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


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.

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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.

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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

1. EXAFS, 5 keV < Eg < 15 keV;
2. Station for X-ray diffraction, λ > 0.8 Å;
3. Station for photoemission spectroscopy, 
   20 eV < Eg < 200 eV;
4. Technological channel;
5. Station for VUV luminescence;
6. Station for infrared spectroscopy;
7. Station for infrared spectroscopy;
8. EXAFS (soft X-ray Eg < 3 keV);
9. Station for surface analyses of multilayer structures;
10. Station of coherent infrared radiation;
11. Diagnostics station.
12. Station for radiometrical measurements in VUV region.
13. Station of photo-electron microscopy.
15. Technological channel.
16. Technological channel.
17. Station of deep lithography.

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 $\beta$-function in the centre of the section from 1 to 16 m.

![Fig. 4. Tune diagram with investigated working point.](image-url)
Table 2
Charging times for the SR Source

<table>
<thead>
<tr>
<th></th>
<th>Single bunch</th>
<th>Multibunch (mode 4)</th>
<th>Multibunch (mode 96)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>e-Gun</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak current</td>
<td>$I$, A</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Energy/rate</td>
<td>$E$, keV/Hz</td>
<td>200/10</td>
<td>200/10</td>
</tr>
<tr>
<td>Bunch duration</td>
<td>ns</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Number of bunches</td>
<td>$k_b$</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Current pulse duration</td>
<td>ns</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td><strong>e-Linac</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy/rate</td>
<td>$E$, MeV/Hz</td>
<td>150–200/10</td>
<td>150–200/10</td>
</tr>
<tr>
<td>Emittance</td>
<td>$e$, m$_{rad}$</td>
<td>$&lt; 10^{-5}$</td>
<td>$&lt; 10^{-5}$</td>
</tr>
<tr>
<td>Energy spread</td>
<td>%</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>RF frequency</td>
<td>MHz</td>
<td>2856</td>
<td>2856</td>
</tr>
<tr>
<td>Linac transfer efficiency</td>
<td>%</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Beam current (in the pulse)</td>
<td>$I$, A</td>
<td>0.45</td>
<td>0.04</td>
</tr>
<tr>
<td>Current pulse duration</td>
<td>ns</td>
<td>—</td>
<td>50</td>
</tr>
<tr>
<td>Number of bunches</td>
<td>$k_b$</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Transfer efficiency (L-B)</td>
<td>%</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td><strong>Booster, 10 Hz</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam current</td>
<td>$I$, mA</td>
<td>7.5</td>
<td>15</td>
</tr>
<tr>
<td>Energy/rev. time</td>
<td>$E$, GeV/fo, ns</td>
<td>1.2/150</td>
<td>1.2/150</td>
</tr>
<tr>
<td>Circumference/harm. number</td>
<td>C, m/h</td>
<td>45/72</td>
<td>45/72</td>
</tr>
<tr>
<td>RF frequency</td>
<td>MHz</td>
<td>476</td>
<td>476</td>
</tr>
<tr>
<td>Number of the particles, total</td>
<td>$N$</td>
<td>$7.5 \times 10^9$</td>
<td>$1.5 \times 10^{10}$</td>
</tr>
<tr>
<td>Number of bunches</td>
<td>$k_b$</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Num.of the part. per bunch</td>
<td>$n/k_b$</td>
<td>$7.5 \times 10^9$</td>
<td>$7.5 \times 10^9$</td>
</tr>
<tr>
<td>Charge per cycle</td>
<td>$\Delta Q$/cycle, nC</td>
<td>1.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Transfer efficiency (B-SRS)</td>
<td>%</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td><strong>SR source</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Beam current</td>
<td>$I$, mA</td>
<td>125</td>
<td>500</td>
</tr>
<tr>
<td>Energy/rev. time</td>
<td>$E$, GeV/fo, ns</td>
<td>1.2/200</td>
<td>1.2/200</td>
</tr>
<tr>
<td>Circumference/harm. number</td>
<td>C, m/h</td>
<td>60/96</td>
<td>60/96</td>
</tr>
<tr>
<td>RF frequency</td>
<td>MHz</td>
<td>476</td>
<td>476</td>
</tr>
<tr>
<td>Number of the particles, total</td>
<td>$N$</td>
<td>$1.5 \times 10^{11}$</td>
<td>$6 \times 10^{11}$</td>
</tr>
<tr>
<td>Number of bunches</td>
<td>$k_b$</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Num. of the part. per bunch</td>
<td>$n/k_b$</td>
<td>$1.5 \times 10^{11}$</td>
<td>$1.5 \times 10^{11}$</td>
</tr>
<tr>
<td>Charge per cycle</td>
<td>$\Delta Q$/cycle, nC</td>
<td>25</td>
<td>100</td>
</tr>
<tr>
<td>Numb. of charging cycles</td>
<td></td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>Filling time</td>
<td>$t_f$, s</td>
<td>4</td>
<td>8</td>
</tr>
</tbody>
</table>

$^a$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
