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MAGNETIC DESIGN OF THE FIRST PROTOTYPE PURE PERMANENT MAGNET UNDULATOR FOR THE ILSF

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Abstract

Iranian light source facility (ILSF) is a 3GeV, 400 mA, 3rd generation light source under design and construction. This paper describes the details of the preliminary magnetic design of the first prototype PPM undulator for the ILSF. In the preliminary design, the undulator period and some other parameters have been determined to reach desired x-ray spectrum to be used for soft x-ray application. A PPM layout and a model undulator with 8-periods are used to calculate the properties of the designs.

INTRODUCTION

Intermediate light sources are usually using bending magnet or undulator as soft x-ray radiation source. Soft x-ray radiation has a wide range of interesting applications, including biological x-ray microscopy, x-ray proximity lithography, holography, etc [1]. Pure permanent magnet undulator is a good candidate to getting soft x-ray radiation with high brilliance. For transmission x-ray microscopy, one needs a spectrum in the typical energy range between 250 and 1500 eV (wavelength range 1-5 nm). Therefore, we have decided to design an undulator with sufficient high brilliance for collection of high resolution data in the ILSF. Hybrid structure has been used to reach higher harmonics (i.e., for protein crystallography).

DESIGN CALCULATIONS

The design calculations have been done using RADIA [2]. The optical characteristics of the radiation have been evaluated by the SPECTRA [3] code. The 16 poles undulator has been modeled as central section and the end section has been chosen ESRF type B end section to terminate the field [4].

MAGNETIC DESIGN

The permanent magnet dimensions have been determined according to some considerations. The period of the undulator depends on the thickness, the on-axis maximum flux density depends on the height and the transverse roll-off depends on the width of the magnet. The width of end section magnets is half of central section magnets. The main permanent magnet parameters have been listed in Table 1. The PPM undulator parameters have been shown in Table 2.

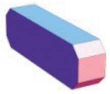
PM block and 16 poles model of undulator is shown in Fig. 1. The end section magnets have half thickness of the main magnet. By symmetry, the first field integral is an even function of the x-coordinate and the odd integrated multipoles are zero. This is a benefit of PPM undulators. A 5 mm chamfer has been added to each corner of all magnet blocks. This preserves the symmetry in the block, reduces demagnetization in the corners and allows for mechanical clamping of the block into their holders. Its influence over the field inside the magnetic gap is negligible.

Table 1:Permanent Magnet Main Parameters

Material	NdFeB
B_r (T)	1.18
H_{ci}(kA/m)	1900
Width (mm)	60
Height (mm)	30
Thickness (mm)	15

Table 2:Undulator Main Parameters

Parameter	**unit**
Period [mm]	60
Min/Max gap [mm]	10/40
Length [m]	1
K value	1.23-6.38


(a)


(b)

Figure 1: (a) Main PM block with chamfers on corners and (b) 8-periodsundulator model.

The on-axis magnetic flux density is shown in Fig. 2. For minimum gap value (10 mm) the maximum magnetic flux density is 1.13 T.

The brilliance of undulator has been shown in Fig. 3. This spectrum covers the water window wavelengths needed for soft x-ray transmission microscopy application with the appropriate brilliance.

As design consideration, 15 mm is assumed for the good field around the undulator central axis and the magnetic field deviation from central field would not exceed 0.8%. Figure 4 shows the transverse roll-off of the undulator for different gap values.

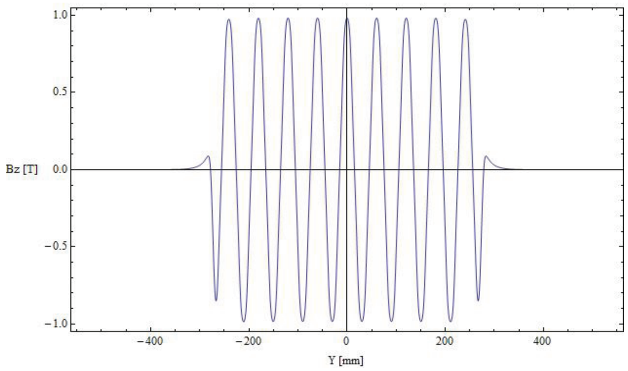


Figure 2: On-axis magnetic flux density for an eight periods central model.

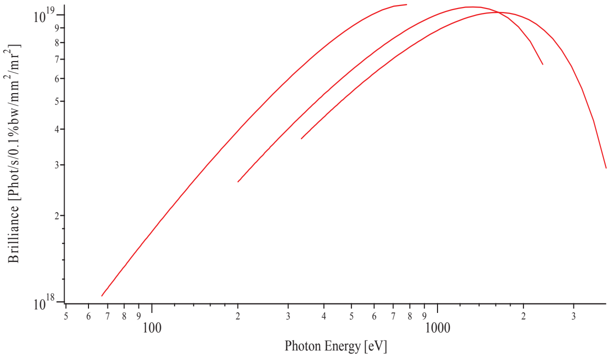


Figure 3: Undulator brilliance tuning curve for the first five harmonics.

