BOOSTER DESIGN FOR THE ILSF*

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Abstract

A full energy 3 GeV booster synchrotron has been designed to boost the electron beam to the target energy of 3 GeV for the proposed third generation synchrotron light source (ILSF) that will be constructed in Iran. The primary goal of the ILSF booster is to design a synchrotron which can deliver a small emittance while at the same time has a low cost in construction.

INTRODUCTION

The main task for the injectors of the ILSF storage ring [1,2] is to generate and accelerate the electrons to the target energy of 3 GeV. The ILSF injector consists of four main systems.

- Linac
- Transfer line from linac to booster (LTB)
- Booster synchrotron
- Transfer line from booster to storage ring (BTS)

An electron beam produced with an electron gun, is accelerated by a travelling wave linear accelerator to the energy of 150 MeV. Electrons then enter the booster synchrotron via LTB transfer line. The booster accelerates the electron beam to the energy of 3 GeV using a radio frequency (RF) cavity with the frequency of around 500 MHz. After reaching to the target energy, the electron beam is transferred from the booster to the storage ring through a BTS transport line almost 40 m long.

In order to design lattice for the booster, two configurations for booster have been considered. In the first configuration, booster is designed based on locating in a separate tunnel as 3 GeV storage ring inside the ring and in the second configuration, the booster is optimized for placing inner to the ring with one shared wall as service area of the ILSF storage ring. Several types of lattice with various circumferences have been explored for the booster synchrotron in each configuration. In this paper, we introduce specifications of the candidate lattices for the booster synchrotron as the main part of injector system for the ILSF accelerator complex and give linear optimization results of the booster designs in both configurations.

LAYOUT OF THE ILSF BOOSTER

A full energy 3 GeV booster synchrotron has been designed to boost a 150 MeV electron beam, extracted from the linac, to the target energy of 3 GeV for the proposed Iranian third generation light source (ILSF). The performance requirements considered for a booster synchrotron are generally less stringent than those for a storage ring but more severe are demands for high efficiency beam injection and extraction into/from booster. The limitations on the dispersion and chromaticity in booster synchrotron are comparatively weak; as the electron beam circulates in the booster synchrotron for a very short time, lifetime is not an important issue and the booster is not itself a light source. The primary goal in the design of the ILSF booster is to deliver a small emittance (ε<30 nm-rad), while keeping the construction costs as low as possible. The small emittance is required for low loss at injection into the storage ring and efficient top-up operation. The low repetition rate of 2 Hz was chosen to avoid the induction of strong sextupole fields at the dipole vacuum chamber by eddy currents during the magnet ramping process.

In order to design a lattice for the booster, two configurations have been considered. In the first configuration, the booster has a circumference of 144 m and is placed in a separate tunnel inside the storage ring. The booster has 4 straight sections each with a length of 4.392 m for the accommodation of RF systems, extraction, and injection equipments. General layout of the ILSF booster is shown in Fig. 1.

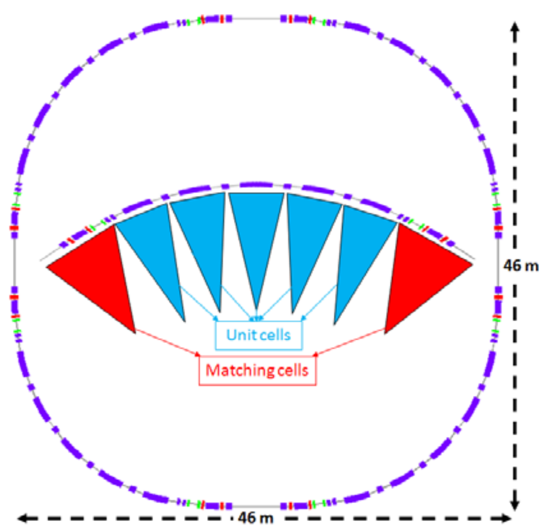

Figure 1: General overview of the ILSF booster.

A magnified view of one quadrant of the booster is shown as an inset at the center of Fig. 1. The magnetic lattice is comprised of four super-periods based on the FODO structure with dipoles, providing a small emittance and a high degree of flexibility with regards to injection, extraction and working tune point. Each super-period of the booster is composed of two matching cells and 5 unit cells. As depicted in Fig. 1, the matching cells are located

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at beginning and at the end of a super-period and the 5 unit cells are placed between the matching cells. Main parameters of booster and its dipole magnets are given in Table 1 and Table 2 respectively.

