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PHOTOEMISSION ELECTRON MICROSCOPY BRANCH OF SPECTROMICROSCOPY BEAMLINE OF THE IRANIAN LIGHT SOURCE FACILITY

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Abstract

Spectromicroscopy (SM) beamline is planned to be one of the day one beamlines of the Iranian Light Source Facility project (ILSF) to open high impact research investigations in the field of soft x-ray spectroscopy and microscopy for the Iranian and regional users. This beamline offers the possibility of performing photoelectron emission microscopy (PEEM) and scanning photoelectron microscopy (SPEM) to a large community of users including researchers working on nanomaterials, strongly correlated electron system, catalysis, etc, and related industries and companies. This beamline includes of two branches: PEEM and SPEM. This paper shortly reports first optical design of the PEEM branch by ray tracing calculations using XOP and SHADOW standard codes [6].

INTRODUCTION

Iranian Light Source Facility project has been initiated since 2010 in order to design and construction of a third generation synchrotron facility for developing basic and engineering researches in Iran. In parallel with the design and construction of the storage ring a scientific division has been organized to reach the purpose of capacity building, organizing the users' community, design and construction of the ILSF beamlines. Seven day-one beamlines with its specifications has been specified by the users' community [1]. Spectromicroscopy beamline is one of the most priorities in ILSF beamlinesdue to its wide range of applications and big potential user community in Iran. The SM beamline will be devoted to the photoemission spectroscopy techniques and will have two end stations in two independent branches: one for PEEM measurements and the other for scanning transmission x-ray microscopy. At this paper we report the ray tracing calculation of the PEEM branch of the beamline.

BEAMLINE OVERVIEW

This beamline is devoted to the soft x-ray spectroscopy in the 90-2500eV energy range with about 8000 energy resolving power, and the minimum spot size of about 10×4 μm^2 at sample position. Main characteristics of ILSF SM beamline are presented in Table 1.

Source

The source of this beamline is selected as a pure permanent magnet linear undulator with a length of 4.3 m and a 6.6 cm period length [3]. The important source parameters are given in Table 2. A helical undulator with capability of polarized light production could be considered as a source if the users need the linear or circular polarized light.

Table 1: The Main Characteristics of the Beamline

Parameter	Value
Source	Linear Undulator
Optics	Varied included angle PGM- KB bendable mirrors
Photon energy range	90-2500 keV
Energy resolving power	8000 @ 1000 eV
Beam size at sample, H×V (FWHM) μm^2	4×2 - 74×27
Beam divergence at sample, H×V (FWHM) mrad^2	2.8×0.97

Table 2: Parameters for the Linear Undulator Source at K_{max}.

Parameter	Value
Period length (mm)	66
Number of periods	65
Max. Undulator strength, K_{max}	5
First harmonic energy (eV)	96
Max. Photon flux (ph/s/0.1%BW@400mA) at 96 eV	3.04×10^{15}
Max. Brilliance (ph/s/mrad^2/mm^2/0.1% B.W.) at 773 eV	1.2×10^{20}

The tuning curves for the flux delivered by the source through the circular aperture ($2\theta_{Central\ cone}$= 152 μrad), calculated by the Spectra code [5], are shown in Figure 1.

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As can be seen, the first harmonic covers the energies in the 90-800 eV range with the flux of 3×10^{15}-2×10^{15} ph/s/0.1%B.W., and the third and fifth harmonic covers the rest of the energy range, till 2500 eV, with the flux of 3×10^{14} ph/s/0.1%B.W at 2500 eV.

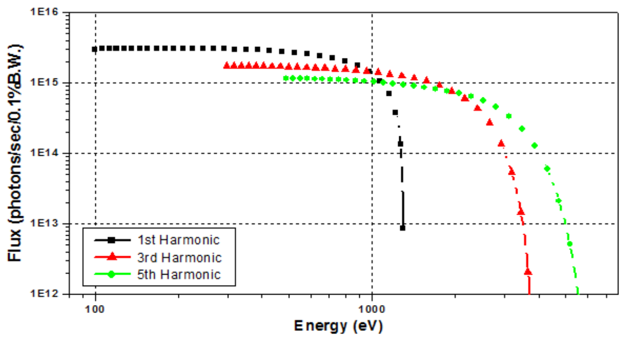

Figure 1: Calculated photon flux of linear undulator (from table 1) for ILSF, emitted in central cone at tuned energy for the 1st, 3rd, and 5th harmonics.

