MODERNIZATION AND DEVELOPMENT OF KURCHATOV CENTER OF SYNCHROTRON RADIATION AND NANOTECHNOLOGY

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Abstract

Kurchatov Synchrotron Radiation Source (KSRS) works for the experiments in the range of SR from VUV up to hard X-ray. Recently a project of technical modernization of KSRS was carried out. It consists of 3 parts: the enlargement of useful experimental hall surface by means of the new building; upgrade of accelerator facilities and injection scheme to improve the SR complex capabilities; construction of new beam lines and experimental stations around Siberia-2 facility. The building was started from the end of 2007. The technical upgrade of SR complex will start in 2009. The report describes the current work and plans at accelerator facilities.

INTRODUCTION

The accelerator complex of KSRS consists of the linear accelerator and two storage rings. SR Share Center founded at the base of KSRS. Main parameters of the KSRS accelerator facilities are shown in Table 1.

Table 1: Parameters of KSRS facilities

Linac	SIBERIA-1	SIBERIA-2
E = 80 MeV	E = 80÷450 MeV	E = 0.45÷2.5 GeV
I = 0.2 A	I = 0.2÷0.3 A (single bunch)	I = 0.1÷0.3 A (multibunch)
L = 6 m	C = 8.68 m	C = 124.13 m
DE/E = 0.005	B = 1.5 T	B = 1.7 T
ε_0≈300 nm·rad	ε_{x0}≈800 nm·rad	ε_{x0}≈78÷100 nm·rad
T = 18 ns	T_0 = 29 ns	T_0 = 414 ns
f_{rep} = 1 Hz	T_{rep} = 25 s	τ =10÷25 hrs
	λ_c=61 Å , BMs	λ_c=1.75 Å, BMs

Linac works as forinjector for SIBERIA-1 with 80 MeV electron beam. Small electron storage ring SIBERIA-1 operates in two regimes: as a booster for a large storage ring SIBERIA-2 and as SR source in VUV and soft X-ray spectral range. Large storage ring SIBERIA-2 is a dedicated SR source in hard X-ray overlapping the SR spectral range of 0.1-2000Å [1]. Possible number of photon beam lines from BMs equals to 24, others SR sources like SC wigglers and warm wigglers (undulators) are planed to offer 6-8 SR beam lines from IR to hard X-ray radiation.

KSRS FACILITIES WORK

Now the work of SIBERIA-2 on experiments is carried out at energy 2.5 GeV with an electron current 100-200 mA with use of SR from bending magnets in energy range of photons 4-40 keV and spectral flux (10^{13}-10^{11}) ph/s/0.1%BW during week runs in a round-the-clock mode. Within one week 7-9 working 12-hour shifts are presented. During 11.5 months of 2007 year - 351 shifts, including 212 day time and 139 night shifts are fulfilled. In Table 2 work of accelerator complex in 2007 is shown.

Table 2: Work of accelerator facilities in 2007

Parameter	Siberia-1	Siberia-2
Working time, hrs	3989	3895
Injection time, hrs:	486 (12%)	200 (5%)
Stored current, mA	≤434.3	≤309.7
Experiment time, hrs:	219 (6%)	1653 (42%)
Accel. current, mA	≤339.4	≤209.9
Average current, mA	67	74
Total doze, A*hrs	225	527
Doze of 2008, A*hrs	15	126
Best life time, hrs: min (current, mA)	0:38 (173) 1:20 (100)	12:50 (202) 32:50 (50)

INSTALLATION OF INSERTION DEVICES

First SC wiggler installation [2]

First SC wiggler was manufactured in BINP SB RAS according to the technical requirements and the boundary conditions developed in RRC KI. It was installed in the dispersion-free straight section of first superperiod of SIBERIA-2 on 2007, December 25.

Table 3: Project SC wiggler parameters

Max. field, T	3-7.5
Period, mm	164
N_{poles}	19+2
Elliptic liner, Cu. V*H, mm	13*120
$E_{ph\ crit}$, keV	31.2
Flux, ph/s/0.1%BW	10^{14}-10^{12}
Working spectrum, keV	5-200
Θx max, mrad	± 23.5
Energy loss/turn, keV	365
P_{tot} (100 mA), kW	36.5

Project SC wiggler parameters are presented in Table 3. They correspond to 100 mA electron beam at 2.5 GeV in the SIBERIA-2 ring. Thanks to the SC wiggler the SR intensity will be increased comparing to SR from BMs in ~ 100 times and more in hard X-ray spectrum region up to 200 keV photons. This opens the

possibility to investigate the elements with large atomic numbers.

