STATUS OF THE KURCHATOV SYNCHROTRON LIGHT SOURCE

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Abstract

The Kurchatov synchrotron light source operates in the range of synchrotron radiation from VUV up to hard X-ray. To improve facility capabilities in the last few years technical modernization of all facility systems is underway and new beam lines are constructed. In this report the present status and future plans of the Kurchatov synchrotron light source are presented.

INTRODUCTION

The Kurchatov synchrotron light source [1] includes 80 MeV electron linear accelerator, 450 MeV storage ring Siberia-1 with the horizontal emittance 800 nm·rad, the 2.5 GeV storage ring Siberia-2 with the horizontal emittance 78-100 nm·rad and two transport lines. Siberia-2 supplies users' experimental stations by synchrotron radiation in photon energy range 4-40 keV from its bending magnets. Siberia-1 is mostly used as a booster for Siberia-2 but also as an independent SR source.

KSRS OPERATION

The Siberia-2 operates nine months per year in around the clock mode. Within one week 9 working 12-hour shifts are provided. One more shift is dedicated to accelerator physics and machine tuning. As a rule there is one beam storing per day, typical electron current is 100 – 150 mA. Beam lifetime is equal 15 – 20 hours at 100 mA level and defined by vacuum conditions. Injection process at 450 MeV usually takes about 1 hour, energy ramping takes 3 minutes with 2-3% beam loss.

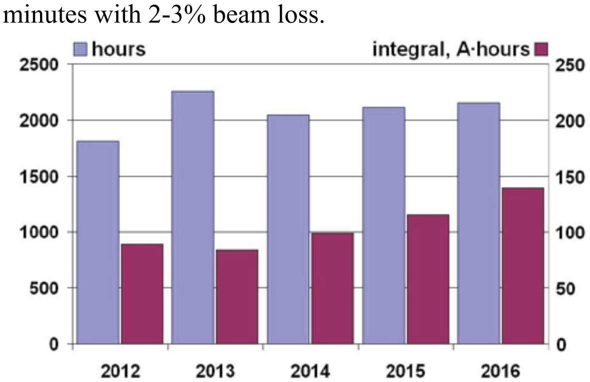

Figure 1: Total time used for experiments and beam current integral at 2.5 GeV for Siberia-2.

Fig. 1 demonstrates total time devoted for SR experimental work at Siberia-2 and electron current integral at 2.5 GeV during last 5 years.

A magnetic lattice of Siberia-2 provides horizontal emittance equal to 98 nm at 2.5 GeV. Betatron coupling is maintained at very small level of 0.001 so vertical beam size is determined by non-zero vertical dispersion function. At injection energy betatron coupling is artificially increased up to 10-15% in order to enhance beam lifetime.

There are 11 experimental stations using SR at Siberia-2 and 4 stations at Siberia-1. Three stations were put into operation during last year (Photoelectron spectroscopy, Phase-sensitive solid-state research, X-ray structure analysis). Two other stations will be commissioned next year (moved from DESY).

Siberia-2 Closed Orbit Distortions

Serious problem for users is slow drift of photon beam in vertical direction. It is caused by heating of machine basis from thick aluminum conducting bar of bending magnet power supply. This induces a progressive slope of magnets and vertical close orbit distortion as a result. We observe the slope with two time constants. First one is equal to approximately one hour and acts just after energy ramping. Second one is equal to one day and is observed during whole working week. As a result we must correct vertical orbit each time before beam storing and jus after energy ramping. As a rule we have RMS distortion of closed orbit about 40 microns in vertical plane and 500 microns in horizontal plane.

In order to stabilize photon beam position feedback system is used. Every beamline has luminophor sensor with TV camera for fixing beam image on luminofor strip. The feedback provides local orbit bump to stabilize photon beam with accuracy of 2-4 microns in sensor location. Plans for future are to improve cooling of power supply conductor by increasing of water flow using more powerful pumps.