Source Size and Divergence

Figure 2 shows the energy dependence of the source size and its divergence. The horizontal dashed lines represent these parameters for the electron beam. The lower and upper data in each figure represents the vertical and horizontal directions, respectively. One can see easily that the horizontal source size is almost energy independent in the whole energy range, and it is equal to the electron beam size. Our calculations show that the vertical source size is mainly determined by diffraction limit that it is a function of the undulator length and photon beam energy, and is almost independent of the electron beam [2]. The horizontal and vertical source divergences are also determined by the diffraction limit respectively at the low energies and at the whole energy range. For example, the vertical divergence changes from 40.2 µrad at 96 eV to 6 µrad at 2500 eV.

Optical Layout

Figure 3 shows a primary layout of PEEM branch of the beamline includes of two main parts: 1) varied included-angle plane grating monochromator (PGM) SX700-type [4] consist of a horizontally deflecting spherical cylinder mirror, the plane mirror, plane grating and the troidal mirror, and 2) refocusing system consist of a KB bendable elliptical cylinder mirror.

Spherical Cylinder Mirror

The first optical element, M_1, located at 20 m from the source is a spherical sagittal cylinder mirror which horizontally deflects the incoming beam at 88.5°grazing angle. This mirror collimates the beam vertically. The mirror reduces the vertical divergence of the beam from 38.6 µrad to1.36 µrad at 96 eV. It has significant effect of increasing the energy resolving power. The incidence angle of the other mirrors has been specified to be 88.5° as a compromise between the high reflectivity and the mirror length in the whole energy range. Also all mirrors and gratings have Au coating.

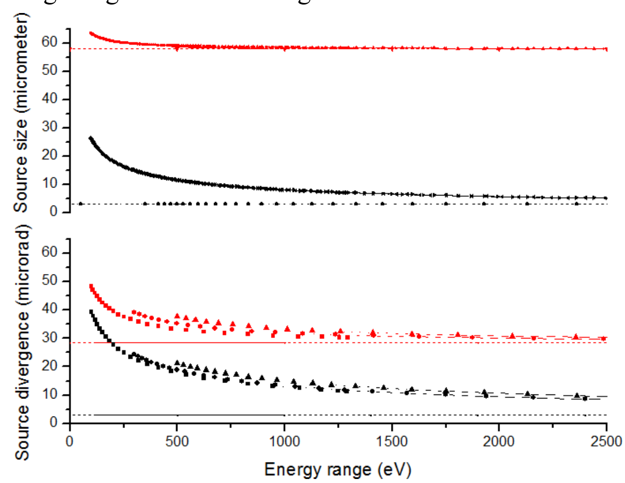

Figure 2: Spot size and divergence of the source. In each figure the lower and upper data refer to vertical and horizontal dimension respectively. In the spot size curves, all the first, third and fifth harmonics overlap each other.

Plane Mirror and Gratings

The second optical element, M_2, is the plane mirror for deflecting the central ray of light coming from M_1 to the center of the grating. Three different gratings with different line density have been used to cover whole the energy range: 1) line density of 700 l/mm covering energy from 66-600 eV, 2) line density of 900 l/mm covering energy from 500-1500 eV, and 3) line density of 1200 1/mm covering energy from 1000-2500.

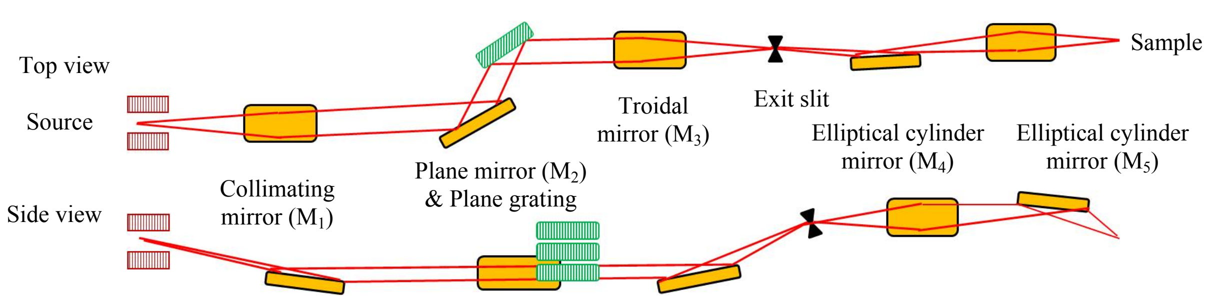

Figure 3: The layout of SM beamline including of the varied-included angle PGM, consist of a collimating mirror; a plane mirror; three plane gratings; a troidal mirror, and a KB pair for refocusing.

