SESAME **Technical Note**

Amman, August. 04, 2006
Note: **M-03**

A 2.1 Tesla Hybrid Multipole Wiggler for SESAME

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1. INTRODUCTION

In this note a design proposal of a wiggler magnet for SESAME storage ring is described. This wiggler will provide photon energies from 3-25 keV, which are defined by the scientific case of the SESAME light source [1].
The Multipole Wiggler is a hybrid device in order to achieve a high peak magnetic field. A period length of 160 mm, a minimum gap of 14.5 mm and maximum flux density of 2.10 Tesla have been achieved. This device fulfills the beam stay clear requirements defined by the SESAME lattice [2] leading to a decent vacuum lifetime. The beam lifetime is an important issue for the 2.5 GeV SESAME storage ring since the injection energy is 800 MeV [3].
An extensive 2D and 3D calculations of the magnetic field have been made with the codes FEMM [4] and Radia [5] whereas the characteristics of the resulting light are studied with the SPECTRA code [6].

2. MAGNET DESIGN

2.1. MODEL OF THE MPW WIGGLER

The configuration of the hybrid multipole wiggler (MPW) consists of two different materials, permanent magnet (NdFeB assumed with B_r= 1.3 T and intrinsic coercive force of 980 kA/m) is used to produce a magnetic field and high saturation field strength soft magnetic material (Vanadium Permendur) is chosen for the pole pieces in order to increase the effective magnetic field and channel it to create a high peak field on the electron beam trajectory.
The magnetic design of the basic cell is the compromise in the field performance and the cost. A good compromise occurs when using a rectangular blocks of the PM material and h/λ=0.625 where h is the height of the PM block and λ is the wiggler period length [7]. The schematic of 8 full-sized poles is shown in Figure 1.
In order to reduce the wiggler nonlinearity or the transverse field roll-off in the vicinity of the wiggler centre-line, a pole width of 100 mm has been chosen. This stems from the fact that the reduction in the dynamic aperture and hence the lifetime is highly closed orbit dependent [8].
The pole-tip region has been chamfered with 45° degrees in both longitudinal and transverse direction to reduce saturation, and hence the higher multipole contents. The main parameters of the SESAME MPW wiggler magnet are shown in Table 1.

Table 1: The design parameters of the SESAME MPW wiggler.

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

2.2. 3D MAGNETIC FIELD CALCULATIONS

The model magnet, 19 full-size poles, used to evaluate the magnetic calculation is about half size of the full-size magnet. The poles are modeled using a non-linear B-H curve for the vanadium permendur whereas a linear B-H representation for the PM block has been used.
The achieved magnetic profile along the centre-line of the model MPW magnet is shown in Figure 2 whereas a 3D plot of the achieved flux distribution is shown in Figure 3.

