SESAME MAGNETS SYSTEM

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Abstract

In this paper the SESAME† storage ring magnet system is described. The storage ring consists of 16 bending magnets with a maximum field of 1.455 T and vertical gradient of 2.79 T/m, 32 focusing quadrupoles with a working gradient of 16.92 T/m, 32 defocusing quadrupoles with a working gradient of 10.23 T/m, 32 focusing sextupoles with a differential gradient of 200 T/m^2 and 32 defocusing sextupoles with the differential gradient of 300 T/m^2[1]. The horizontal(vertical) correctors will be embedded inside focusing(defocusing) sextupoles. For the quadrupole and sextupole a design similar to ANKA has been adopted. The magnetic and electrical design of dipoles and correctors, field profile and higher order multipoles optimization will be presented.

INTRODUCTION

In SESAME the electrons are injected from a 20 MeV microtron into a 800 MeV booster synchrotron, with a repetition rate of 1 Hz. The 800 MeV beam is transported through the transfer line to the main storage ring and after accumulation, accelerated to 2.5 GeV[2]. Work on the design of conventional dipoles, skew quadrupoles and corrector embedded inside sextupoles has been briefed. The magnetic field distributions shown have been evaluated using the 2D POISSON code.

DIPOLE MAGNETS

The SESAME storage ring requires 16 dipole magnets with the maximum magnetic field of 1.455 T and a vertical gradient of 2.79 T/m. The dipole is a "C" type magnet, with parallel end and with the yoke laminations stacked in parallel according to the nominal bending radius; the full gap is 40 mm at the transverse magnetic centre [3]. With a bending angle of 22.5^0, field strengths of 0.4657T and 1.4554T are required for injection and full energy. For the magnetic analysis, the iron permeability of Cockerill steel was used. At full energy the saturation effects cause the field strength to be non-linear with the excitation current. After a number of iteration, a pole geometry that substantially meets the required field quality and also manufacturing optimization was generated. On the other hand the task of pole profile optimization and harmful harmonic reduction has been carried out in an iterative way by looking at the dynamic aperture. A cross section of top-half of dipole magnet lamination in the Poisson code is shown in Fig.1. The calculated ampere-turn of 52184 is required for the 2.5 GeV operation, which assuming 80 coil turns gives a maximum excitation current of 653A for the power supply.

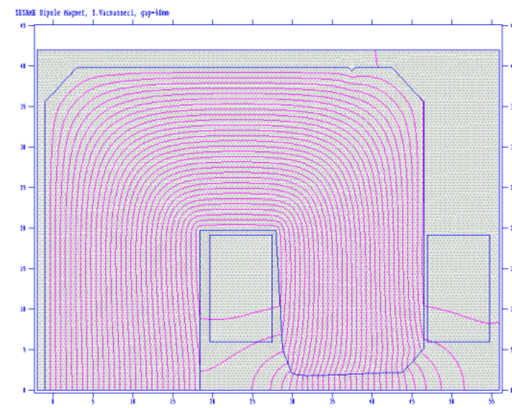

Figure 1: SESAME dipole magnet top-half cross section for POISSON code.

Table 1. Multipoles within ±2cm

Multipole	At 2.5 GeV	At 800 MeV
X^2	$+2.76\times10^{-4}$	$+7.12\times10^{-4}$
X^3	-3×10^{-6}	-3.66×10^{-5}
X^4	$+7.3\times10^{-6}$	$+1.81\times10^{-5}$
X^5	-2.95×10^{-5}	-2.97×10^{-5}
X^6	-1.41×10^{-4}	-1.4×10^{-4}

Considering a good field region of ±2cm, the calculated multipole field components, B_n/B_0 for SESAME dipole design, are given in Tab.1, while the predicted homogeneity of the vertical field along the x-axis in terms of $\Delta B_y/B_{y0}$ is shown in figure.2.

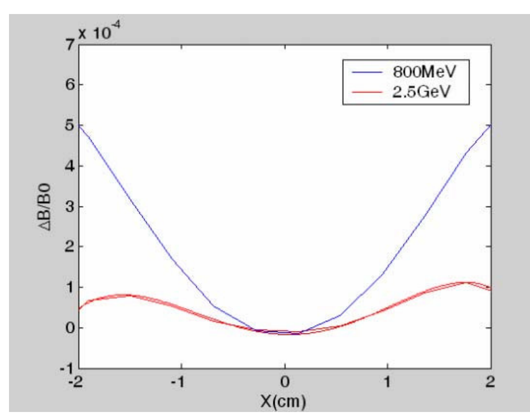

Figure 2: Transverse field quality in the mid-plane, within ±2cm, at 2.5GeV and 800MeV.

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† Synchrotron-light for Experimental Science and Applications in the Middle East is an independent intergovernmental organization developed under the auspices of UNESCO. It involves at present the following member states: Bahrain, Egypt, Israel, Jordan, Pakistan, Palestinian Authority and Turkey. Iran is in the process of finalizing its formal membership.

