Nuclear Instruments and Methods in Physics Research A 448 (2000) 32–36

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

www.elsevier.nl/locate/nima

Design considerations of source of synchrotron hard X-ray and coherent infrared radiation at JINR

V.S. Alexandrov*, P.F. Beloshitsky, N.Yu. Kazarinov, E.A. Perelstein, V.N. Shaliapin, A.N. Sissakian, S.I. Tyutyunnikov

Laboratory of Nuclear Problems, Joint Institute for Nuclear Research, Dubna 141980, Moscow region, Russia

Abstract

The review on a source of synchrotron hard X-ray and coherent infrared radiation at JINR is presented. The requirements on the SR source and on the accelerating complex are given. The structure scheme of the SRS is described. The preliminary calculations of the QBA lattice of the main ring are performed. © 2000 Published by Elsevier Science B.V. All rights reserved.

PACS: 29.20.-c; 41.60.Ap

Keywords: Storage rings; Electron beams; Synchrotron radiation

Presently, a source of synchrotron radiation for the energy of 1.2 GeV as a part of designed JINR storage ring complex [1] is being studied. The source has to ensure conditions for carrying out experiments on the condensed matter physics with use of hard X-ray, vacuum ultraviolet radiation and coherent infrared radiation with the re-tuning frequency. The requirements on SR source are:

1. It has to provide the maximum of the SR spectral density at 1 Å.
2. It has to provide a high level of the SR flux in the mentioned spectral span with utilization of a superconducting wiggler.

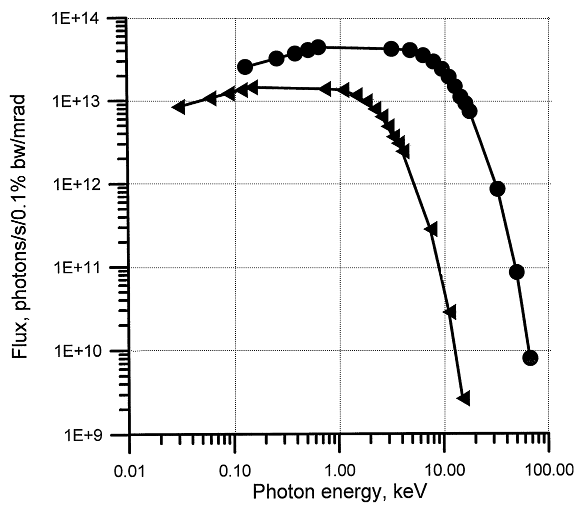

Fig. 1. Flux produced by: (▲) 1.58 T bend ($E_c = 1.51$ keV); (●) 7 T 3-pole wiggler ($E_c = 6.7$ keV).

* Corresponding author. Tel.: + 7-09621-62-429; fax: + 7-09621-66666.

E-mail address: aleks@nusun.jinr.dubna.su (V.S. Alexandrov).

PII: S0168-9002(00)00203-5

3. It has to have two SR channels with the photon energy about 10 keV from superconducting wigglers.
4. It has to have 5 SR channels from bending magnets for X-ray microfluorescent analysis, LIGA technology and vacuum ultraviolet and others.
5. Predestination and parameters of other SR beams from the bending magnets will be determined by future users.

The fluxes produced by 3-pole superconducting wiggler and 1.6 T bending magnet are shown in Fig. 1. The schematic layout of the accelerating

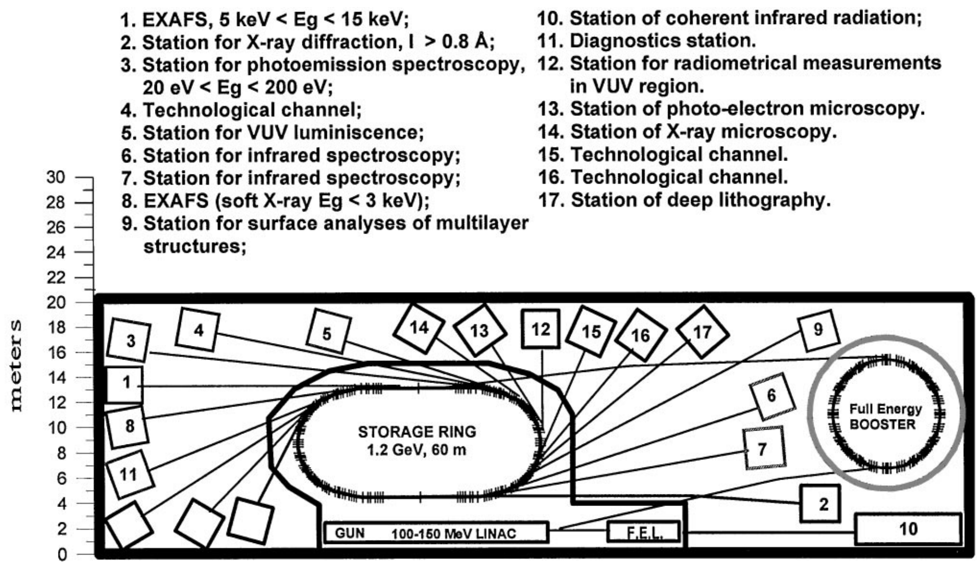

Fig. 2. Schematic layout of the SRS facility.