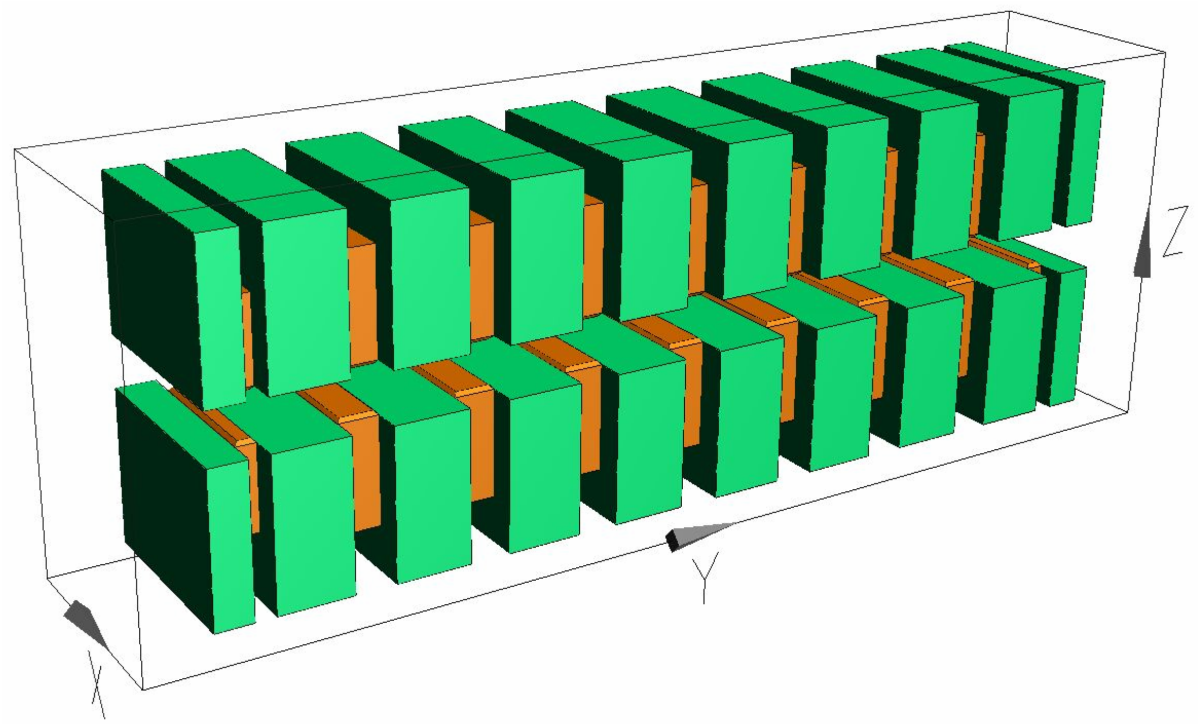

Figure 1. Schematic for 8 full-size poles of the MPW wiggler.

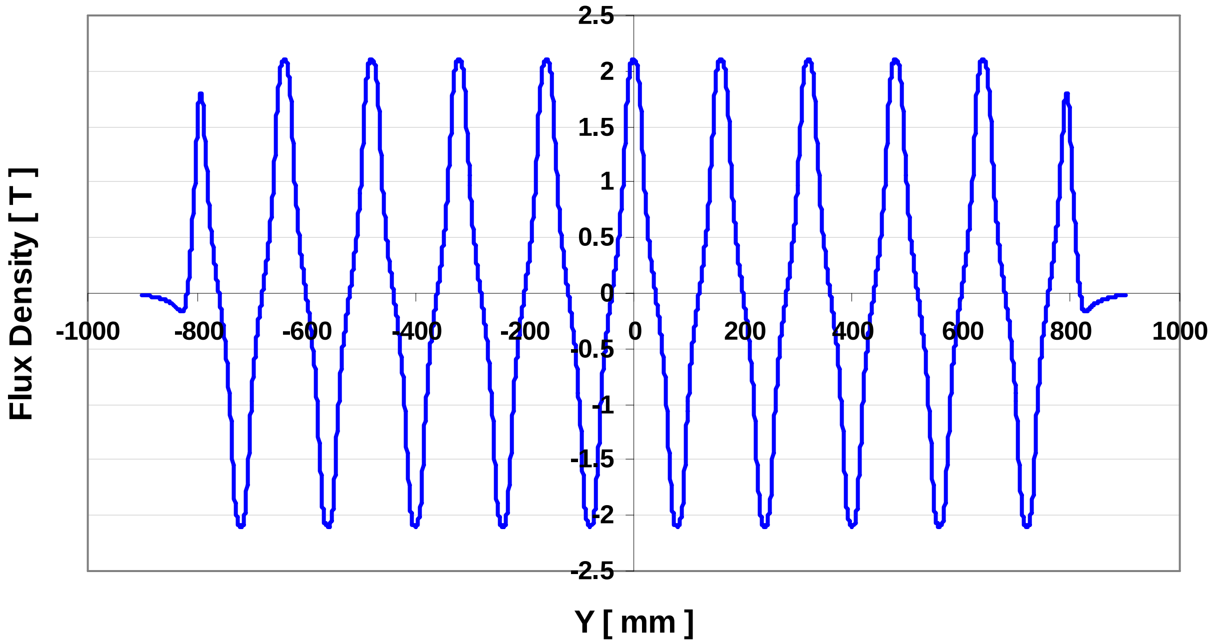

Figure 2. On-axis magnetic flux density along the MPW wiggler for 19 full-size poles.

