THE STATUS OF THE FACILITIES OF KURCHATOV`S SYNCHROTRON RADIATION SOURCE

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Abstract

The first electron beam had been received 20 years ago in a storage ring SIBERIA-2 - a dedicated synchrotron radiation source in the Kurchatov Institute and, also, the official opening of the SR source for the experiments marks 15th anniversary in year 2014. The report focuses on the development of the SR source accelerator complex systems in 2014.

INTRODUCTION

The electron accelerators complex of the Kurchatov`s SR source includes: a for-injector - the 80 MeV linear accelerator; the 450 MeV storage ring Siberia-1 with the natural emittance 800 nm·rad; the 2.5 GeV storage ring Siberia-2 with the natural emittance 78-100 nm·rad; two electron-optical channels – EOC-1 and EOC-2. Official opening of the Kurchatov SR source took place 1.09.1999.

KSRS FACILITIES WORK

The work of Siberia-2 on experiments is mainly carried out using SR from bending magnets in photons energy range (4-40) keV and spectral flux (10^{13}-10^{11}) ph/s/mrad/0.1%BW during the week runs in a round-the-clock mode. Within one week 9 working 12-hour shifts are presented.

Figure 1: Experimental time at Siberia-2 in 2000-2013.

Diagram in Fig.1 shows the integral time devoted for SR experimental work at Siberia-2 in 2000 – 2013 years. Table 1 presents a statistics of SR source Siberia-2 work at SR experiment in 2013 and on June 2014. Note that in 2014 the SR source spent relatively much time in standby and adjustment mode due to stops for the works of firms according contracts (opening shielding walls, new beam lines installation, etc).

The purpose of works on 2013-2014 is both modernization of the existing equipment and introduction of new diagnostics systems mainly on Siberia-2 storage ring.

Table 1: Statistics of Siberia-2 on 2013-June 2014.

Period	2013	Jan.-June 2014
Max. electron current	112 mA	128 mA
Life time (100mA)	41.8 hrs	38.5 hrs
Operation time	3480 hrs	2371 hrs
Experiment	2257 hrs / 50%	1074 hrs / 38%
Injection	10%	11%
Tuning / Other works	17% / 23%	16% / 35%

DEVELOPMENT OF KSRS ON 2014

Siberia-2 New High Voltage Generators

The important aim was to replace old generators of the injection kickers based on the HV gas-filled electric discharge devices and the HV forming lines (20 ns, <55 kV) on the new compact LV generators (≤3 kA, 25 kV) working only with solid electrical components and without SF_6 gas using.

After the testing in 2011-2012 of the prototype 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 Systems” Ltd. (Ryasan). The final scheme of new generators is shown in Fig.2.

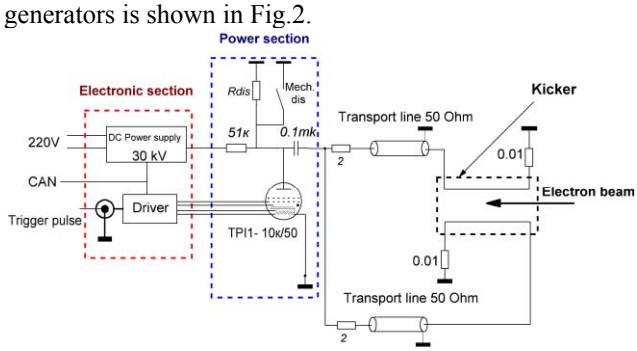

Figure 2: The scheme of new generators.

To guarantee a stable operation of the generators we have increased the working pulse duration till 1 μsec making 2.5 times longer than revolution period and have reduced the voltage on capacitance.

The calculation without taking into account any collective excitations showed that in the case long pulse shouldn’t affect the injection efficiency [2], see Fig.3.

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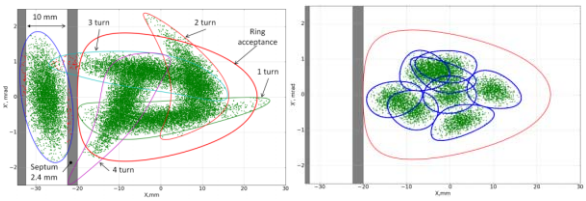

Figure 3: Horizontal phase trajectories of the injected and the stored bunches at the injection moment

Nevertheless, the maximum injection efficiency factor is limited near 50-70% (with 10 kV - on "kicker" and 7 kV- on "pre-kicker) due to the excitations of multibunch instabilities by long pulses of kickers. To avoid the excitations we shall continue the generator scheme modernization to shorten the pulse duration.

