HELICAL UNDULATOR AS A SOURCE OF SPECTROMICROSCOPY BEAMLINE OF ILSF

S. Amiri, A. Gholampour Azhir, M. Lamehi Rachti, M. Jafarzadeh, J. Rahighi
Iranian Light Source Facility (ILSF), Institute for Research in Fundamental Sciences, Tehran, Iran

Abstract

Spectromicroscopy (SM) beamline is planned to be one of the day one beamlines of the Iranian Light Source Facility project (ILSF) in the field of soft x-ray spectroscopy and microscopy [1]. It includes of two branches: PEEM and SPEM. Regarding user requirements such as high flux, small spot size, linear and circular polarization light, a helical undulator have been selected as a source for this beamline. This paper shortly shows source radiation calculations by theoretical formula and using SPECTRA code.

INTRODUCTION

Spectromicroscopy beamline is one of the day one beamlines of Iranian Light Source Facility that is devoted to the photoemission electron microscopy, x-ray magnetic circular dichroism as well as x-ray magnetic linear dichroism. Regarding these techniques, it is necessary to have linear and circular polarized light. Because of it, the helical undulator has been selected as a source of the beamline. In this paper, radiation properties of the source which have been calculated by the theoretical formula and SPECTRA code are presented.

HELICAL UNDULATOR

The PPM (Pure Permanent Magnet) APPLE-II helical undulator proposed as a source of SM beamline has a length of 1.67 m and a period length of 6.18 cm. It is capable to produce linear (horizontally and vertically) and circular polarized light. The summary of the source parameters is given in Table 1. K_x and K_z are the standard deflection parameter of the undulator which is proportional to the undulator period and the magnetic field in the horizontal and vertical directions respectively. The flux in the central cone and the brilliance in the maximum K as well as the total power radiated to all angles and all harmonics at nominal current of 400 mA are listed for the circular and linear polarization modes.

Undulator Tuning Curves

The tuning curves of the source into the central radiation cone ($\theta_{Cen}(K_{Max})$= 86.28 μrad) for the linear polarization in the 1st and 3rd harmonic, and the circular polarization in 1st harmonic are illustrated in Fig. 1. It has been calculated by SPECTRA code [2]. In the case of the circular polarization, the 1st harmonic covers the energies in the 100-1300 eV energy range and in the linear polarization mode energy ranges, 100-1000 eV and 1000-1500 eV, are provided by 1st and 3rd harmonic respectively.

Table 1: Parameters for the Helical Undulator Source

Parameter	Value	
Period length (mm)	61.8	
Number of periods	27	
Polarization mode	Linear (H&V)	Circular
Energy (eV)	100-1500	100-1300
Max. Undulator strength, K_x	0	3.6
Max. Undulator strength, K_z	5	3.6
Photon energy (n=1, K_{Max})	100 eV	100 eV
Central cone half-angle (K_{Max})	86.3 μrad	86.6 μrad
Flux in central cone (ph/s) @ K_{Max}	2.4×10^{16}	4.5×10^{16}
Max. Brilliance (ph/s/mrad^2/mm^2/0.1% B.W.), (n=1, K_{Max})	3.2×10^{18}	6.1×10^{18}
Total power (K=, all n, all θ)	2.93 kW	2.98 kW

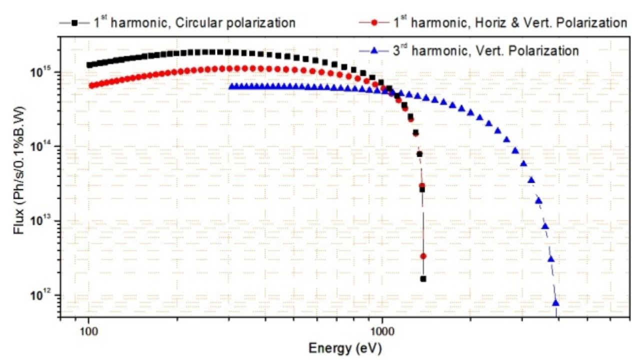

Figure 1: Tuning curves of the helical undulator source of SM, into central radiation cone. linear polarization: 1st and 3rd harmonics, circular polarization: 1st harmonic

Source Size and Divergence

Size and divergence of the electron beam at a low beta straight section which is reported by beam dynamic group are given in Table 3 [3].

Table 2: Size and Divergence of the Electron Beam

RMS	RMS
Electron beam X size (μm)	92.98
Electron beam Z size (μm)	3.70
Electron beam X divergence (μrad)	5.13
Electron beam Z divergence (μrad)	1.29

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The horizontal and vertical source size and divergence of the photon beam are shown in Figure 2 and Figure 3, respectively, for the required energy range of the beamline. As illustrate, the horizontal source size is limited by the electron beam size and because of that it is almost constant in the whole energy range. While the vertical source size as well as the horizontal and vertical divergences are determined by the diffraction limit. The vertical source size differs from 6 μm at 1500 eV to 16 μm at 100 eV.