First run of SC wiggler was carried out on 2008, June, 7. The magnetic field of wiggler was lifted up to 3 T. At this condition the wiggler SR beam had an angle divergence Θmax=9.4 mrad, SR power reached P=1.46 kW with a critical wavelength λc=1Å at 2.5 GeV. The horizontal COD was no more than 1 mm at the pick-up azimuths.

The betatron tunes and the chromaticity shifts were in the good accordance to project expectations at 2.5 GeV. Hard component of SR was observed at luminescent screen at front end of the central wiggler line with a TV camera.

IDs planed at SIBERIA-2

The planned scheme of the insertion devices on the ring of Siberia - 2 is shown in Fig.1. Eight IDs are to be installed, among them 4 superconducting, 3 normal conducting wigglers and one mini-undulator. Besides that one photon line of infra-red (IR) edge radiation will be taken out. IDs approached parameters are given in the Table 5.

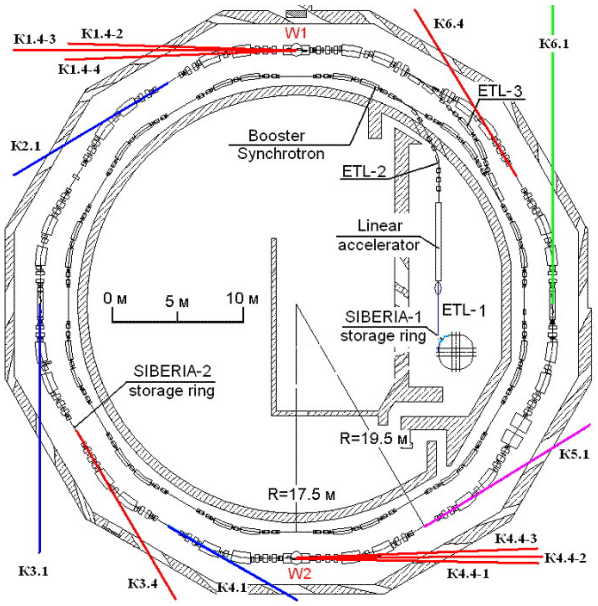

Figure 1: Plan of IDs location at Siberia-2

Table 5: Possible Insertion Devices planed on SIBERIA-2

SR line name	Insertion device	Max. field, T	Field period, cm	Number of periods	Photon energy	Number of SR lines
K3.4, K6.4	2 SCW	2-4	5-6	25-30	20-40 keV	2
K4.4-1, K4.4-2, K4.4-3	1 SCW	7.5	16.4	10	20-200 keV	3
K1.4-2, K1.4-3, K1.4-4	1 SCW	6 (7.5)	12-16.4	10	20-100 keV	3
K2.1	1 NCW	0.1-1	15	~10	5.5-270 eV	1
K3.1	1 NCW (U)	0.1-1	15	~10	5.5-270 eV	1
K4.1	1 NCW	0.1-1	15	~10	5.5-270 eV	1
K6.1	1 in-vacuum mini - U	0.087	0.7	100-150	2 keV	1
K5.1(?)	IR radiation				≤ 300 eV	1

We note two points. The installation in-vacuum mini-undulator with a variable pole gap and a very short period of a magnetic field will be expedient and effective only after realization of modernization of optics of the storage ring SIBERIA - 2 and reception in the modernized structure natural emittance ~ 5 nm·rad at an energy ~1.33 GeV. In this case one could say about a possibility of work with a very bright diffraction-limited source in vertical plane in the range of 6 Å fundamental harmonics [3].

Infra-red radiation (so-called edge radiation) on SIBERIA-2 can be received using an interference of radiation from fringe areas with a week magnetic field strength of a dipole bending magnets separated by straight sections [4].

MODERNIZATION OF SYSTEMS

RF system of Siberia-2

By the end of 2007 two existing RF cavities have reached the end of its service life and did not increase a total accelerating voltage above 1.2 MV (water leakage and multipactor discharge). But the planed installation of two SC wigglers with magnetic field 7.5 T will amplify the SR losses from 680 keV (with only BMs) to 1.41 MV per a revolution. So, in order to support a large energy acceptance and life time it needs to increase a total voltage at accelerating gaps of cavities up to 2 MV.