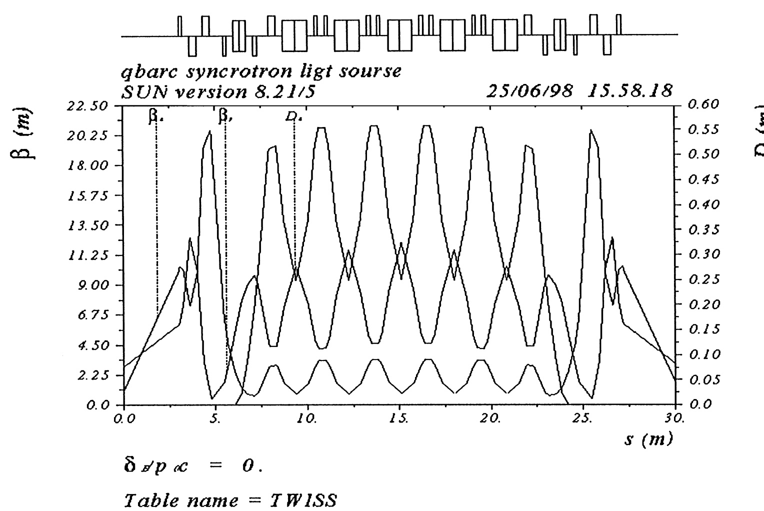

Fig. 3. The lattice and the Twiss functions for the SRS superperiod.

complex of the synchrotron radiation source and the SR channels is presented in Fig. 2.

The requirements on the accelerating complex of the synchrotron radiation source are:

1. Minimum cost (its evaluation will be given later).
2. Minimum overall dimensions for the purpose of using of the free areas available at the JINR for its placing.
3. The accelerating complex consists of an injector, a booster and the main storage ring.

The injector is a linear resonance accelerator on energy about 100 MeV. Independent of the SR source, a FEL also works on the injector beam in the infrared span, considerably widening the program of the condensed matter investigations. The main accelerating ring has two straight sections for placing there two superconducting wigglers, a device for the beam injection and 1 RF station. The electron injection into a storage ring is executed at the final energy about 1.2 GeV.

To obtain low emittances and the zero dispersion in the straight sections the modified QBA-lattice [2] has been chosen. Each arc of the ring designed with a modified QBA-optic contains five standard cells and two modified cells. Standard cell has two focusing quads and one bending magnet (length 1.32 m) with the defocusing gradient. In the modified cells, the magnet has the length 0.66 m with the gradients equal to ones in the long magnets. Eight quads are placed in the long straight section. This allows to change the value of the horizontal β-function in the centre of the section from 1 to 16 m.

Table 1
Parameters of the storage ring at JINR designed with a modified QBA-optic

Achromatic structure	QBA
Electron energy, GeV	1.2
Superperiod	2
Stored current (multibunch mode), A	0.5
Circumference, m	60.0
Arc diameter, m	11.3
RF frequency, MHz	476
Harmonic number	96
Natural emittance, nm rad	32.0
Natural energy spread, %	0.1
Damping times ($x/y/s$), ms	3.6/6.6/5.8
Betatron tunes Q_x/Q_y	5.16/3.21
Natural chromaticities ξ_x/ξ_y	$-9.87/-11.53$
Momentum compaction factor	0.025
Beta functions, m	
max. (horizontal/vertical)	20.6/12.5
min. in straight section (hor./vert.)	1.0/3.0
Maximum dispersion, m	0.56
Number of bends	10/4
Dipole length, m	1.32/0.66
Bending field (T) /gradient (T/m)	1.58/3.0
Number of quadrupoles	12/28
Length of quadrupoles, m	0.4/0.2
Maximum gradient, T/m	18.0

	Bends	Wiggler	Undulator
Number of insertions	10 + 4	1	1
Magnet field, T	1.58	7.0	0.13
Bending radius, m	2.53	—	—
Number of periods	—	3	80
Length of insertion, m	1.32	0.60	2.0
Deflection parameter, K	—	130.0	0.3
Critical photon energy, keV	1.51	6.7	0.52
Critical wavelength, A	8.193	1.849	23.711
Photon flux, ph/s/0.1% bw/mrad hor	1.4×10^{13}	4×10^{13}	—
Brilliance, ph/s/mrad^2/0.1% bw	—	—	1.6×10^{17}
Total SR power, kW	1.5	13.0	0.02
Linear power density, W/mrad horizontal	6.0	77.0	38.0
On-axis power density, W/mrad^2	9.0	118.0	58.0