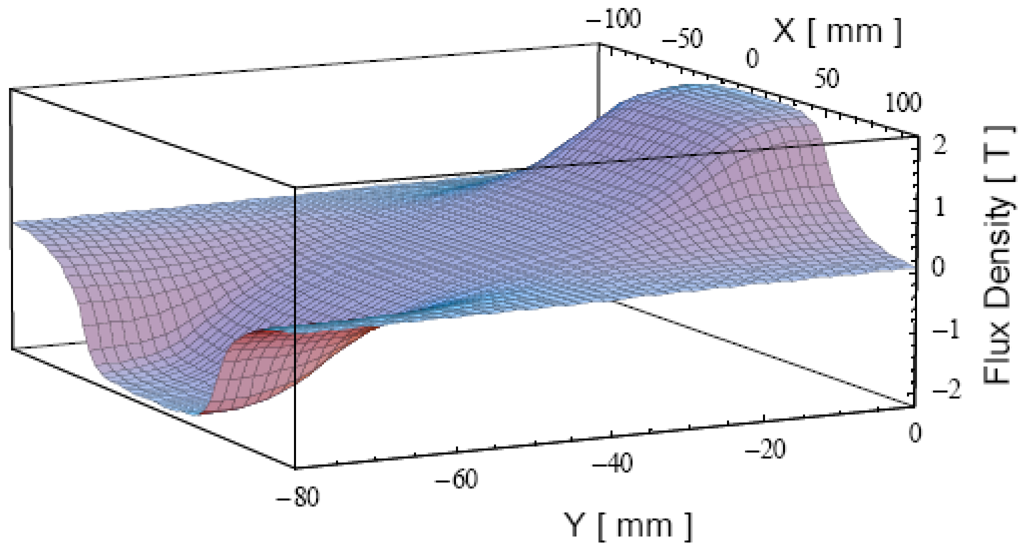

Figure 3. 3D magnetic flux density distribution for half a period of the MPW wiggler.

The peak field calculated under the central pole as a function of gap is given in Figure 4. As mentioned earlier the large pole width reduces the transverse roll-off of the achieved magnetic field. Figure 5 shows the transverse roll-off at minimum gap as a percentage of the on-axis peak field, B_0=2.1T, for horizontal offset range of x= ±20 mm.