Therefore, 11 - 22.12 2007 together with employees of BINP SB RAS, two new one-case bimetallic resonators were ranged on a place of the removed old resonator 2 in dispersion-free straight section. Two new coaxial feeders were mounted between the waveguide and two new cavities. A radical modernization of electronic control system of RF generators of SIBERIA - 2 was simultaneously carried out. The old resonator 1 remaining on a ring will be replaced with the new resonator 1 during 2009.

RF system of Siberia – 1

At the same time (11 - 22.12 2007), installation and run of new 34.5 MHz RF generator and control electronics for SIBERIA-1 were carried out also. The new generator allows to increase quickly a voltage on accelerating gap of the RF cavity up to 30 kV (instead of 12 kV of old generator) and to reduce the longitudinal size of an ejected electron bunch in a

factor 1.5, thus to improve efficiency of capture in SIBERIA-2 at injection due to reduction of losses of particles by "tails" of distribution.

Operating control [5]

The new automated control system of KSRS facilities is in progress. The network of operating terminals consists of workstations under control of MS Windows XP, combined in a local network Ethernet.

Programs of management and diagnostics receive the information from a database (DB) server on the basis of MS SQL Server where it arrives from the application server. All executing modules, ADC and DAC are united in a CAN-network.

Handle programs read out these queries and form special commands to units of a CAN-network or access to CAMAC crates. The received information is sent back to a DB server. Then it is read out by the operator application and it is represented to the user through the programs.

In the moment the graphic interface of the vacuum system current data working in a local network with operative extraction of background is developed. New control system of Siberia–2 RF generators is developed and successfully introduced on the basis of controller K167 and managing server of a class Pentium IV. Management of power supplies of lenses and steering magnets of Siberia - 2 from new controllers K167 was made, new operational control software is started in routine work.

IMPROVEMENT OF SIBERIA-2 BEAM PARAMETERS

Ultimate goal of improvements of parameters of electron and photon beams is the increase of brightness, spatial and time stability of SR source.

Orbit stabilization system

Since 2007 this system covers 7 SR beam lines (lines 1.2, 4.4.e, 1.3б, 4.3, 4.4.e, 5.6., 6.6). Tests of system for stabilization of each of SR lines separately and five lines simultaneously are carried out. Stability of SR beam position at the experimental stations is within the limits of 5 micron in a vertical direction.

Vertical emittance reduction

A correction of COD by using dipole correctors and a change of skew - quadrupoles connection scheme have allowed reducing a coupling factor of betatron oscillations essentially. In fact, vertical emittance arising due to betatron coupling can be reduced till 0.01 % of the horizontal value.

Correction of vertical dispersive function (arising due to errors in positions of lenses and COD of a vertical plane) has allowed reducing its maximal value on the azimuths of pickups more than 3.5 times. By estimations, vertical emittance, arising due to presence of a vertical dispersion, makes about 1 % from horizontal one.

Diagnostics

A new electronics for betatron tunes measurement will be run at Siberia - 1 and Siberia - 2 at the turn of the year 2008.

Besides that a new nuclear magnetic resonance (NMR) probe with auxiliary electronics and control code will be installed in testing bending magnet of Siberia - 2 for accurate measuring the magnetic field. New electronics will serve as a part of feedback system of electron energy stabilization.

Vacuum

After the new equipment (2 cavities and SC wiggler) installation was finished low pressure of residual gas in vacuum chamber was reached, and Siberia-2 started to operate as SR source for users again. During April-June 2008, and after summer vocation since September, 22 the work on SR was continued with electron current of 100-130 мА and life time 12 hours.

Let's note, that after closing the vacuum chamber, for the achievement of life time of 12 hours at the 100 мА electron current it was required to collect an integrated doze of 16 A*hrs, that is 10 times less, than it was required at the very beginning of SIBERIA-2 work with electron beam.

THE PROJECT OF MODERNIZATION OF SR SOURCE

The aims of modernization

Enlargement with additional building will expand the useful surfaces of experimental hall from 950 m^2 till 4850 m^2. This allows installing long photon lines and new experimental stations.

The Project of technical upgrade of accelerator complex was developed [6] with the aim to create SR source of 2.5÷3 generations on the base of existing accelerator complex. This will increase the spectral brightness more than in 30÷100 times in comparison with the realized project.