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Troidal Mirror

The primary focusing both sagittally and meridionally is performed through the horizontally deflecting troidal mirror. In the horizontal and vertical directions, the source of the beamline and the virtual image of the gratings become the source of the troidal mirror, respectively. The vertical demagnification of the mirror has significant influence on the energy resolution. Also because of the troidal geometry of the mirror, there is an astigmatism aberration on the image. The sagittal radius of the troidal mirror, ρ=23.47 cm, has been determined by optimizing the energy resolution and the image quality of the troidal mirror. The focused beam image onto the exit slit and the resolution is shown in Figure 4 and Figure 5.

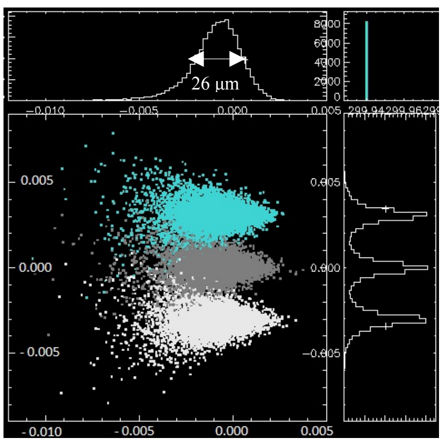

Figure 4: The spot size of the beam onto the exit slit.

Refocusing

Regarding the need of the small spot size onto the sample, the refocusing system have been chosen to be the KB mirrors, containing of two bendable elliptical cylinder mirrors. The first one, M_4, is the horizontally refocusing mirror which is located at a distance 503.13 cm from the exit slit with a demagnification of 3.5. The vertically refocusing mirror, M_5, is 60 cm downstream of M_4 and demagnifies the horizontal direction of the beam by factor of 6. The vertical spot size at the sample is changed from the 4 μm to 27 μm through changing the radius of the horizontally focusing mirror from 5.99 cm to 5.94 cm and the horizontal spot size of the mirror is changed from 2 μm to 74 μm by changing the radius of the vertically focusing mirror from 7.13 cm to 7.05 cm.

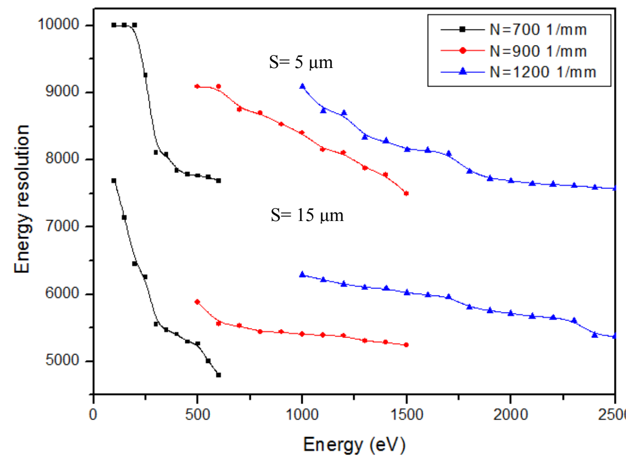

Figure 5: Monochromator resolving power at two different fixed exit slit sizes, S=5 & 15 μm, for three different gratings calculated by the shadow code.

CONCLUSION

In this paper the PEEM branch of the ILSF spectromicroscopy beamline has been designed by optical ray tracing. It has been concluded that the linear undulator could be a suitable source of this beamline in general case to cower whole energy of this beamline (90-2500 eV) with high flux and brilliance, however for the polarized light uses it should be changed by helical undulator. The layout has been decided to be includes of the varied-included angle PGM monochromator and refocusing KB mirror. The ray tracing calculations done by SHADOW, gives us the most important parameters of the photon beam in different part of the beamline.

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