DEVELOPMENT OF KSRS IN 2015-2016

The purpose of works in 2015-2016 was both modernization of the existing equipment and introduction of new diagnostics systems on Siberia-2 storage ring. Much attention was paid to developing of KSRS control system.

Siberia-2 New High Voltage Generators

Two new generators based on pseudo-spark switches (a thyrotron TPI1-10k/50) and RLC resonant circuits with a semi-sinusoidal form of currents were produced on "Pulse

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Systems” Ltd. (Ryasan) and installed inside machine tunnel. Total pulse duration is equal 1 µsec.

Due to the excitations of multibunch instabilities by long pulses of kickers the maximum injection efficiency factor is limited near 50-60% (with 10 kV on “kicker” and 6 kV on “prekicker”). To avoid the excitations we shall continue the generator scheme modernization to shorten the pulse duration.

Feedbacks for Instabilities Suppression In Siberia-2

Longitudinal and transverse feedback systems (KCSR and IT, Slovenia) for damping the beam excitations are now under commisionning.

A special small RF cavity is intended as a kicker for suppression of coherent synchrotron excitations. Its own measured frequency is 954.7 MHz and a quality factor is equal to 9.1 [2]. The longitudinal kicker reflectivity measurement and resulting reflectivity dependence on the frequency of the excitation are shown in Fig.2.

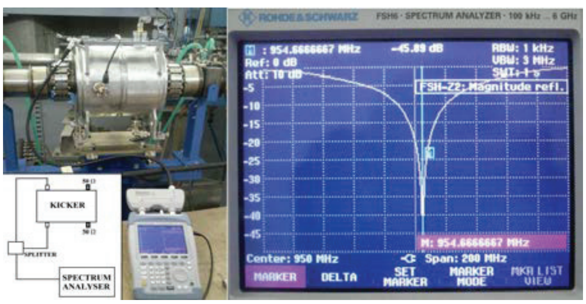

Figure 2: The reflectivity measurement of longitudinal kicker at the Siberia-2 straight section.

Strip lines existing on Siberia-2 ring are used as transverse kickers for suppression of coherent betatron oscillations in X- and Y- plane. One of BPM is used as a sensor. The digital electronics, broadband amplifiers (25 W and 100 W), phase detectors, the modulator, RF control are installed in the rack outside Siberia-2 tunnel.

Siberia-2 Station Of Optical Supervision

The station of optical supervision (SOS) [3] was mounted outside to biological protection of Siberia-2 in 2013. Now all six SOS diagnostic systems are in operation. They permit to measure transverse (resolution is ~1µm) and longitudinal (resolution is 40 psec) bunch sizes, beam dynamics TV monitoring, relative beam displacement (1280×960 pixels CCD camera, 100 Mbit Ethernet interface), a turn-by-turn registration of a chosen bunch transverse profile, synchrotron and betatron frequencies. An example of obtained data is given in Figure 3. Lengthening of the bunch is caused by microwave instability and Touchek effect (at 450 MeV).

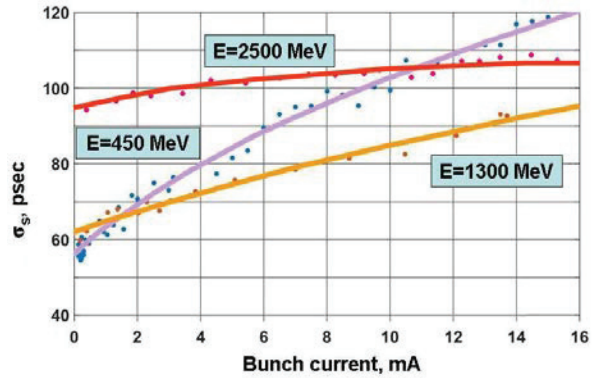

Figure 3: Bunch length vs. beam current in single-bunch mode for different machine energies (approximated dissector data).

