995 and the beam was transported from SIBERIA-1 to SIBERIA-2 with the efficiency better than 90%. At the beginning of operation with electron beam in Siberia-2 the decision was made did not try a 'soft optics' mode but to start with the project lattice together with the chromatic sextupoles excluding harmonic sextupole. 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 achromat $X_m=\pm 4$ mm. A first measured tune point was ν_x = 7.573,ν_z = 7.376. A successive lattice tuning was made 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 of 800 Hz. After the chromaticity was compensated we had ξ_x = -0.2, ξ_z = -0.58.

Our attempts to improve a single capture in SIBERIA-2 led us to necessity of careful measurement of dynamic aperture (DA). We measured DA by means of pulsed thyratron generator exciting x- or z-oscillations. DA was treated as an amplitude of oscillations when 1/2 of beam current was lost. Moving probes were used for calibration of deflection amplitude of kicked beam. It was shown that existing orbit distortions and revolution frequency defined horizontal DA as not more than ±7 mm. By other words a horizontal acceptance A_x= $4.0 \cdot 10^{-4}$ cm·rad that was evidently small for injected beam with horizontal emittance ε_x = $0.86 \cdot 10^{-4}$ and existing random errors in input coordinates .

In April 1996 we decided to change optic structure of SIBERIA-2 in order to get new working point with tunes ν_x = 7.773, ν_z = 6.701, differing by $\Delta\nu_z$ = -1 from the old one. This tune point with more larger theoretical DA was found earlier when we studied nonlinear dynamic in SIBERIA-2 [6]. Main parameters of new structure are shown in Table 1 in fact.

DA measurements made at 450 MeV beam energy for new magnetic structure gave following values (all values are measured from equilibrium orbit at septum azimuth):

- in horizontal direction DA_x = 16.4 mm;
- in vertical direction DA_z = 8.4 mm.

Horizontal acceptance for new structure became $A_x = 2.17 \cdot 10^{-3}$ cm·rad in accordance with DA_x and β_{x_0} = 12.4 m.

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

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

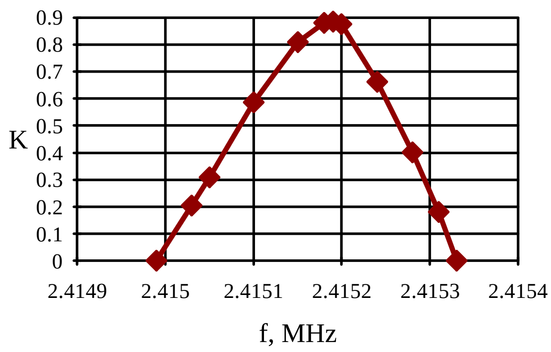

Figure 3. Dependence of injection efficiency K (≤ 1) of electron charge on revolution frequency f. Basic value of revolution frequency is 2.41519 MHz.

Designed revolution frequency f_0 = 2.41519 MHz decreases a maximum correction (8 - x steering magnets and 5- z ones) deviations of 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 pickup azimuths. This got a possibility to accumulate up to 25 mA in one separatrix. Note good accordance between designed and measured parameters of magnetic structure.

Figure 4 shows process of current storing vs time. One can see that with current increasing a lifetime rapidly decreases due to vacuum disease. Equilibrium between beam losses due to scattering at residual gazes and growth after injection arrives at 25 -28 mA.

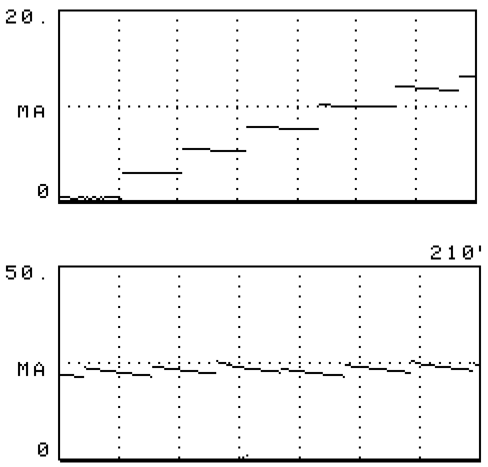

Figure 4. Process of current storing versus a time in SIBERIA-2 storage ring. Full time scale is 210 s.

For natural chromaticity compensation we used only two families of sextupole lenses located inside achromatic bend. Harmonic sextupoles were not switched on. In recent time we work at $\xi_x = \xi_z = +0.72$.

3.4 Beam dimensions

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

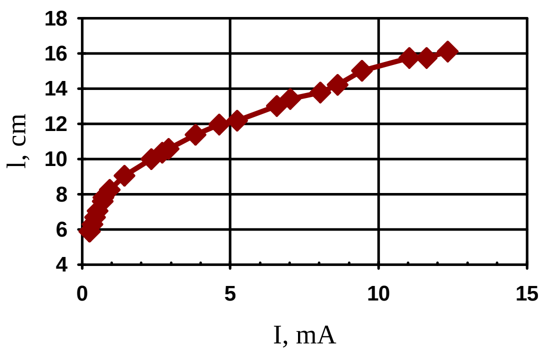

Figure 5. Longitudinal beam size l at one half level vs bunch current I in SIBERIA-2.

In fact the real longitudinal size is more bigger than a natural one 60 kV cavity voltage. It is observed the decreasing of the synchrotron frequency with the bunch current. Perhaps this phenomenon is due to interaction between electron bunch and cavity 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 achived.

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

3.6 Life time

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

4 REFERENCES

[1] V.V.Anashin et al., Nucl.Instrum.Meth., A282, p.369-374,(1989).

[2] V.N.Korchuganov et al. Proc. of the PAC, Washington, D.C., May 17-20, 1993. Vol.1.p.564-566., Particle accelerator conference, Berlin, March 24-28, 1992. Vol.1. p.474-476.

[3] V.V.Anashin et al., The Proc. of 7th National particle physics conference, Dubna, 1980, Vol.1, p.306.

[4] V.V.Anashin et al., The Proc. of 11th National particle physics conference, Dubna, 1988, Vol.2, p.281-284

[5] P.Yu.Abramskii et al.,.The Proc. of 11th National particle physics conference, Dubna, 1988, Vol.1, p.227-229.

[6] V.Korchuganov, E.Levichev and V.Sajaev, The Proc. of the PAC. Washington D.C., Mai 17-20, 1993. Vol.1, p.230-232.