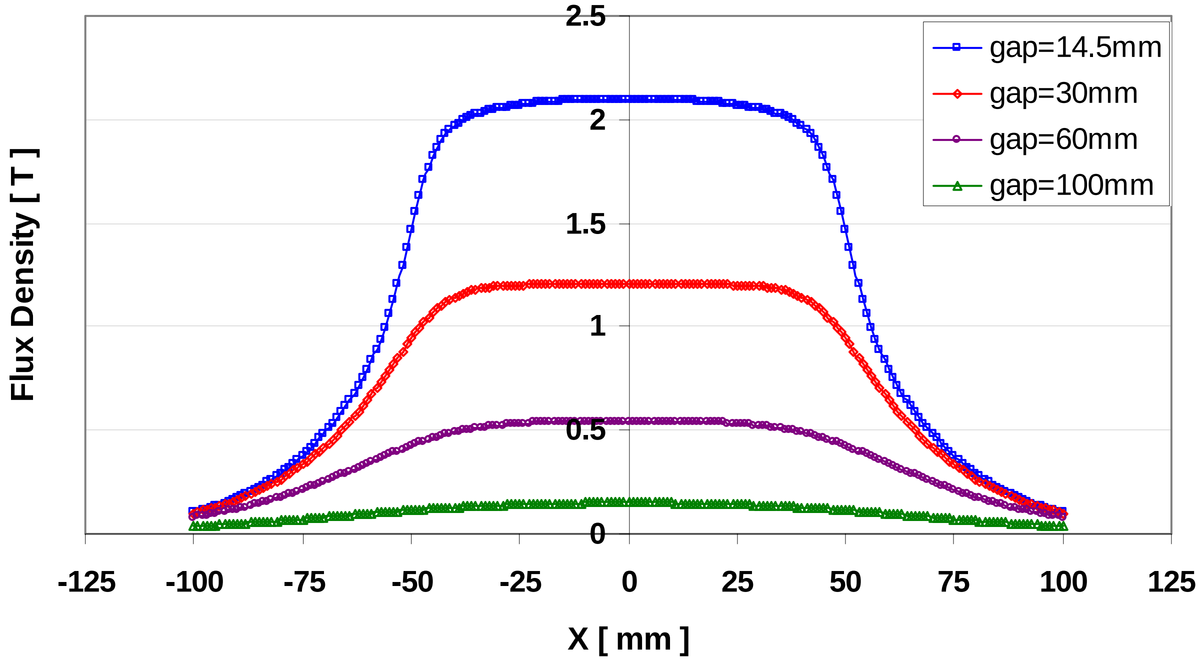

Figure 4. Transverse flux density at the middle of a full-size pole of MPW wiggler.

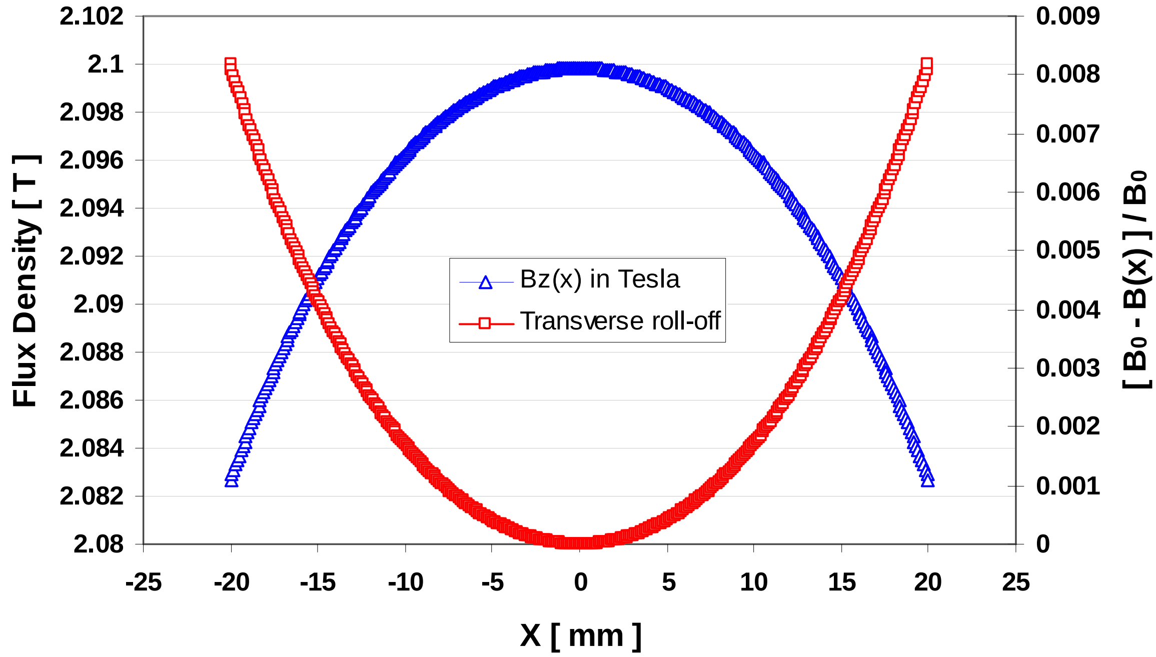

Figure 5. Transverse roll-off as a percentage of the on-axis peak flux at minimum gap.

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, see Table 1. The first and second vertical field integrals are shown in Figure 6 whereas the 2.5 GeV electron beam trajectory and angle along the SESAME MPW wiggler are shown in Figure 7.