Siberia-2 RF System Modernization

The RF system includes two generators and three accelerating cavities, two of which are powered by one common generator. In January 2014 four new and more reliable powerful tetrodes of TH781 type with the pirographite grids (THALES, France) were installed in the output cascades of two RF generators instead of the old GU-101A type tetrodes [1].

Now we investigate the feature of stabilization system of voltages and phases of two coupled cavities. We observe that with electron current growing the RF voltages on accelerator gaps of the coupled cavities change oppositely (when keeping the summarized voltage). This reduces the voltage of one (of two) coupled cavity till the level which is do not stabilized and stops the electron storage. To continue the storage process we must increase the sum RF voltage and, so, to decrease injection effectiveness. The RF measurements and the calculation with a theoretical coupled cavity model have proved that the existing errors in the lengths of the feeders, in the matching of the cavities with the feeders and the waveguide are the reasons of an incorrect distribution of RF voltages between the cavities, limits the accumulation of electron beam current and leads to an increase of the generator load. To solve this problem most directly but rather costly each cavity should be powered by an individual generator and tuned separately by an individual feedback system. Other (difficult) way is to make a new feedback system for the independent stabilization of the voltages and phases of two cavities powered by one RF generator.

New System "Orbit" at Siberia-2[3]

The main purpose of new system "Orbit" is an improvement of the electron orbit diagnostics providing continuous measurements and carrying out turn-by-turn measurements of the electron beam trajectory during injection process. In addition, it will be a part of fast feedback system which will damp the distortions of the closed orbit.

The closed orbit correction system of Siberia-2 contains up to 48 vertical correctors, 48 horizontal correctors and 24 BPMs. In 2013 the BPMs were supplied with the new high-precision electronic equipment and software product for measurement of an equilibrium orbit transverse coordinates. The electronics of "Libera Brilliance Instruments" was mounted in the 4 racks inside of the Siberia-2 tunnel, each containing 6 "Libera Brilliance" units and 1 Libera Clock Splitter" unit. A new accelerator physics framework "Ocelot" was integrated with the new orbit correction system for high level beam control. Spatial resolution of new system "Orbit" with measurement time of 5 milliseconds for beam average current value 5-300 mA makes 1μm. The first results of orbit measurements and corrections are shown at BPMs azimuths at energy in Fig.4.

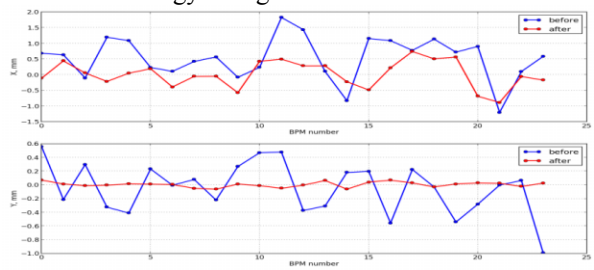

Figure 4: An orbit before (blue) and after (red) correction. H.:rms 880/420 μm; V.:rms 380/38 μm.

RMS of vertical orbit distortion is about 40 μm after correction. For horizontal plane the situation is worse due to the irregular locations of BPMs in betatron phase and the lack of correctors and BPMs in horizontal plane. In our case the currents of some correctors must be more than 13A when maximum sources current is 5A at 2.5 GeV. To minimize the horizontal orbit distortion the number of BPMs is planed to be increased in future.

Feedbacks for Instabilities Suppression

Longitudinal and transverse feedback systems for damping the beam excitations in Siberia-2 will be commissioned to the end of 2014. As a kicker for suppression of coherent synchrotron excitations a special small RF cavity is intended with own frequency of 950 MHz and a quality factor of 10 [4]. It was introduced in the straight section of ring in 2013. The longitudinal kicker reflectivity measurement and resulting reflectivity dependence on the frequency of the excitation are shown in Fig.5.