Table 1: Main Parameters of The ILSF Booster (1st Configuration)

Parameter	Value
Energy at injection (GeV)	0.15
Energy at extraction (GeV)	3
Circumference (m)	144
No. of super-period	4
Maximum current (mA)	10
Emittance (nm-rad)	13.451
Harmonic number	240
RF frequency (MHz)	500
Tune [Q_x/Q_y]	11.227/3.288
Nat. energy spread	1.0248E-3
Nat. Chromaticity [ξ_x/ξ_y]	-19.91/-8.89
Momentum compaction	5.167E-4
Radiation loss per turn (KeV)	823.4
Damping times[τ_x/ τ_y/ τ_s](ms)	2.25/3.50/2.42
Revolution frequency (MHz)	2.084

Table 2: Main Parameters of Dipole Magnet in The ILSF Booster (1st Configuration)

Parameter	Value
Magnetic field at injection (T)	0.057
Magnetic field at extraction (T)	1.150
Length [Matching/Unit cell] (m)	1.390/2.278
Deflecting angle [Matching/Unit cell] (Deg.)	7.5/15
Bending radius (m)	8.701
Quadrupole component (m^{-2})	-0.275
Sextupole component (m^{-3})	-3.136

The optical functions in quadrant of booster are shown in Fig. 2.

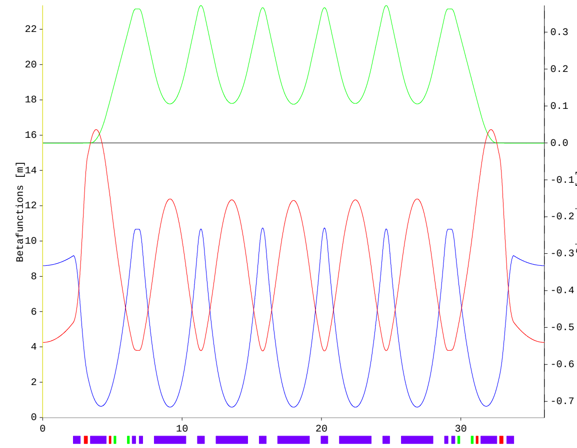

Figure 2: Optical functions in a quadrant of the ILSF booster (1st configuration). Blue and red curves represent horizontal and vertical beta functions respectively and the green curve remarks dispersion function.

In the second configuration, the booster is designed for being placed inside the storage ring sharing a wall with the storage ring's service area. The general layout of the booster in this design is shown in Fig. 3.

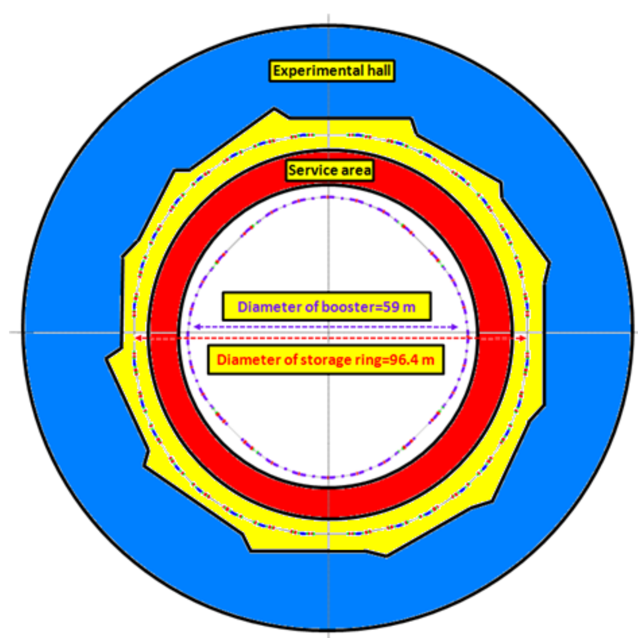

Figure 3: Layout of booster in second configuration.

