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INSERTION DEVICES FOR THE DAY-ONE BEAMLINES OF ILSF

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Abstract

Iranian Light Source Facility (ILSF) is a 4th generation light source under construction with a 3 GeV storage ring. The ILSF consists of seven different beamlines with linear polarization (i.e. X-ray Powder Diffraction (XPD) beamline, Single Crystal X-ray Diffraction (SXRD) beamline, EXAFS beamline, and Macromolecular Crystallography (MX) beamline) and variable polarization (i.e. Solid State Electron Spectroscopy (SSES) beamline, Spectromicroscopy (SM) beamline, and gas phase electron emission (ESCA) beamline). The insertion devices of ILSF beamlines with variable polarization are needed to be of helical types and the insertion devices with linear polarization are needed to be able to generate hard X-ray synchrotron radiation. In designing day-one ILSF beamlines, several different insertion devises are considered. The APPLE II types undulators, which are of the most operational undulators to generate soft X-ray synchrotron radiation with variable polarization in synchrotron machines [1], are considered as candidates for beamlines with variable polarization in ILSF. As candidates for hard X-ray beamlines with linear polarization, two in-vacuum undulators (IVU), one cryogenic permanent magnet undulator (CPMU), and one in-vacuum wiggler (IVW) are considered. In this paper, magnetic design and important parameters of the day-one beamlines of ILSF are presented.

INTRODUCTION

The storage ring (SR) of ILSF is a low emittance 3 GeV storage ring with 528m circumference and 20 super periods, which is based on a Five-Bend Achromat lattice providing an ultralow horizontal beam emittance of 0.27 nm-rad [2, 3]. In Table 1, beam parameters of ILSF storage ring in the middle of its straight sections are given and Table 2 lists the IDs required for the day-one ILSF beamlines. Their names include their period lengths in millimetre.

PHYSICAL CONSIDERATION

With regarding to the fact that each straight section in ILSF storage ring has 7.02 m long and 4.2 mm minimum vertical beam stay clear aperture in its middle, the minimum magnetic gap of in-vacuum undulators is considered to be 4.4 mm. In addition, the maximum magnetic length of in-vacuum undulators is considered to be about 6 m since approximately 1 m of magnetic length will be occupied with valves, absorbers, flanges and tapers. The helical undulators, i.e. APPLE II undulators, are chosen to be out of vacuum types undulators with a minimum magnetic gap of 11 mm and a maximum length of 6 m. The minimum magnetic gap and the maximum magnetic length of in-vacuum Wiggler are also considered to be 4.4 mm and 6 m, respectively.

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Table 1: Beam Parameters of ILSF Storage Ring in the Middle of its Straight Sections [2]

Parameter	Value
Beam Energy	3 GeV
Beam current	100 mA
Energy Spread	6.79×10^{-4}
Horizontal Emittance	0.26 nm-rad
Vertical Emittance	0.00267 nm-rad
Horizontal Beta function	17.787 m
Vertical Beta Function	3.294 m
Horizontal Beam Size (rms)	68.9 μm
Vertical Beam Size (rms)	2.96 μm
horizontal beam divergence (rms)	3.87 μr
vertical beam divergence (rms)	0.9 μr

UNDULATORS

Because of smaller electron beam emittances in a 4th generation light source facility, brilliance can be enhanced until the diffraction limit is reached. To reach higher brilliance as well as higher photon flux in a 4th generation light source, using of undulators is necessary.

APPLE II type undulators are of the best candidates for generating soft X-ray with non-linear polarization. To generate hard X-ray synchrotron radiation, it is necessary to use standard undulators (undulators with K>2) with short period length. In order to keep the magnetic gap of an insertion device small enough to reach higher magnetic peak field, it is necessary to use in-vacuum undulators. In order to generate synchrotron radiation with wide range of energy spectrum, it is also necessary to use an undulator with higher harmonics. CPMUs with respect to their high magnetic field quality are of the best candidates for undulators with higher harmonics [4, 5].

