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The project of a new source for the Siberian Synchrotron Radiation Center

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ABSTRACT

The Siberian Synchrotron Radiation Center has an urgent necessity for a new third generation source for effective implementation of synchrotron radiation methods for different scientific and technological directions.

This project is under development at Budker Institute of Nuclear Physics now. The main conceptual ideas for this source as well as the lattice design are described in the current report.

1. Introduction

At present time, the number of operating synchrotron radiation (SR) centers in Russia is extremely low as compared with other industrial counties.

The Siberian Synchrotron Radiation Center (SSRC) has a long history and unifies many SR users from different institutes of the Siberian Scientific Center (Siberian Branch of Russian Academy of Science, Novosibirsk) [1]. Broad interdisciplinary relations at the SSRC create a constructive basis for effective innovations in SR application in different scientific and technological fields.

Unfortunately, the main problem of the SSRC is the absence of a specialized SR source. The currently used storage rings VEPP-3 and VEPP-4 were designed as electron and positron colliders and SR beam parameters in these cases do not meet modern requirements for beam quality. Moreover, users can utilize SR only in the time sharing mode because the main part of operation time (about 75%) is intended for high-energy physics experiments and machine study works.

On the other hand, Budker Institute of Nuclear Physics has great experience in the design and manufacture of different types of magnetic elements for accelerators. In addition, the Institute was responsible for common design and construction of the SR center at Kurchatov Institute (Moscow). So, the technical ability of the Institute to create a similar SR center in its own territory is beyond any doubt.

The project for a compact hard X-ray SR source was proposed at the Institute in 2005 [2]. The main idea of this project was to use high-field (upto 9 T [3]) superconductive bending dipoles and relatively low beam energy (1.2 GeV). The resulting SR spectrum from these superconductive magnets was hard enough ($\varepsilon_c \sim 10$ keV) for realization of a big variety of popular X-ray methods using SR. The circumference of the proposed storage ring is 57 m. Thus, due to the compactness of this facility, similarly organized SR sources can be very useful for creating small research centers at universities, hospitals, and industrial enterprises. But the SSRC is a big scientific center, and the center obviously needs a larger source. After analysis of SSRC users' requests and wishes, the main parameters of the source were selected. A relatively compact scheme with a circumference of about 210 m was chosen to fulfill the requirements of users.

The development effort for the SR source for the SSRC started at the institute in 2007. The main strategy for this source design will be described in this report.

2. Main parameters of the SR source

Maximum fulfillment of currently working users' requirements is the main figure of merit of this project. One of the important wishes of all users was the possibility to move the currently used experimental beamlines to the new source without serious modification. For this reason, beam energy for the new source was selected to be 2.2 GeV. In this case, the SR spectra from conventional bending magnet (with 1.6 T field) should be approximately similar to the currently used SR beam (the VEPP-3 storage ring, a beam energy of 2 GeV, and a wavelength shifter field of 2 T). For techniques which require hard X-ray spectra, it was proposed to use a few superconducting bending magnets. Therefore, the magnetic structure of the new source is to permit using at least two types of bending magnets: conventional normally conducting dipoles with a field of about 1.6 T and superconducting ones with peak field upto 9 T.

Since many of the modern methods require high-brightness multipole wiggler or undulator radiation, the lattice has to include

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many straight sections for installation of different insertion devices (ID).

High brightness of modern SR sources is mainly provided by low natural equilibrium emittance. So, the emittance of new source should not exceed the modern third generation SR source requirement, e.g. it should be equal to a few nm rad. Of course, the beam current should be as high as possible. The modern technologies of vacuum chamber fabrication permit making a smooth profile to avoid high impedance and wake fields, which create limitations for the beam current. The project value for the beam current was chosen to be 500 mA or more.

Beam stability is also very important for users' parameters of the SR beam. The full energy injection (top-up injection) scheme was proposed for beam current stability.

Some details of the lattice design are described in next chapter.

3. Lattice design

A triple bend achromatic (TBA) structure was chosen to be the main superperiod structure for the new source lattice. There are at least two serious reasons for selecting the TBA model. The first reason is the possibility to combine two types of magnets in a common structure, because the central and side magnets in the TBA should not be similar. So, there is a good way to conjugate superconductive magnets (the central one) with normal conductive magnets (the side magnets). Moreover, the side magnets can hide the internal structure of a theoretical minimal emittance (TME) cell, so it is possible to combine TME cells with different types of central magnets. Therefore, one can choose the number of superconducting magnets in the ring structure. For example, for 12-fold ring symmetry, one can use 2, 3, 4, 6, 8, 9, or 10 cells with a superconducting central magnet with a big violation of symmetry.

Another reason for using the TBA is the relatively big number of straight sections for ID in comparison with other TME schemes, e.g. QBA, FBA, etc. In case of TBA, one straight section corresponds to every trinity of magnets, so the total number of IDs can be noticeably big.