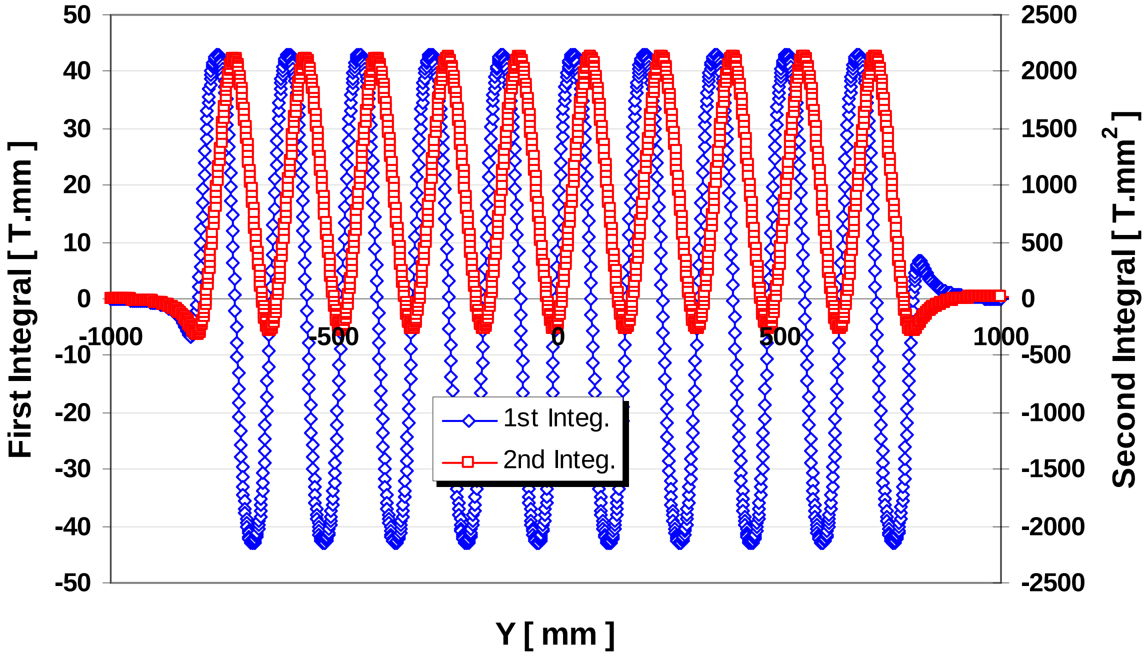

Figure 6. Field integrals of the MPW wiggler.