As shown, the diameter of the booster is 59 m. Similar to first configuration; the booster has a four-fold symmetry. Each super-period starts and ends with two matching cells and there are 5 unit cells between them. The circumference of the booster in this design is 192 m and the length of the straight sections is 4.5 m. The main parameters of the booster in this design are given in Table 3. For linear and nonlinear optimization, one type of combined dipole magnet with sextupole component has been employed. All dipoles have the same sextupole component to correct the natural chromaticity of booster and nonlinear optimization. Unlike the dipoles in the first configuration, the dipoles in the second configuration have the same length and have no quadrupole component. Main parameters of dipole magnets are listed in Table 4.

Table 3: Main Parameters of The ILSF Booster (2nd Configuration)

Parameter	Value
Energy at injection (GeV)	0.15
Energy at extraction (GeV)	3
Circumference (m)	192
No. of super-period	4
Maximum current (mA)	10
Emittance (nm-rad)	32.42
Harmonic number	320
RF frequency (MHz)	500
Tune [Q_x/Q_y]	11.222/4.259
Nat. energy spread	8.478E-3
Nat. Chromaticity [ξ_x/ξ_y]	-19.87/-10.01
Momentum compaction	5.903E-4
Radiation loss per turn (KeV)	787.6
Damping times[τ_x/ τ_y/ τ_s](ms)	4.97/4.87/2.41
Revolution frequency (MHz)	1.56

Table 4: Main Parameters of Dipole Magnet in The ILSF Booster (2nd Configuration)

Parameter	Value
Magnetic field at injection (T)	0.055
Magnetic field at extraction (T)	1.110
Length (m)	1.190
Deflecting angle (Deg.)	7.5
Bending radius (m)	9.097
Quadrupole component (m^{-2})	0.0
Sextupole component (m^{-3})	-1.603

The linear parts of booster lattice have been optimized for several runs to find a tune point far away from the major resonance lines. The optical functions in a super-period of the lattice of booster are shown in Fig. 4. Unlike the first design, the dispersion function in the straight section is nonzero and has a low negative value of -0.0842 m. The associated working tune point within a tune diagram that includes the 5th order of resonance lines is shown in Fig. 5.

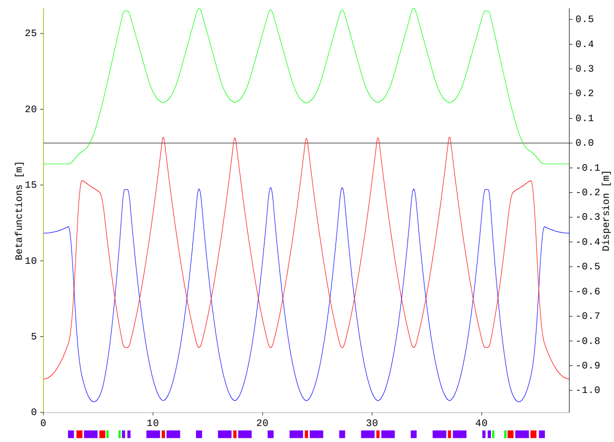

Figure 4: Optical functions in a quadrant of the ILSF booster (2nd configuration). Blue and red curves represent horizontal and vertical beta functions respectively and the green curve remarks dispersion function.

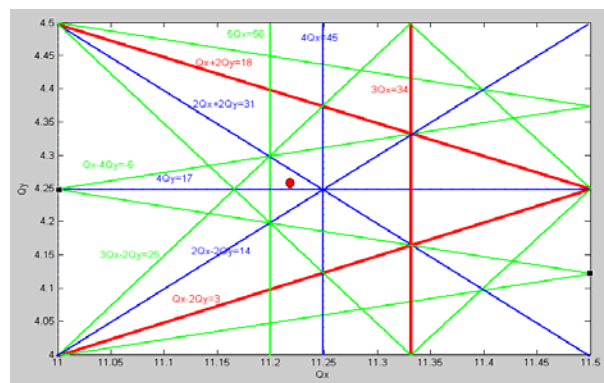

Figure 5: Tune point of the ILSF booster. The red circle represents the tune point in tune diagram with 5th order of resonance line.

This point for working tune is very good enough however we examined some other tune points near to this point and studied how the booster works.

REFERENCES

[1] J. Rahighi, *Proposal for a 3rd Generation National Iranian Synchrotron Light Source*, IPAC2010, Kyoto, Japan, WEPEA023, p. 2532 (2010).

[2] H. Ghasem et al., *Lattice candidates for the ILSF storage ring*, THPC024, this proceeding.