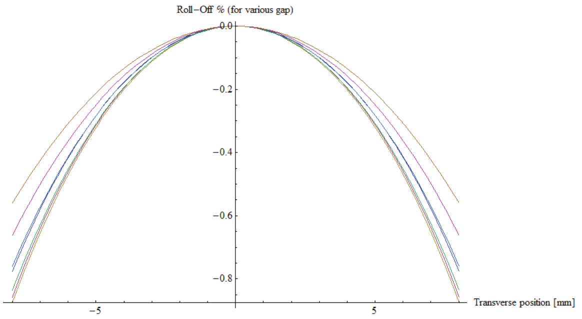


Figure 4: The transverse roll-off for different gaps.

The gap length has been varied between 10-40 mm according to vacuum consideration and beam line specifications. According to these specifications, it is possible to use gap values less than 10 mm but it is not necessary for desired application. Figure 5 shows the orbit for a 3 GeV electron through model undulator. ESRF B-type end section is chosen to reduce horizontal offset of electron orbit at the exit of undulator.

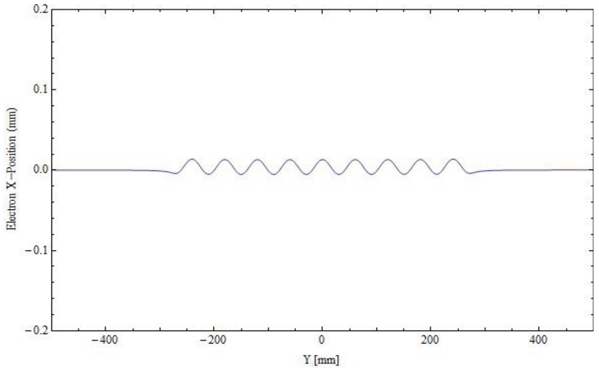


Figure 5: The 3 GeV electron trajectory at the center of the ideal undulator.

1ST AND 2ND FIELD INTEGRAL

The tolerances of this section require future input from the ILSF technical accelerator people. In the interim, we use the constraint that the rms closed orbit distortion around the ring circumference should be 1/10 of the rms beam size over a full gap range of 10 to 40 mm which yields the following relationships to the first and second field integrals. We note that the typical values achievable for the first and second field integrals.

$$\left|I_x, I_y\right| \le 50\ G.cm$$

$$\left|J_x, J_y\right| \le 5000\ \ G.cm^2$$

$$I_y[G.cm] \le 30\,E[GeV]\sqrt{\frac{\varepsilon_x[nm]}{\beta_x[m]}}\,\mathrm{Sin}(\pi\nu_x) = 72\ \ G\,cm$$

$$I_x[G.cm] \le 30\,E[GeV]\sqrt{\frac{\varepsilon_z[nm]}{\beta_z[m]}}\,\mathrm{Sin}(\pi\nu_z) = 15\ \ G\,cm$$

$$J_x\,[G\,cm^2] \le 3000\,E[GeV]\sqrt{\varepsilon_z[nm]\beta_z[m]}\ \mathrm{Sin}(\pi\nu_z) = 1997\ \ G\,cm^2$$

$$J_y\,[G\,cm^2] \le 3000\,E[GeV]\sqrt{\varepsilon_x[nm]\beta_x[m]}\ \mathrm{Sin}(\pi\nu_x) = 14467\ \ G\,cm^2$$

In the above expressions, we have the variables I, J, E, ε , β , ν , which are the first field integral, second field integral, beam energy, beam emittance, beta function, and tune in the two transverse coordinates [5]. The first and second field integrals are the angle and offset with respect to the central orbit as the electron exits the undulator. The horizontal first and second field integral in the magnetic midplane are zero due to symmetry. The first field integral is less than ± 1.8 G-cm (± 1.8×10-6 Tm) and the second is less than ± 180 G-cm2 (± 180 ×10-8 Tm2) for a full gap range of 10 mm to 40 mm.

CONCLUSION

ILSF is a 3rd generation light source and among some planed beam lines, for the soft x-ray transmission microscopy application one need a PPM undulator with sufficient brilliance. The first PPM undulator for the ILSF has been designed magnetically. This is our first experiment on design and construction of insertion devices. This magnetic design will be used to construction of a prototype model of a PPM undulator for soft x-ray application and we hope reporting it at future conferences.

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