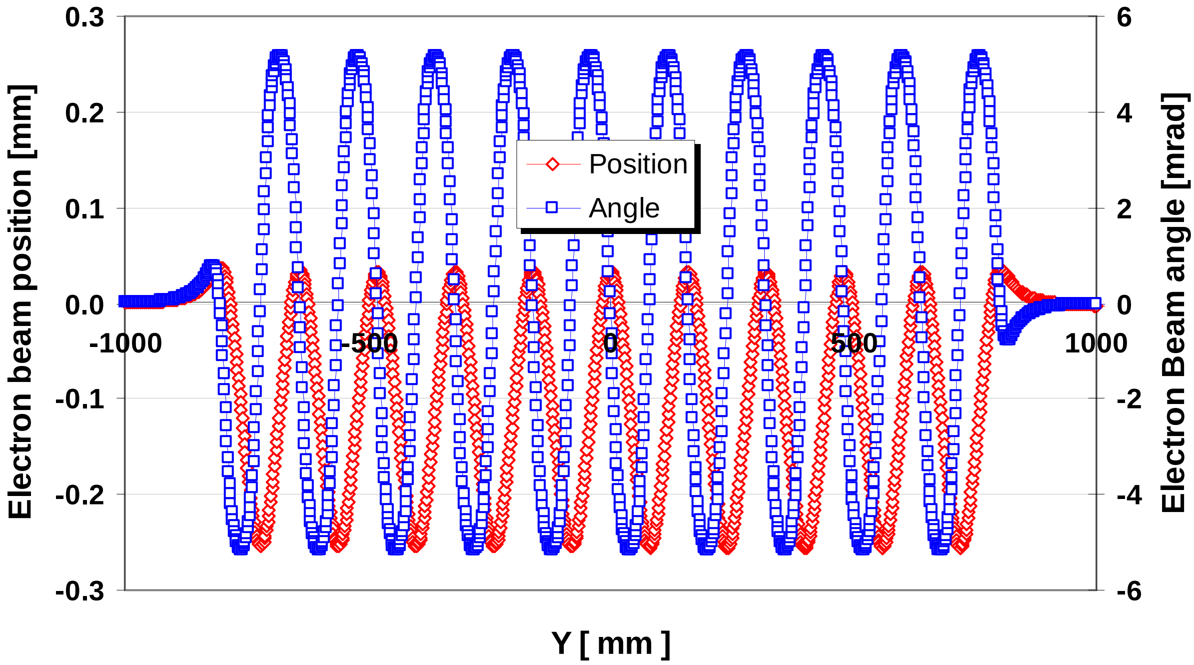

Figure 7. Position and angle of the electron beam in the MPW wiggler.

The magnetic flux integrated longitudinally at different horizontal offsets is shown in Figure 8 for the model magnet. A 6th order polynomial has been fitted to the calculated flux density in the range of $x=\pm 20$ mm to estimate the integrated multipoles as shown in the equation below;

$$\textit{Integrated B [T.mm]} = 0.0240 - 8.2874\times10^{-13}\,x - 2.2923\times10^{-04}\,x^2 + 7.7802\times10^{-15}x^3 + 2.1520\times10^{-07}\,x^4 + 5.9631\times10^{-19}\,x^5 - 3.1629\times10^{-10}\,x^6$$

The integrated vertical flux on the magnet centre-line of 0.024 T.mm is rather easily compensated by a simple trim coil fitted to the MPW wiggler magnet. The quadrupole and the sextupole components of the equation affect the betatron tunes and the chromaticity of the electron beam respectively. The matching of the optical functions is rather easily achieved, locally with the flanking quadrupole doublet and globally with the two quadrupole families of the SESAME lattice [2]. An integrated sextupole component of -0.23 T/m, originated from the field roll-off towards the edges of the wiggler, affects the chromaticity of the SESAME lattice. The two sextupole families are used to restore the chromaticity to zero in both planes.

In the BETA code [9] any insertion device can be described by interpolation tables which provide an angular kick in T^2m^2 as a function of the coordinates of the particle passing that element, i.e. mapped insertion device [9]. Such a map has been generated for the SESAME MPW wiggler and used for tracking particles, within the map, to investigate the effect of the higher multipoles on the dynamic aperture of the SESAME lattice, see Figure 9.

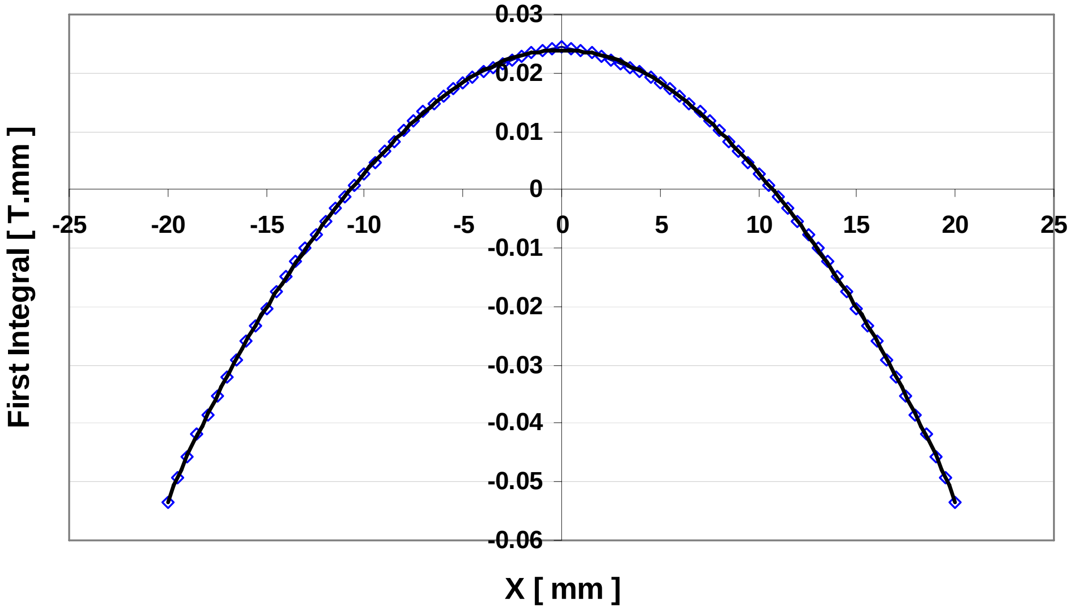

Figure 8. The magnetic flux integrated longitudinally at different horizontal offsets.