Control System

Upgrade of CS consists in changeover of the old CAMAC equipment on modern one and the organization of new architecture. The full-function monitoring system and controls - CitectSCADA works at the top level [4]. CitectSCADA provides visualization of processes, automated workplace control, tracing of systems in real time in a graphic form and access to contemporary records, preparation of the detailed reports, execution of the sub-programmes developed on CitectVBA and CiCode. Now CitectSCADA controls number of subsystems:

- Vacuum system.
- Temperature measurements and temperature stabilization of linac structure.
- Siberia-2 RF generators measurements.
- Siberia-2 magnetic system control, including ramping process, cycle of remagnetization, betatron tune correction and so on.
- Control of photon absorbers in SR beamlines from bending magnets.
- Control of equipment in superconducting wiggler beamline.

At present main goal of KSRS control system staff is to provide CitectSCADA control over all machine systems.

Superconducting Wigglers

SC wiggler (SCW1) with maximum field 7.5 T is installed on Siberia-2 ring. Unfortunately we cannot reach this field with electron beam current value more than 7-10 mA. Rapid beam lifetime decreasing took place for larger values of electron current. The lifetime didn’t restore after beam loss. We suggest that ion trapping occurs inside wiggler vacuum chamber because of insufficient pumping rate near wiggler position.

SR users plan to limit maximum field value by 4 T. Earlier there were 3 beamlines of SR from the wiggler, now only one will stay. 100 mA electron current was received with this value of the magnetic field.

At present 2 new superconducting wigglers are fabricated for KSRS in BINP (Novosibirsk). They will be ready to

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install on the ring in the end of 2018. Parameters of all wigglers are presented in Table 1.

Table 1: Wiggler's Parameters

SCW parameters	SCW1	SCW2,3
Max field	7.5 (4) T	3 T
Field period	164 mm	46 mm
Number of poles	19+2	50+4
Undulator parameter	115 (61)	12.9
Emitted energy at 100 mA	35 (10) kW	4.1 kW

KSRS MODERNIZATION

KSRS accelerators and their supply systems will be upgraded according to Federal Program of modernization of synchrotron and neutron laboratory of NRC Kurchatov Institute. General scheme of KSRS will stay unchanged. The modernization will provide an improvement in all valuable machine parameters such as electron current, lifetime, operation time, SR spectral range and flux. Main features of the program are:

- Additional RF generator for Siberia-2, new system of power supply and cooling for all three RF generators. New scheme for RF system: separate generator for every RF cavity instead of old scheme (2 generators for 3 cavities). Three new waveguides.
- New pneumatic vacuum valves, additional vacuum monitors, ion pumps, BPM monitors, eliminating of "hot spots" in the vacuum chamber near inflectors and superconducting wiggler.
- New power supply for bending magnets and quadrupole lenses of Siberia-2, bending magnets of Siberia-1 and transfer lines.
- Two new 3 T superconducting wigglers and their beamlines.
- New generators for linac klystron station and pulse magnets.
- Upgrading of the accelerators' control system and safety system of the facility.
- New water cooling and air-cooling systems for all equipment, new air conditioning for accelerator and experimental halls.
- New beamlines and experimental stations. Total number of stations will achieve 21.

KSRS parameters after modernization are given in Table 2.

Table 2: KSRS Parameters Before And After Modernization

Siberia-2 parameters	2016	2020
Time for users per year, hours	2000 - 2400 (in 24/5 mode)	3000 (4200 in 24/7 mode)
Maximal current, mA	200	300
Maximal total RF voltage, MV	2.0	2.7
Lifetime, hours (at 100 mA)	20 - 25	35 - 40
Lifetime restoring after vacuum chamber repair	2 weeks	3 – 4 days
Number of wigglers	1	3
Number of experimental stations	11	21

CONCLUSION

KSRS continues to work as the only dedicated SR source in Russian Federation. An improvement of accelerators' parameters is a result of continuous efforts in the solution of scientific and technical problems. KSRS modernization will allow to achieve new quality of facility operation.

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