The optical function for the proposed lattice design of the new SSRC source is presented in Fig. 1. The total number of TME cells was selected equal to 12, and four cells have a superconductive central magnet. The number of superconducting magnets (four) was selected after some analysis of users' needs in SR in the hard X-ray region. The bending angle in the superconducting dipole is 15°, which permits organizing at least three SR extraction beamlines without serious technical problems.

For reduction of the circumference and total number of quadrupoles, it was proposed to join three TBA cells in one superperiod. Thus, the internal straight sections have 3 m length and a relatively high vertical beta-function. These sections are basically intended for installing multipole wigglers, RF cavities, and the injection system.

The long straight sections between the superperiods are intended for undulators and are 7 m long.

All central magnets have a deflecting angle of 15°. The side magnets bend the orbit by 7.5°.

The current stage of lattice design is limited by linear optimization. Fig. 1 shows that there are some places with big beta-function separation. These points are good for installation of sextupole lenses for effective suppression of natural chromaticity without strong reduction of the dynamic aperture. This work is underway now.

The estimated horizontal equilibrium emittance for this lattice is about 5 nm rad, which is within the third generation SR source range.

Main parameters of the proposed lattice are presented in Table 1.

Some other basic solutions for a number of systems are described in next chapter.

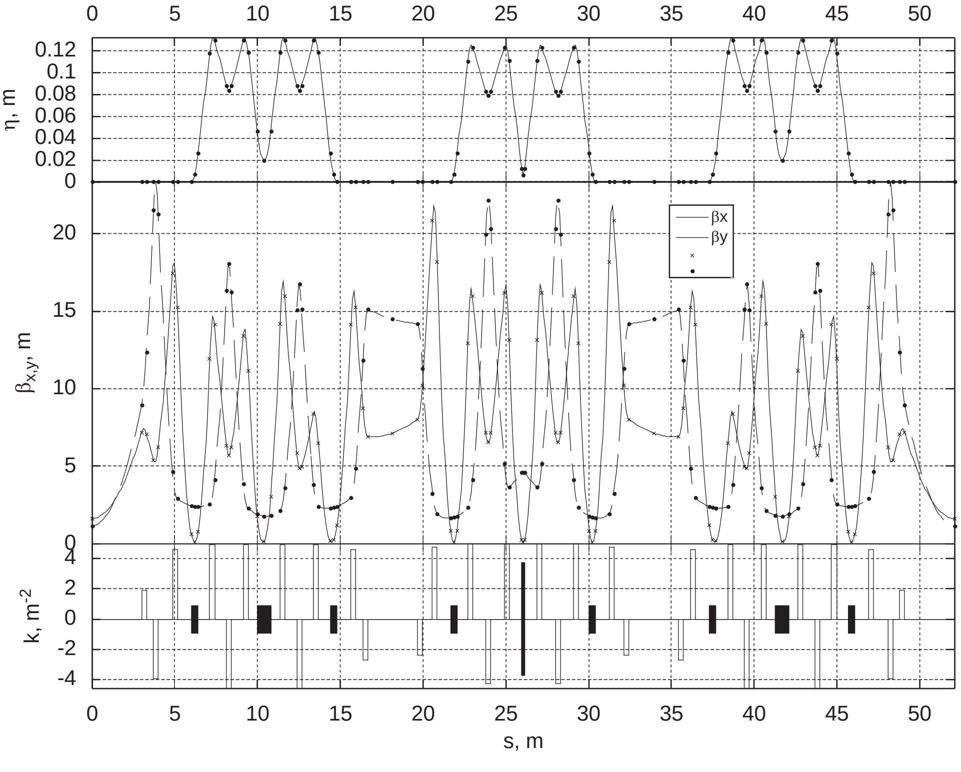

Fig. 1. The optical function for the proposed lattice design of the new SSRC source.

Table 1
Main parameters of proposed lattice.

Parameter	Value
Beam energy	2.2 GeV
Circumference	208.16 m
Horizontal emittance	5.5 nm rad
Lattice type	TBA
Number of TBA cells	12
Number of superperiods	4
Number of superconducting magnets	4
Magnets bending angles	15° in superconducting magnets 15° in central normal magnets 7.5° in side normal magnets
Horizontal tunes value, Q_x	20.588
Vertical tunes value, Q_y	9.0195
Horizontal natural chromaticity, C_x (without sextupoles)	−102
Horizontal natural chromaticity, C_y (without sextupoles)	−48
IBS estimated lifetime, hours	8–10 (for 1 A beam current)