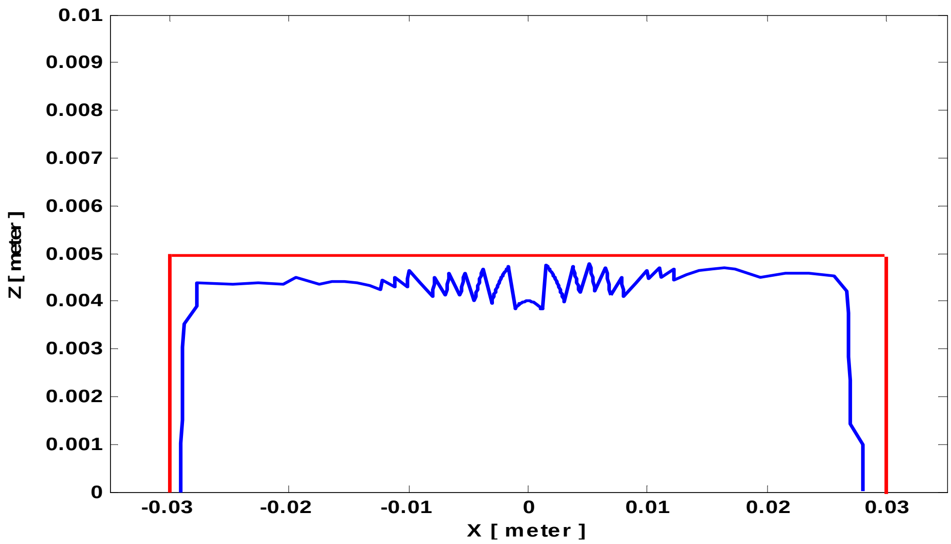

Figure 9. The SESAME lattice dynamic aperture (blue), the map size considered as a physical limitation (red)

3. LIGHT CHARACTERSTICS OF THE MPW WIGGLER

The magnetic field model has been used to calculate the synchrotron radiation output from the SESAME MPW wiggler using the SPECTRA code [6]. The machine parameters used to evaluate the photon flux density, Figure 10, of the MPW wiggler magnet at the middle of SESAME long straight section are shown in Table 2. The criterion for the useful photon energy range has been chosen such that the flux densities are within 10% of their maximum value. Table 3 shows the predicted output photons from the MP wiggler magnet. The brilliance is shown in Figure 11.

Table 2. Machine parameters at the middle of SESAME long straight section.

Beam Energy	2.5 GeV
Beam Current	400 mA
Horizontal Emittance	25.7 nm.rad
Natural Energy Spread	1.086×10^{-3}
Coupling	1 %
$\beta_x / \alpha_x / \eta_x / \eta'_x$	13.61m / 0 / 0.53m / 0
$\beta_y / \alpha_y / \eta_y / \eta'_y$	1.65m / 0 / 0 / 0

