INSERTION DEVICES FOR SESAME

Hamed Tarawneh, Geatano Vignola
SESAME, c/o UNESCO Amman Office, P.O. Box 2270, Amman 11181, Jordan

Abstract

The Phase-I SESAME beamlines have been defined by the scientific research programme of the SESAME users and Insertion Devices (IDs) will be the primary photon sources. It foresees two planar wigglers dedicated for WAFS/XRF and powder diffraction beamlines covering spectral range of 3-30 keV and 3-25 keV respectively, one elliptically polarizing undulator dedicated for Photo-absorption spectroscopy that covers a spectral range of 0.1-1 keV, one undulator dedicated for material science that covers 8-12 keV, one In-vacuum undulator dedicated for MAD protein crystallography covering 5-15 keV and two IR ports from a bending magnet dedicated for IR Spectromicroscopy covering 0.01-1eV. This paper describes the proposed designs for the first two devices and their effects on the SESAME lattice [1].

INTRODUCTION

SESAME is a third generation synchrotron light source, with an electron beam energy of 2.5 GeV and 400 mA beam current, located in Allan, Jordan. The SESAME storage ring is optimized for the use of Insertion Devices (IDs) and can allocate up to 12 IDs which will serve the SESAME users community. In this note, the magnetic design for two IDs, Hybrid Multipole Wiggler (HMW) and an Elliptically Polarizing Undulator (EPU), suitable for the Phase-I beamlines of SESAME will be presented.

Both devices fulfill the electron beam stay clear requirements defined by the SESAME lattice leading to an acceptable vacuum lifetime. The beam lifetime is an important issue for the 2.5 GeV SESAME storage ring since the injection energy is 800 MeV and top-up injection will be implemented in a second stage.

The magnetic design and optimization of the two IDs was done using the computer codes Radia [2] and FEMM [3] whereas the characteristics of the output photons are studied with the SPECTRA code [4]. The effects of the IDs on the electron beam were studied numerically using the particle tracking code BETA [5].

EPU UNDULATOR

The Apple-II type helical undulator [6] has been chosen to provide high flux circularly polarized radiation in the soft X-ray spectral range. This magnet will operate out of vacuum with minimum magnetic gap of 13 mm, period length of 60 mm and 28 periods. This satisfies a stay clear aperture 8.5 mm for an ID length of about 2 m [1] and fundamental photon energy of elliptically polarized light less than 100 eV at the minimum undulator gap.

In this undulator, NdFeB magnet blocks with a remanent field B_r= 1.22 T and a relative permeability of 1.05 parallel to and 1.17 perpendicular to the easy axis of the blocks are used. The blocks have a thickness of ¼ period and 40 mm × 40mm cross section with 5 mm × 5mm cuts needed to clamp the blocks in the holders.

The magnet structure has four sub-assemblies, two above and two below the beam axis. By moving the sub-assemblies longitudinally relative to each other, the relative strength of the transverse components of the magnetic field is altered leading to change in the polarization of the emitted radiation. Only the helical mode of operation has been considered where horizontal, vertical and elliptical polarized light can be obtained.

An asymmetric layout has been adopted for the SESAME EPU, i.e. the vertical magnetic field has the same polarities at the entrance and exit of the magnet, with the end sections of the Elettra type [7]. The achieved magnetic flux densities for the three modes of operation as a function of the undulator gap and phase are shown in Fig. 1. Tab. 1 summarizes the main magnetic properties of the SESAME EPU at minimum gap.

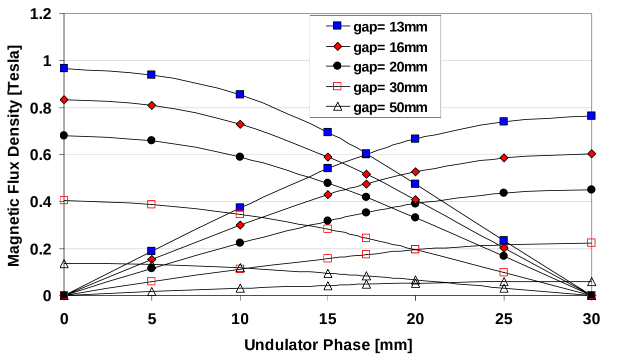

Figure 1: On-axis magnetic flux densities of the SESAME EPU undulator at different gaps and phases.

Table 1: Flux densities, K-values and minimum photon energies at minimum gap of 13 mm.

Undulator Phase	B_x [T]	B_z [T]	K-value	Ph Energy [eV]
Horizontal. 0mm	-	0.97	5.44	62
Circular 17.2mm	0.60	0.60	3.36	79
Vertical 30mm	0.76	-	4.26	98

HMW WIGGLER

The HMW will provide photon energies from 3-25 keV, which are defined by the scientific case of the SESAME. The HMW is a hybrid device with period length of 160 mm, a minimum gap of 14.5 mm, maximum flux density of 2.10 Tesla and total magnetic length of 3.092 m.