Table 2: Names and Types of Day-one ILSF Beamlines Insertion Devices

Beamline	Spectral Range	ID name	Type
XPD	6-30 keV	U17	CPMU
SXRD	5-25 keV	U20	IVU
EXAFS	3-35 keV	W44	IVW
ESCA	15-1000 eV	U110	APPLE II
SSES	10-1000 eV	U114	APPLE II
SM	100-1500 eV	U60	APPLE II
MX	3-25 keV	U18	IVU

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In-vacuum Hybrid Undulators

For the SXRD and MX beamlines, two in-vacuum undulators are modelled. For example, the undulator of MX beamline, i.e. U18 undulator, is a hybrid type in-vacuum undulator with NdFeB (B_r = 1.22 T) magnets and soft iron poles. The dimensions of U18 magnets are $65 \times 6.8 \times 24\ mm^3$ and the dimensions of its poles are $50 \times 2.8 \times 20\ mm^3$. In addition, its vertical physical aperture is 4.2 mm and there is a 0.1 mm thick sheet covering its pole faces, which results in magnetic aperture of 4.4 mm. The magnetic field of U18 is modelled by the computer code Radia [6]. In Figure 1, the magnetic model of U18, and in Table 3, its several important parameters are given.

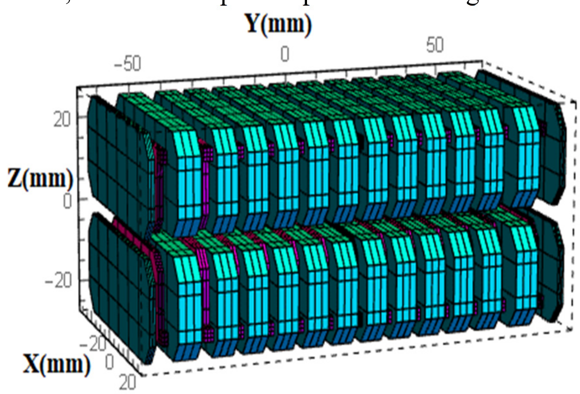

Figure 1: The magnetic model of U18 by Radia code [4].

Cryogenic Permanent Magnet Undulator

To generate hard X-ray synchrotron radiation with wide energy spectrum and with overlapping harmonics, higher magnetic field with higher quality is required. CPMUs operate at temperatures lower than 150 K and therefore produce higher magnetic field with higher quality. For the XPD beamline, a CPMU undulator (i.e. U17, with parameters given in Table 3) is modelled. The permanent magnets of U17 are considered to be of NdFeB magnets with B_r = 1.22 T and dimensions of $65 \times 6.4 \times 20\ mm^3$. The dimensions of U17 poles are considered to be $40 \times 2.1 \times 15\ mm^3$. In Figure 2 the magnetic model of U17 is presented.

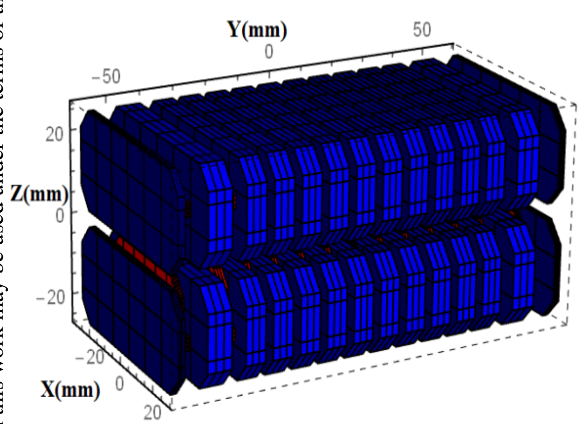

Figure 2: Magnetic model of U17 undulator, modelled by Radia [4].