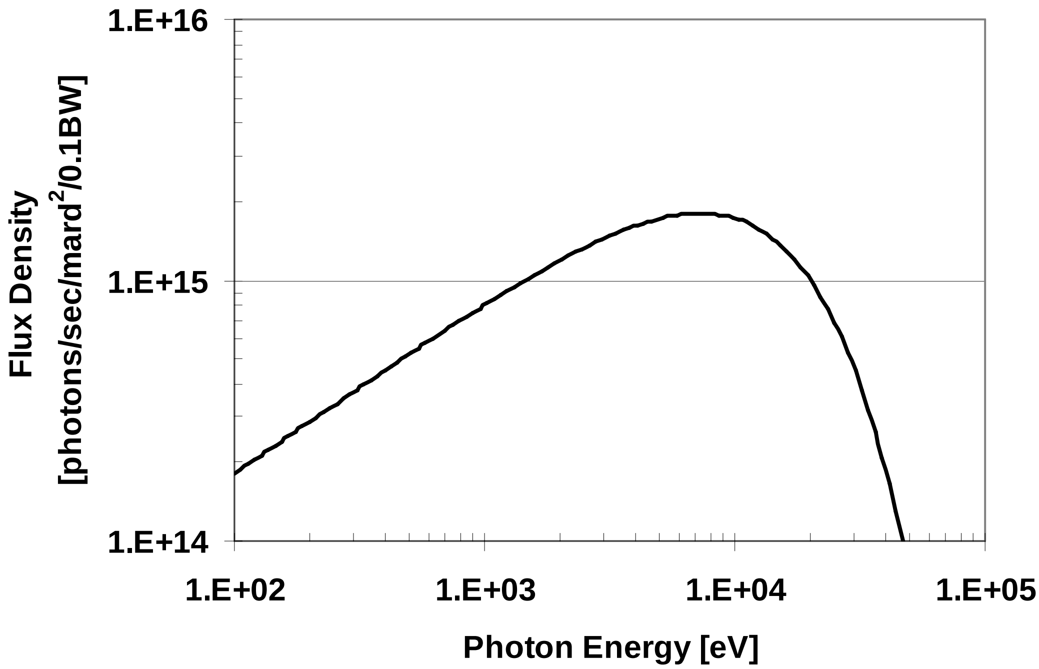

Figure 10. Photon flux density of the SESAME MPW wiggler magnet.

Table 3. Parameters of the output photons of the SESAME MPW 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

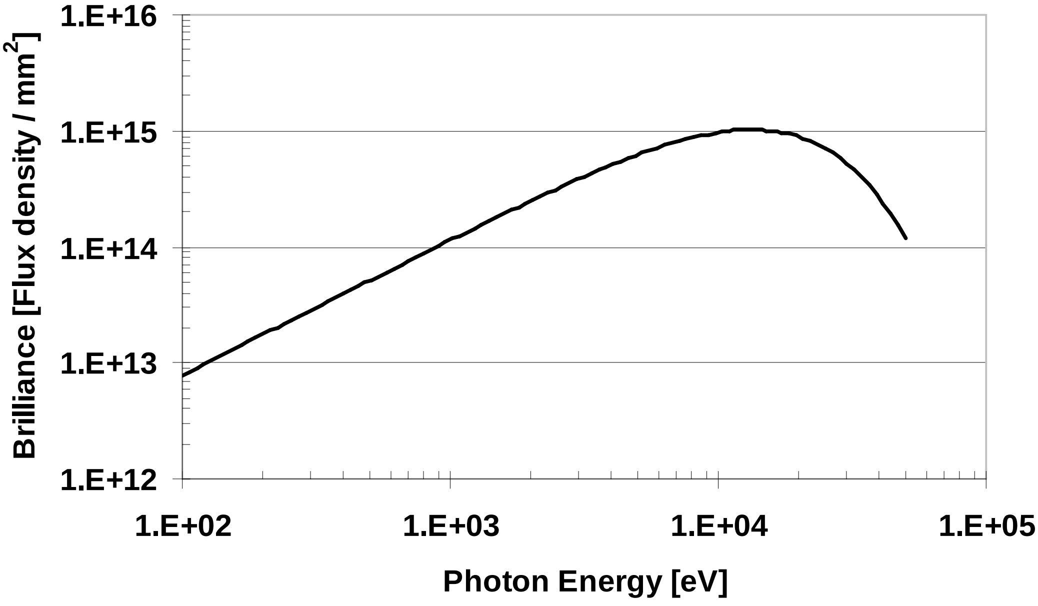

Figure 11. Brilliance of the SESAME MPW wiggler.

4. CONCLUSIONS

The Design of a hybrid multipole wiggler magnet has been presented for the SESAME light source which satisfies the demand of the SESAME users. This design provides low field integral that can be corrected with simple trim coils and small reduction of the dynamic aperture of the SESAME lattice due to the higher multipole contents.
Further work on the optimization of the support system has to be done to achieve minimum deflection due to the strong magnetic force.

REFERENCES

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