The magnet configuration consists of NdFeB magnet blocks with B_r= 1.3 T to produce the magnetic field and Vanadium Permendur material is chosen for the pole pieces to increase the effective magnetic field and channel it to create a high peak field on the electron beam trajectory. The main parameters of the SESAME HMW wiggler magnet are shown in Tab. 2.

Table 2. Design parameters of the SESAME HMW.

Period length, mm	160
Peak Field, Tesla	2.10
The deflection parameters {K}	31.37
Minimum gap, mm	14.5
Number of periods	19
Total length, m	3.092
Total number of full-size poles	78
Total number of full-size PM block	80
Main PM block dimensions [mm^3]	140×52×100
End PM block dimensions [mm^3]	140×26×100
Main pole dimensions [mm^3]	100×28×80
End pole dimensions [mm^3]	100×14×66

The pole width has been optimized to reduce the transverse roll-off of the achieved magnetic field, as shown in Fig. 2.

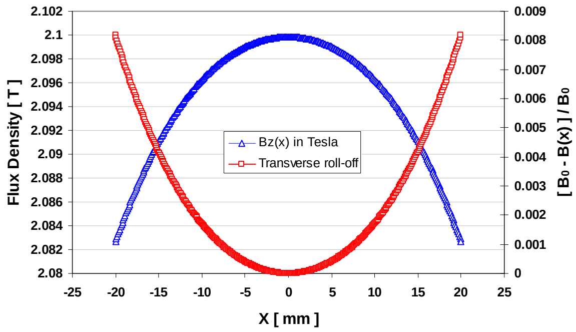

Figure 2: Transverse roll-off as a percentage of the on-axis peak flux at minimum gap.

The end section is half in length for the PM block and the pole. An extensive 3D calculation shows that the height of the end pole is 14 mm less than the full-size pole to give minimum field integrals. The first and second vertical field integrals are shown in Fig. 3.

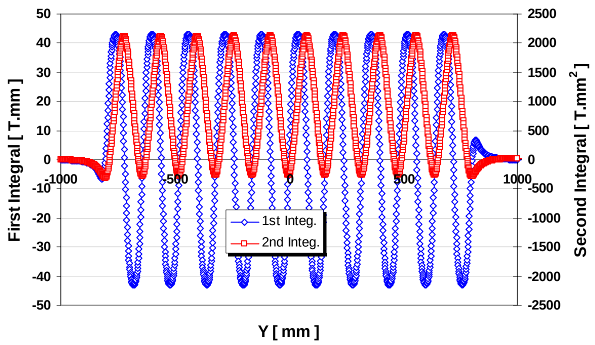

Figure 3: Field integrals of the HMP wiggler.

EFFECT ON SESAME LATTICE

In the BETA code any insertion device can be described by interpolation tables which provide an angular kick as a function of the coordinates of the particle passing through that element, i.e. mapped insertion device [5]. Such a map has been generated for both IDs and used for tracking particles, within the map, to investigate the effect of the higher order multipoles on the dynamic aperture of the SESAME lattice. The map has a finite size, ±30 mm in x-axis and ±5 mm in z-axis, which is considered as a physical limitation in the BETA code. Tracking the particles for 500 turns within this map (aperture) for both devices has not lead to significant reduction in the dynamic aperture of the SESAME lattice, see Fig. 4 and Fig. 5.

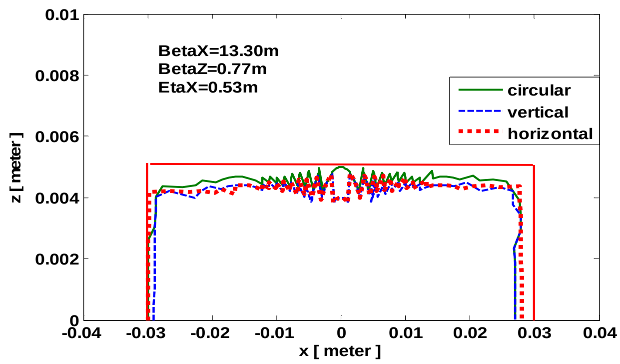

Figure 4: Dynamic aperture for the SESAME lattice with the mapped EPU magnet engaged at different phases.

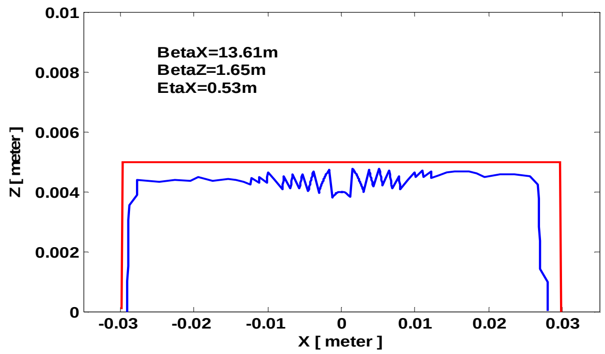

Figure 5: Dynamic aperture for the SESAME lattice with the mapped HMP wiggler engaged.

