MAGNET LATTICE OF THE SYNCHROTRON RADIATION SOURCE DELSY

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Abstract

DELSY, a 1.2 GeV synchrotron radiation source is planned to be constructed at JINR, Dubna, Russia. This source is dedicated to the investigations on condensed matter physics, atomic physics, biology, medicine, chemistry, micromechanics, lithography and others. For DELSY the layout with four straight sections was chosen. Every quadrant consists of MBA-structure, which provides emittance of 11 nm and two halves of straight sections. The circumference of the ring is about 140 m. For the preliminary chosen working point $Q_x / Q_y = 9.58/3.56$ the dynamic aperture in the presence of the very strong wiggler (7 T) and undulator (0.75 T, 150 periods) is large enough for efficient injection, which is made at 0.8 GeV. The possible configurations of machine are discussed.

1 INTRODUCTION

DELSY is being constructed on the base of the accelerator facility, which is dismounted and transferred to Dubna from the Netherlands National Institute for Nuclear Physics and High Energy Physics (NIKHEF) in compliance with the agreement between NIKHEF and JINR. The NIKHEF accelerator facility consists of a linear electron accelerator MEA [1] with energy of electrons of 700 MeV and the electron storage ring AmPS with the maximum energy of 900 MeV and beam current of 200 mA [2].

The DELSY lattice is prepared in a way to use most of the AmPS ring magnetic elements but to change significantly optics and reducing in 1.5 times machine circumference.

The spectrum of synchrotron radiation from the DELSY dipole magnets lies in the range from the infrared radiation up to the hard X-ray radiation. The insertion of the "microundulator" in the DELSY ring increases the source brilliance up to $3 \cdot 10^{18}$ ph/(s·mm^2·mrad^2·0.1% bandwidth). The application of the superconducting wiggler with the magnetic field of 10 T, which is planned, to installation provides generation of the hard X-ray radiation of the photons with energy of 20-50 keV.

2 LINEAR OPTICS

Machine consists of 4 quadrants, every quadrant includes straight section for an insertion device. Three variants of a quadrant arrangement based on use of AmPS magnetic elements have been investigated with MAD program [3]:

1. The matching cell includes triplet and half of DBA cell, the arc consists of FODO cell.
2. The matching cell includes triplet and half of DBA cell, the arc consists of DBA cell.
3. The matching cell includes triplet and half of TBA cell (one more quadrupole added to easy matching); the arc consists of DBA cell.

The first variant of the ring optics provides emittance of 20 nm. In the second variant it decreases down to 11 nm, however 72 quadrupoles are required. The third variant allows one to reduce the number of periodic cells in the ring from 12 to 8 (two in every quadrant) with additional dipole added to the matching cell. The emittance is equal to 11 nm in this case also. But the number of quadrupoles is reduced to 64, which are well inside of 68 quadrupoles available from AmPS. The number of required sextupoles is reduced also. This variant has been chosen for the further development.

The periodic cell (Fig.1.) consists of two dipoles and three quadrupoles. The phase advance in the periodic cell is equal to $\mu_x = 0.43 \cdot 2\pi, \mu_y = 0.15 \cdot 2\pi$. The horizontal phase advance is determined by the condition of the horizontal emittance minimization, yet maintaining reasonable natural chromaticity.

The matching cell contains two dipoles and provides zero dispersion in the straight section. The particular values of the beta functions in straight sections are adjusted by use of doublet.

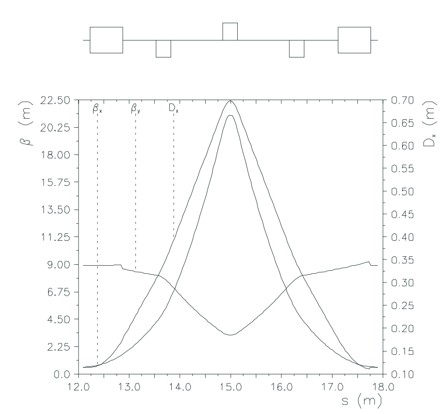

Fig.1: Lattice functions in the periodic cell.