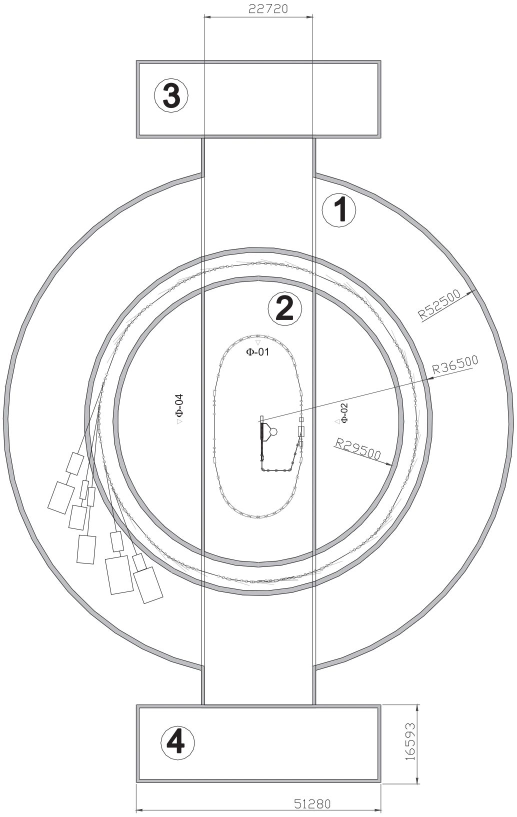

Fig. 2. The general layout of the SSRC source buildings: (1) the ring building for the storage ring and user beamlines; (2) a central building for the injection complex with a gantry crane; (3) a building for scientific offices and laboratories; and (4) a building for the technological system and a workshop.

4. System description

The top-up injection capability permits keeping operating current above a certain level during a whole user shift. As a result, the thermal load on monochromator crystals can be kept almost constant. It is a very popular solution now for many modern SR sources. The new SSRC source will also include this capability.

Top-up injection will be provided by the buster synchrotron, which will accelerate the electron beam from the linac (with an energy of 100 MeV) upto the operating energy (2.2 GeV). A preliminary buster design was completed in 2008. The buster will use the same magnets as the 1.2 GeV buster synchrotron made by Budker INP for Duke University (North California, USA) in 2007 [4]. The total circumference of the buster is about 72 m. It can be placed inside the main ring. The repetition time for an acceleration cycle is about 10 s.

Standard RF cavities used at Budker INP, with high-order mode suppression and a frequency of 180 MHz, will be installed in the booster and main ring. In spite of big dimensions of the system, relatively long bunches formed by these cavities will help to decrease intrabeam scattering and increase the beam life time.

Top-up injection and relatively long bunches permit keeping a noticeably big current (upto 1 A). Of course, such current requires special effort for a low impedance design of vacuum chamber, but modern approaches to fabrication of aluminum extrusion profiles with smooth transitions allows achieving this current value.

Some effort was directed toward developing a building layout for the new source. The main goal was construction price reduction. A schematic layout of the building complex is shown in Fig. 2. It will contain four inter-connected buildings:

1. a ring building for the storage ring and user beamlines;
2. a central building for the injection complex with a gantry crane;
3. a building for scientific offices and laboratories;
4. a building for the technological system and a workshop.

The most important advantage of this modular building design is the possibility to avoid complicated engineering constructions. All the buildings have a rather simple design and the cost of the whole construction project can be precisely estimated on early stages.

5. Conclusion

BINP has great experience in development and creation of different accelerators. All necessary technologies for fabrication of this facility and all components are also available. Thus, such a compact SR source can really be created. Since the SSRC really needs a specialized SR source, the decision to develop such source was taken at BINP. This source should cover a large part of SR users' needs in the hard and soft X-ray ranges.

A detailed project of this source is under development now. Prototypes of some critical components can be fabricated next year.

References

[1] A.M. Batrakov, S.V. Khruschev, D. Kraemer, G.N. Kulipanov, V.H. Lev, N.A. Mezentsev, E.G. Miginsky, V.A. Shkaruba, V.M. Syrovatin, V.M. Tsukanov, V.K. Zjurba, K.V. Zolotarev, Nucl. Instr. and Meth. A NS-543 (2005) 35.

[2] A.I. Ancharov, V.B. Baryshev, V.A. Chernov, A.N. Gentselev, B.G. Goldenberg, D.I. Kochubei, V.N. Korchuganov, G.N. Kulipanov, M.V. Kuzin, E.B. Levichev, et al., Nucl. Instr. and Meth. A NS-543 (2005) 35.

[3] E.I. Antokhin, A.A. Gvozdev, G.N. Kulipanov, P.V. Logachev, N.A. Mezentsev, V.E. Panchenko, A.V. Philipchenko, Y.V. Rakshun, A.V. Utkin, N.A. Vinokurov, K.V. Zolotarev, Nucl. Instr. and Meth. A 575 (2007) 1.

[4] S.F. Mikhailov, V.N. Litvinenko, P. Morcombe, G. Swift, N.A. Vinokurov, N.G. Gavrilov, Yu.G. Matveev, D.A. Shvedov, Project of booster synchrotron for Duke FEL storage ring, in: Proceedings of the 2001 Particle, Accelectron Conference, Chicago, 2001, pp. 3525–3527.