The plane is to develop the new optical structures for SIBERIA-2 with small natural horizontal emittance 6÷18 nm-rad at electron energy 1.3 GeV and 2.5 GeV accordingly.

The systems of SIBERIA-2 ring will be updated also. Injection system, vacuum system and, partly, magnetic optical system will be changed both during mounting new IDs and in a process of the tuning of optical structures with small natural emittances.

Note that accelerator lattices with the small natural emittances have larger chromaticities and, after compensation of them, as a consequence, the small dynamical apertures.

Then, when operating with small dynamic apertures the task of fast electron current storing in SIBERIA – 2 must be solved.

Top-up energy injection with synchrotron [7]

According to the Project, injection in Siberia - 2 will be made from a booster synchrotron (BS) with rather small natural emittance ε_{x0} 53 nm·rad at 2.5 GeV (compare with SIBERIA-1: ε_{x0} 880 nm·rad at 0.45 GeV). BS will ramp the energy from 0.08 (0.16) GeV till 2.5 GeV with repetition rate of 1 Hz. BS parameters are given in the Table 6.

Table 6: Calculated BS parameters

Injection energy	80-160 MeV
Extraction energy	2.5 GeV
Circumference	110.9 m
Cycling frequency	1 Hz
Emittance	52.6 nm·rad
Momentum compaction	0.0107
Betatron tunes: Qx/Qy	6.83 / 4.57
Chromaticity: ξx/ξy	–14.12/–8.89
Energy loss per turn	622 keV
Damping times: τ_x, τ_y, τ_s	3.08, 2.97, 1.46 ms
Beam current	20 mA
RF frequency	181.13 MHz
Harmonic number	67

A small natural emittance of BS electron beam will ensure a high efficiency of injection into SIBERIA-2 lattice with small dynamic apertures. And, hence, KSSR will produce much brighter SR beams achieving parameters of 3-d generation SR sources.

BS will offer following additional advantages. BS will support the constant level of electron current in SIBERIA-2 so creating an "infinite beam life time" during working with SR. In case of high energy injection, a strong radiating damping will suppress the growing of instabilities in the SIBERIA-2 storage ring.

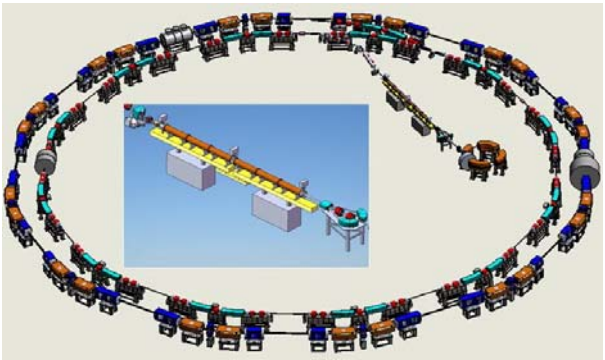

Figure 2: Scheme of modernized accelerator complex (project RRC KI).

In Fig.2 the modernized complex is shown: an external ring - the existing store Siberia - 2, an internal ring - projected BS, the linear accelerator with a projected magnetic mirror and new geometry of unit of a gun, the small ring - a SR source Siberia -1.

Installation of BS will be carried out in the same tunnel where the SIBERIA - 2 is located. This saves not only the areas in themselves, but also uses existing communication lines, minimizing charges on capital construction.

Linear accelerator with energy doubling [8]

According to the Project, the SIBERIA-1 will keep the functions of an independent SR source in spectral ranges VUV and soft X-ray. Existing linear accelerator, working in a mode of a standing wave on the stored UHF energy, will continue to work in quality of injector for SIBERIA - 1 with electron energy 80 MeV. Besides, linac will work as injector for BS with doubled electron energy of 160 MeV by using a magnetic mirror and a second passage of electron through accelerator structure .

New two electron transport lines - from linac to BS (ETL - 2, 160 MeV) and from BS to SIBERIA - 2 (ETL - 3, 2.5 GeV) will be made. Existing ETL - 2 will be demounted.

CONCLUSION

We hope that the scientific and technical decisions offered in the Project "Modernization of KCSR…" will provide for a scientific attractiveness and competitiveness of SR source in Russian Research Center "Kurchatov Institute".

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