The straight section lengths are equal to 7.2 m and 5.3 m. One of the two long straight sections is intended to house the wiggler and the first injection kicker while the other houses RF-stations and the second injection kicker. The undulator is placed in one of the shorter straight sections and the injection septum in the other one.

The beta functions in a very strong wiggler must be small enough to avoid emittance increase and to minimize optics distortion with wiggler on. In our case $\beta_x \leq 3\,m$, $\beta_y \leq 3\,m$ [4].

The vertical beta function in the center of the undulator must be small still keeping tolerable lifetime limited by the residual gas scattering. It was accepted $\beta_x = 14.1\ m$, $\beta_y = 0.8\,m$. Lattice functions for the undulator quadrant are showed in Fig.2.

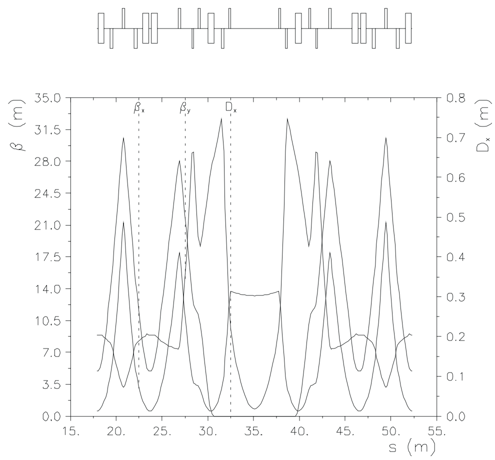

Fig.2: Lattice functions in the matching cell and the straight section for undulator.

In another undulator quadrant injection septum is placed. To relax requirements to its strength, the horizontal beta function in the centre of the straight section is big (about 25 m). The lattice functions for the quadrant with the injection septum are shown in Fig.3.

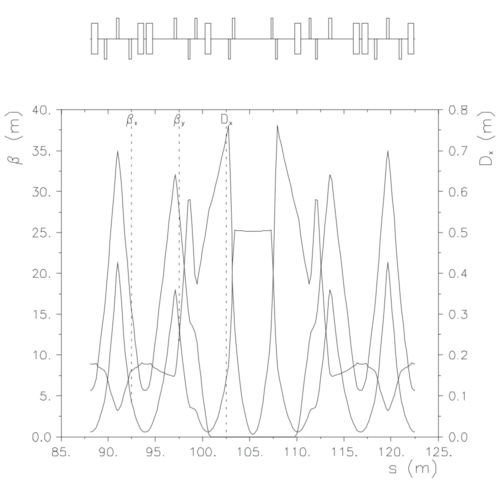

Fig.3: Lattice functions in the matching cell and the straight section for injection.

The main machine parameters are given in Table1.

Table 1. Main parameters of the DELSY ring.

Full energy, GeV	1.2
Injection energy, GeV	0.8
Circumference, m	140.546
Bending radius, m	3.3
Revolution period, µs	0.4685
Betatron tunes horizontal vertical	 9.58 3.56
Momentum compaction factor	$4.8{\cdot}10^{-3}$
Natural chromaticity, m Horizontal Vertical	 -21.3 -17.5
Injection current, mA	10
Stored electron current, mA	300
Horizontal emittance, nm	11.1
RF frequency, MHz	476
Harmonics number	223
Type of lattice	8 bend achromat
Number of bending magnets	32
Number of quadrupoles	64
SR characteristic energy, keV	1.16
Electron energy loss per turn, keV	55.7
SR power from the dipole magnets, kW	16.7