PHOTON OUTPUT

The magnetic field model has been used to calculate the synchrotron radiation output from both devices using the SPECTRA code [4]. The broadening of the peaks due to emittance and electron beam energy spread are included in the calculations. Fig. 6, 7 and 8 show the brilliance of the SESAME EPU for all modes of operation. The overlap between the first four harmonics is very good for the horizontal and the vertical modes of operation.

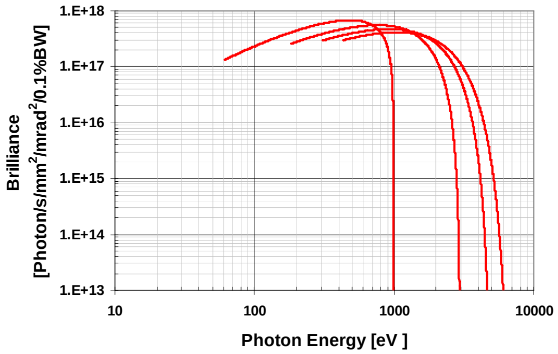

Figure 6: EPU brilliance for horizontal polarization.

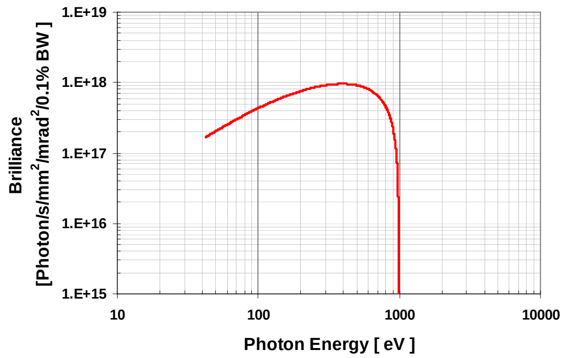

Figure 7: EPU brilliance for circular polarization.

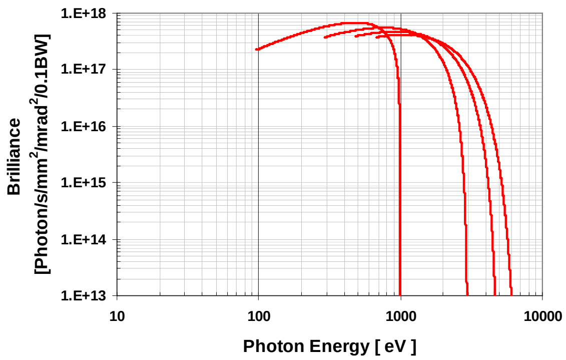

Figure 8: EPU brilliance for vertical polarization.

The HMW wiggler magnet will be housed in a long straight section of the SESAME lattice [1]. The criterion for the useful photon energy range has been chosen such that the flux densities are within 10% of their maximum value. Tab. 3 shows the predicted output photons from the HMW wiggler magnet. The photon flux density is shown in Figure 9.

Table 3: Parameters of the output photons of the SESAME HMP wiggler

Beam Energy Loss, keV	53.0
Total Radiated Power, kW	21.2
Critical Photon Energy , keV	8.73 (6.17)
Maximum Flux density	1.80×10^{15}
Useful Energy Range (10 % of max. flux density)	0.1-40 keV

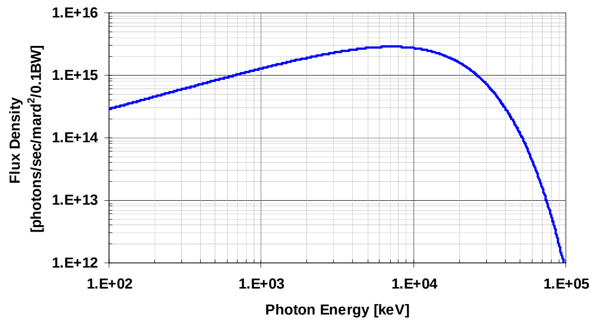

Figure 9: Photon flux density of the HMW wiggler magnet at 400 mA.

CONCLUSIONS

The designs of an elliptically polarizing undulator and a hybrid multipole wiggler have been presented. Both devices satisfy the demands of the SESAME user communities and have very low residual field integrals.
The dynamic aperture of the SESAME lattice has not suffered severe reduction due to the inclusion of both devices and the effect on the emittance and energy spread is negligible.
Further works on the optimization of the support system to achieve minimum deflection of magnet girder and power loading on the vacuum chamber are in progress for both devices.

REFERENCES

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