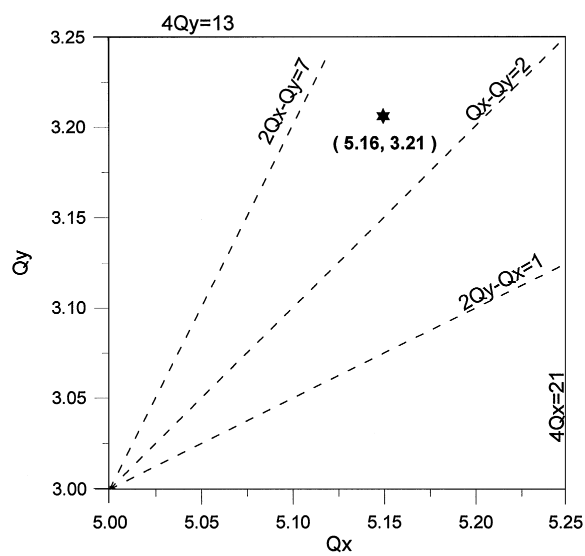

Fig. 4. Tune diagram with investigated working point.

Table 2
Charging times for the SR Source

		Single bunch	Multibunch (mode 4)	Multibunch (mode 96)
e-Gun				
Peak current	I, A	3	3	0.025
Energy/rate	E, keV/Hz	200/10	200/10	200/10
Bunch duration	ns	2	2	150
Number of bunches	k_b	1	2	46
Current pulse duration	ns	2	50	150
e-Linac				
Energy/rate	E, MeV/Hz	150–200/10	150–200/10	150–200/10
Emittance	ε, m · rad	$< 10^{-5}$	$< 10^{-5}$	$< 10^{-5}$
Energy spread	%	1	1	1
RF frequency	MHz	2856	2856	2856
Linac transfer efficiency	%	40	40	40
Beam current (in the pulse)	I, A	0.45	0.04	0.01
Current pulse duration	ns	—	50	150[a]
Number of bunches	k_b	1	2	46
Transfer efficiency (L-B)	%	50	50	50
Booster, 10 *Hz*				
Beam current	I, mA	7.5	15	3.5
Energy/rev. time	E, GeV/t_0, ns	1.2/150	1.2/150	1.2/150
Circumference/harm. number	C, m/h	45/72	45/72	45/72
RF frequency	MHz	476	476	476
Number of the particles, total	N	7.5×10^9	1.5×10^{10}	3.2×10^9
Number of bunches	Kk_b	1	2	48
Num.of the part. per bunch	n/k_b	7.5×10^9	7.5×10^9	7×10^7
Charge per cycle	ΔQ/cycle, nC	1.2	2.4	0.5
Transfer efficiency (B-SRS)	%	50	50	50
SR source				
Beam current	I, mA	125	500	500
Energy/rev. time	E, GeV/t_0, ns	1.2/200	1.2/200	1.2/200
Circumference/harm. number	C, m/h	60/96	60/96	60/96
RF frequency	MHz	476	476	476
Number of the particles, total	N	1.5×10^{11}	6×10^{11}	6×10^{11}
Number of bunches	k_b	1	4	96
Num. of the part. per bunch	n/k_b	1.5×10^{11}	1.5×10^{11}	6.5×10^9
Charge per cycle	ΔQ/cycle, nC	25	100	100
Numb. of charging cycles		40	80	375
Filling time	t_f, s	4	8	37.5

[a] Booster beam duration is equal to 100 ns.

The Twiss functions for the SRS superperiod are represented in Fig. 3. For designed parameters of the storage ring (see Table 1) the working point has been investigated. The tune diagram is shown in Fig. 4. As one can see the tunes are sufficiently far from all dangerous resonances.

Table 2 gives the design specifications for the different modes of operation: single bunch, 4-bunch and 96-multibunch modes. The charging times for the storage ring, the assumed transfer efficiencies are given for these three modes of operation. The charging time in multibunch operation will be of the order of 30 s for the stored current of 500 mA in the storage ring.

References

[1] E.A. Perelstein et al., JINR Tau-Charm factory study, Proceedings of the XV International Conference on High Energy Accelerators, Hamburg, 1992.

[2] D. Einfeld, M. Plesko, The QBA optics for 3.2 GeV synchrotron light source ROSY II, Proceedings of the 1993 IEEE Particle Accelerator Conference, Washington, 1993.