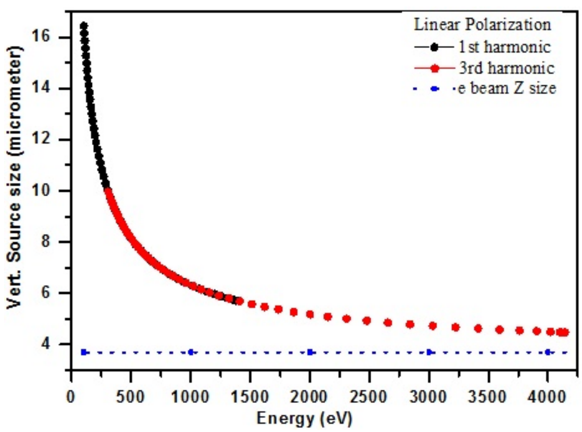

Figure 2: Vertical source size versus photon energy. Black and red refer to 1st and 3rd harmonic of the source.

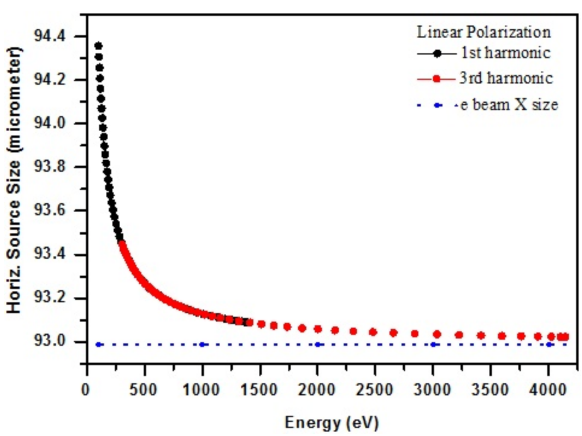

Figure 3: Variation of horizontal source size in the function of the energy. Black and red refer to 1st and 3rd harmonic of the source

Power

As shown in Table 3, maximum total power is emitted in the maximum deflection parameter of the source and it is P_{tot}= 2.93 kW @ (K_{Max}= 5.07) and P_{tot}=2.95 kW @ (K_{Max}= 3.6) in the linear and circular polarization mode, respectively. Regarding the pinhole with the central cone opening angle, the maximum power emitted by the source is about 176W at 100 eV and 26W at 814 eV for linear and circular polarization mode respectively.

Table 3: Total Power and Peak Power Density Emitted by the Source in Three Main Polarization Modes (Horizontal, Vertical, and Circular)

Peak power density ($kW/mrad^2$) @400 mA	**Total power (kW) @ 400 mA**	**Polariz. Mode**
8.3 @ E=100 eV	2.932	Horizontal
8.3 @ E=100 eV	2.932	Vertical
1.12 @ E=923 eV	2.95	Circular

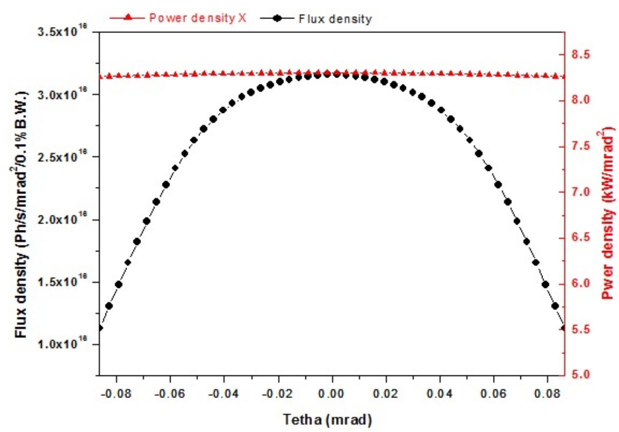

Figure 4: The horizontal flux density and horizontal power density have been obtained by SPECTRA thorough the undulator central cone in the case of vertical polarization.

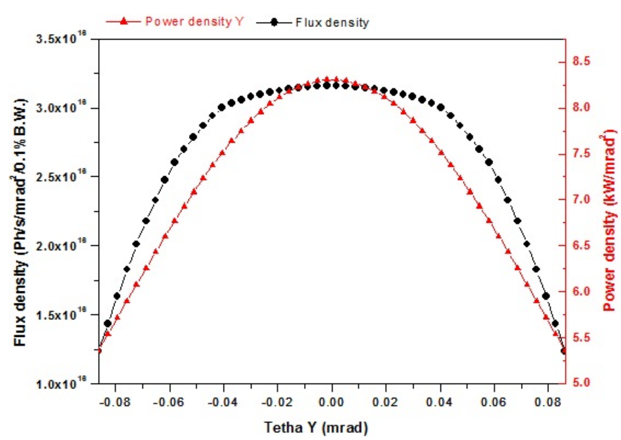

Figure 5: The vertical flux density and vertical power density have been obtained by SPECTRA thorough the undulator central cone in the case of vertical polarization.