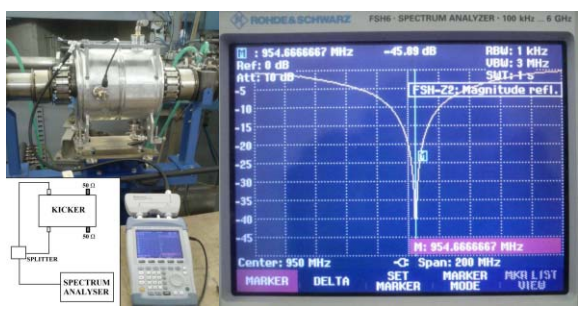

Figure 5: The reflectivity measurement of longitudinal kicker at the Siberia-2 straight section.

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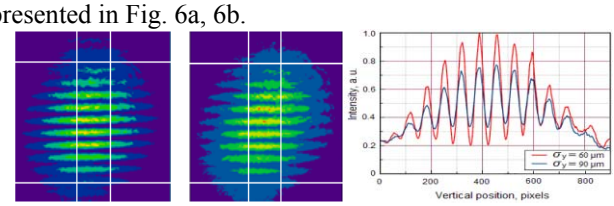
As transverse kickers for suppression of coherent betatron oscillations in X- and Y- plane the strip lines existing on Siberia-2 ring are used. The digital electronics, broadband amplifiers (25 W and 50 W) and a pickup - electrodes, phase detectors, the modulator, RF control were installed in the rack.

Siberia-2 New Station of Optical Supervision

The six diagnostic systems station of optical supervision (SOS) was mounted outside to biological protection of Siberia-2 by April, 2013.

For first measurements [5] of the vertical beam size the double slit interferometer was applied with a slit separation of 15mm and 20mm. The interference patterns for two different vertical beam sizes (σ_y =60μm; 90μm) and their intensity distribution cross-sections are presented in Fig. 6a, 6b.



6a) 6b)

Figure 6a: Interference patterns for vertical beam sizes of 60μm (left) and 90μm (right). Figure 6b: The light intensity was integrated at the region between the vertical lines in Fig.7a.

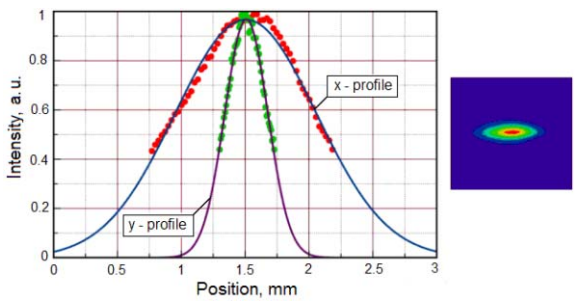


Figure 7: Beam image and its x, y - projections fitted by Gaussian curves.

The beam image was monitored and a fit of its projections by Gaussian curves are presented in Fig. 7. Comparison of the results obtained enables us to determine the value of apparatus function for transverse beam measurement system as $\sigma_{inst} \approx 80$μm. This rather large value can be explained by the poor quality of the first cooled mirror (which will be replaced by new one in December 2014). By means of comparison of the beam size measurements with slit separation of 15mm and 20mm we estimate the resolution of double slit interferometer as $\sigma_{int} \approx 5$μm.

New Power Supplies for Magnetic Correctors

In 2012 the replacement of old power supplies for the magnetic correctors by the new more exact ones developed by "Marafon" (Moscow) [1] was started. In 2013 the all set of the 269 bipolar and unipolar units were made with a new control system and computer programs. The testing shows rather high long time current stability ($2 \cdot 10^{-4}$, 6A and 20A).

New Control System

Upgrade of CS consists in changeover of the old equipment of CAMAC on trunk - modular hardware in the VME standard and the organization of new architecture. CS is conditional subdivided into the upper and lower levels, server level and the periphery. ***The lower level of CS*** realizes a collection of diagnostic information and an execution of control algorithms by the executive systems of the accelerator complex. ***Server level of CS*** includes application servers and the server of management system of a database (DBMS). ***The top level of CS*** includes automated workplaces of operators and other users. The full-function monitoring system and controls - CitectSCADA [6] works at the top level.

Work with 7.5T SC Wiggler

The first experiment started on "X-Ray structure analysis" (RSA) station with SR of existing 7.5T SCW in October 2013.

New SR Beamlines and Experimental Station

In 2013 the beamline and the station PHASA were run in operation. In 2014 we started the commissioning of the SR beamline and the station "Photo Electron Spectroscopy – PES".

CONCLUSION

We are sure that continuous efforts in the solution of the scientific and technical problems will lead to high-quality improvement of the KSRS.

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