3 THE INFLUENCE OF THE WIGGLER ON THE LINEAR OPTICS

For the linear optics and dynamic aperture calculations with wiggler on the measured multipole components of the 7 T wiggler have been used [4]. The very strong wiggler produces great distortion of the linear optics. To maintain the same tunes with wiggler on and avoid increasing the number of matching quadrupoles the following procedure of the preparation of a linear optics has been applied. Initially, strengths of two quadrupoles in doublets matching wiggler section have been modified to maintain constraint ($\alpha_x = 0, \alpha_y = 0$) with wiggler on as well as with wiggler off. This prevents beating of a beta functions everywhere outside wiggler section. The same has been done for the undulator (0.75 T, 150 periods of 2.25 cm), but its effect on machine optics is much weaker. After this machine tunes change significantly. To bring them back as well as to maintain the required beta functions in the straight sections, the “global” matching procedure involving all matching doublets and three quadrupoles of the matching cell has been applied. As result, the deviation of the beta functions for machine with wiggler on from that one with wiggler off are less than 8%. The lattice functions in the wiggler quadrant with the wiggler on are shown in Fig.4.

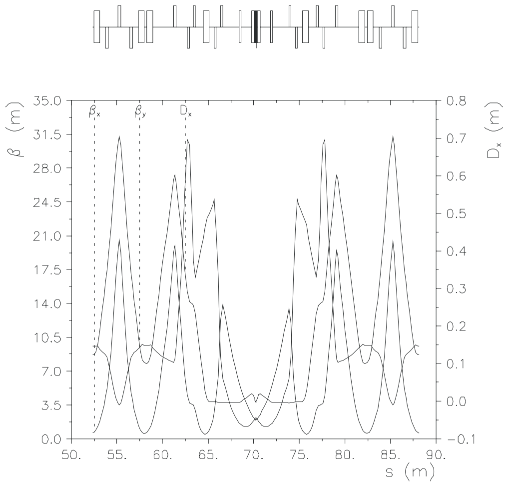

Fig.4: Lattice functions in the wiggler quadrant (wiggler is on)

4 DYNAMIC APERTURE

The injection energy for DELSY is 0.8 GeV, while operation is at 1.2 GeV. This put strong requirements to the dynamic aperture. The required dynamic aperture in the horizontal plane, expressed in the number N of standard deviation σ with the emittance of the injected beam 18.3 nm and the emittance of the circulated beam 4.9 nm at 0.8 GeV must fulfil $N_x > 29$. The dynamic aperture is equal to $74\sigma_x$ and $56\sigma_y$ respectively. It is shown for the machine without errors in Fig.5.

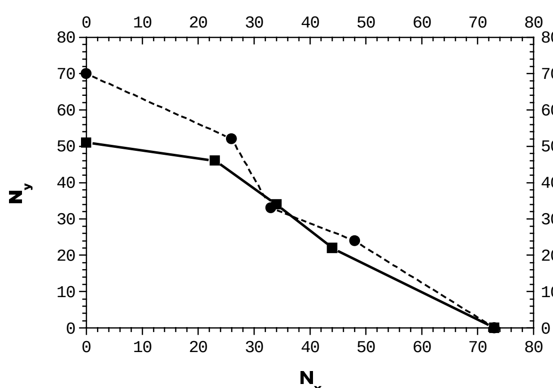

Fig.5: The dynamic aperture, expressed in a number of the standard deviations with the wiggler off (solid line) and on (dotted line).

The dynamic aperture in the horizontal plane is larger when the wiggler is on than off (Fig.5). The possible explanation is the following: the machine optics has the periodicity equal to one in both cases when the wiggler is on and off. But the bandwidths of the 3d-order resonance decreases when the wiggler is on. Moreover, the tune derivatives with amplitude are smaller when the wiggler is on.

The wiggler with the magnetic field of 7 T does damp, as the computing shows, and correspondingly the beam emittance with wiggler on is $\varepsilon_x = 10\,nm$, while with wiggler off it is $\varepsilon_x = 11\,nm$.

5 CONCLUSIONS

A 1.2 GeV synchrotron radiation source was proposed to be constructed at JINR, Dubna, Russia. Based on magnetic elements of AmPS, this synchrotron radiation source belongs to the third generation. Machine optics is designed in a way to install at least one very strong wiggler with magnetic filed about 10 T and one undulator. The expected emittance is 11 nm.

REFERENCES

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