For determining source aperture, the angular distribution of the flux density and power density have been investigated for all the polarization mode by using SPECTRA code. As you can see, for the vertical polarization at the maximum K in the horizontal and vertical directions are shown in Figure 4 and Figure 5 respectively. In the case of circular polarization, the emitted power is into the cone with opening angle of K/γ. For the large K, the on axis power density is reduced therefore delivered power to the beamline can be also reduced [4,5]. Because of it, by choosing proper aperture size of the source, it is possible to have more flux without the high value of power on the beamline components [6,7]. Angular distribution of the flux (a) and power emitted (b) around the axis of the undulator in the circular polarization is represented in Figure .

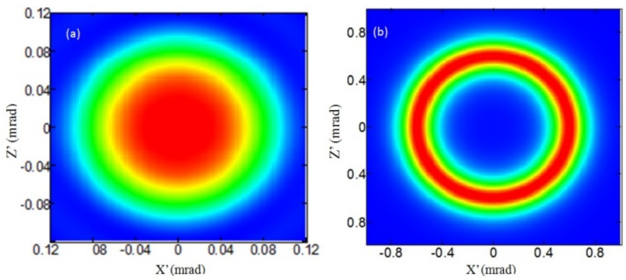

Figure 6: On axis angular distribution of the flux (a) and on axis angular distribution of the power (b) of the undulator in the circular polarization mode.

Considering tradeoff between proper value of power and flux of beamline for maximum of K at linear polarization mode, circular pinhole have been calculated and shown in Figure . The labels indicate the pinhole acceptance. The triangle labels, 2θ= 173 and 270 μrad represent central cone opening angle and opening angle in which 90% of the flux accepted by the beamline.

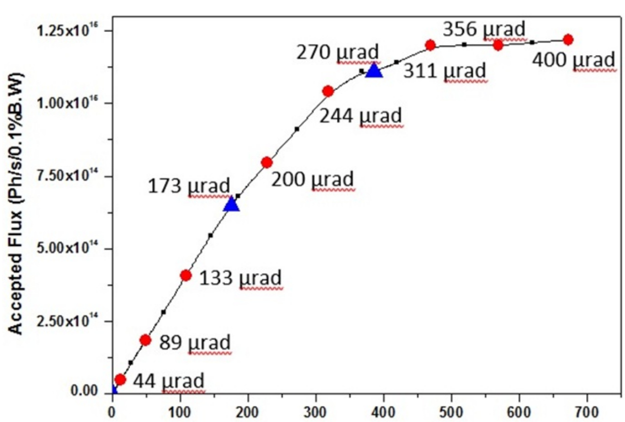

Figure 7: Tradeoff between Power and flux accepted for maximum K value at linear polarization mode

In the maximum and minimum K value, the energy, opening angle of the source aperture and accepted photon flux of the 1st and 3rd harmonics for the linear and circular polarization are listed in Table 4 and Table 5 respectively.

Table 4: Characterization of the Source Aperture in the Linear Polarization Mode

Linear polarization mode	**K=5.07**	**K=1**
1st. Harmonic, energy (eV)	100	901
Flux (ph/s/0.1%B.W)	1.11×10^{15}	6.52×10^{14}
Opening Aperture R (mm)	1.37	0.5
2θ (mrad)	0.27	0.1
Flux (ph/s/0.1%B.W)@Central cone	6.5×10^{14}	3.44×10^{14}
3rd. Harmonic, energy (eV)	299	2744
Flux (ph/s/0.1%B.W)	5.92×10^{14}	1.04×10^{14}
Opening Aperture R (mm)	0.74	0.35
2θ (mrad)	0.15	0.07
Flux (ph/s/0.1%B.W)@Central cone	6.24×10^{14}	8.62×10^{13}

Table 5: Characterization of the Source Aperture in the Circular Polarization Mode

Circular polarization mode	**K=3.6**	**K=0.5**
1st. Harmonic, energy (eV)	97	1083
Flux (ph/s/0.1%B.W)	2.02×10^{15}	4.61×10^{14}
Opening Aperture R (mm)	1.28	0.44
2θ (mrad)	0.13	0.09
Flux (ph/s/0.1%B.W)@Central cone	1.23×10^{15}	2.46×10^{14}

CONCLUSION

Regarding user requirements such as the high flux, small spot size, and the linear and circular polarization light, a helical undulator have been selected as a source for the spectromicroscopy beamline. The proposed undulator is capable to produce horizontally and vertically polarized light as well as circular one. The calculations by using theoretical formulas, and SPECTRA have been done for tuning curve, divergence, spot size, power and flux density.

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