Elliptically Polarizing Undulators

In the first phase of operation, ILSF works with three soft X-ray beamlines with nonlinear polarization. APPLE-II undulators are more likely to be installed in these three beamlines. In Table 3, the important parameters of the three APPLE II undulators, i.e. U60, U110, and U114, with different period lengths are given. The magnetic model of U114 is presented in Figure 3. The magnetic material in this model is chosen to be NdFeB with 1.17 T remanence field and the dimensions of the magnets are considered to be $40 \times 28.5 \times 35\ mm^3$.

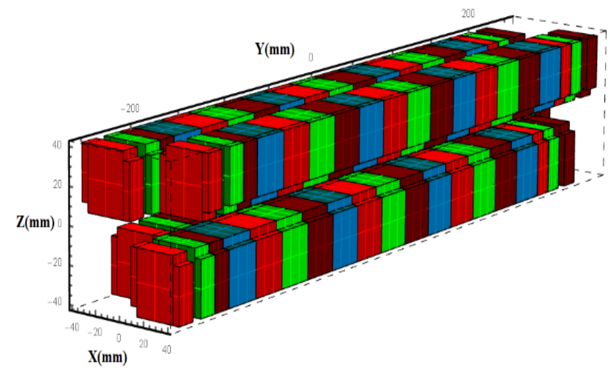

Figure 3: Magnetic model of U114 undulator, modelled by Radia [4].

Table 3: Important Parameters of ILSF Insertion Devices

ID name	ID Type	λ_u mm	K_{max} K_x	K_{max} K_y	L (m)	g_{min} mm
W44	IVW	44	8.53	0	2.2	4.5
U17	CPMU	17	1.79	0	2.3	4.4
U18	IVU	18	2.13	0	2	4.4
U20	IVU	20	2.3	0	2	4.4
U60	APPLE II	60	3.64	3.64	2	11.8
U110	APPLE II	110	8.85	8.85	3	12
U114	APPLE II	114	9.07	9.07	2	12

WIGGLER

In the first phase of operation, only one wiggler will be used in ILSF storage ring, i.e. in EXAFS beamline. The EXAFS beamline requires such a wide range of photon spectrum (3-35 keV) that an in-vacuum wiggler, due to some technical aspects and considerations, is investigated. This in-vacuum wiggler (IVW) could be either of hybrid or superconducting types. Since a hybrid IVW is more economical and less complicated to be built, the hybrid type is chosen for the EXAFS beamline.

Hybrid Type Wigglers

In magnetic design and modelling of hybrid IVW by Radia [4], the magnetic material is considered to be NdFeB with $B_r = 1.22\ T$ and poles are considered to be of Vanadium Permendur blocks. The magnets dimensions are also $70 \times 13 \times 45\ mm^3$ and the dimensions of the poles are $70 \times 9 \times 45\ mm^3$. Other important parameters of the hybrid IVW, i.e. W44 wiggler, are listed in Table 3. Figure 4 shows the magnetic model of W44 wiggler.

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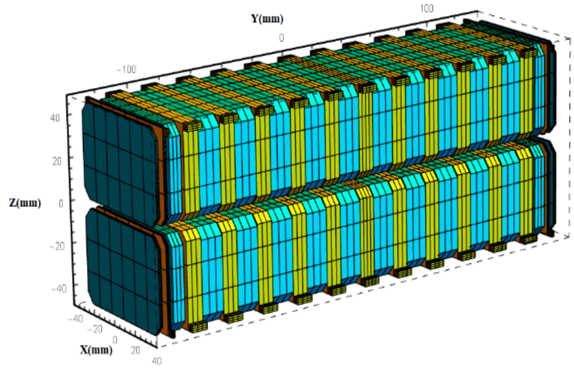

Figure 4: Magnetic model of W44 wiggler, modelled by Radia [4].

SUMMARY

Seven different types of insertion devices are modelled for the ILSF beamlines and their important parameters are listed in Table 3. These insertion devices and their parameters are chosen based on user demands. The modelled insertion devices are three APPLE II undulators, two in-vacuum undulators, one hybrid in-vacuum wiggler, and one cryogenic permanent magnet undulator.

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