Dipole parameters

The coil design is based on copper conductors of square cross section and a central hole for water cooling. Moreover the electrical connections are assumed to be in the centre of the magnet. There will be 8 pancakes; each one consists of 2 layers of 5 conductors. Tab.2 shows the magnetic, electric and hydraulic parameters of SESAME dipole magnets at 2.5 GeV. 3D calculation gives a yoke length of 2.22 m for a magnetic length of 2.25m.

Table 2. SESAME dipole parameter list at 2.5 GeV

Number of magnets	16
Bending angle (degree)	22.5
Energy (GeV)	2.5
Magnetic flux density (T)	1.4554
Gradient (T/m)	2.79
Bending radius (m)	5.72958
Magnetic length (m)	2.25
Iron length (m)	2.22
Central Gap height (mm)	40
Pole width (mm)	177-186
Iron weight (kg)	5660
Copper weight (kg)	622
Total weight (kg)	6282
Packing factor	> 97%
Ampere turns (Total)	52184
Number of turns (Total)	80
Nominal current (A)	653
Number of pancakes (2 layers)	8
Conductor dimensions (mm)	14*14
Cooling hole diameter (mm)	6
Current density (A/mm^2)	3.9
Resistance (mΩ)	41.5
Inductance (mH)	90
Voltage drop (V) per magnet	27.2
Power (kW) per magnet	17.75
Number of cooling circuits	8

Figure3 and 4 give the detailed design of dipole coils and dipole lamination.

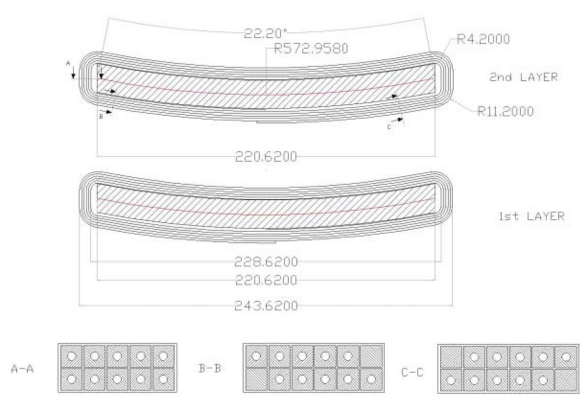

Figure 3: Top view of pancake and cross section.

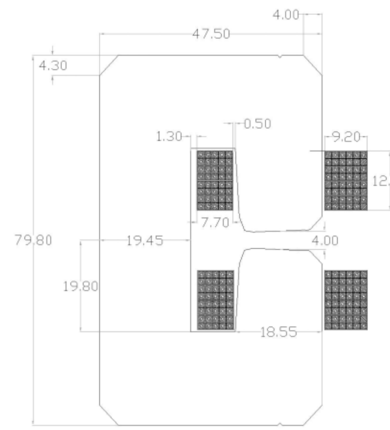

Figure 4: Lamination and coil cross section.

CORRECTOR MAGNETS

In SESAME due to space shortage the Horizontal(Vertical) correctors are embedded in all the sextupoles SF(SD) [4]. In order to have reasonable field uniformity, 6 coils are used for horizontal correctors and 4 coils for the vertical one (Fig.5). The design kick value for each single corrector magnet is 0.5 mrad @ 2.5 GeV. The transverse field profile has been optimized with 2D Poisson code. In order to evaluate the effective magnetic length 3D calculation has also been performed. The transverse field profile for the Horizontal (Vertical) correctors are shown in Fig. 6/7.

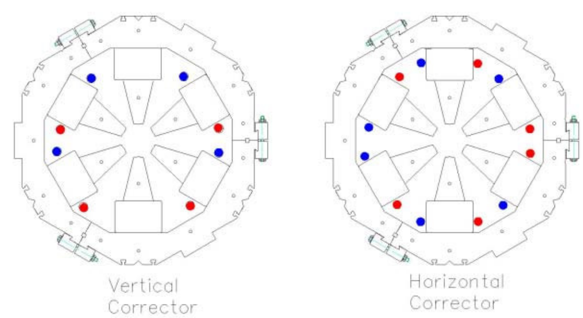

Figure 5: Coil placement for H/V correctors

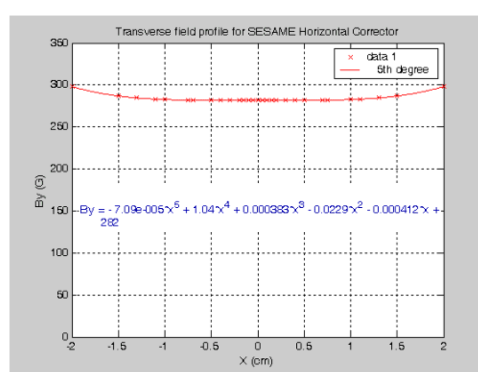

Figure 6: Transverse field profile within ±2cm for the Horizontal corrector.

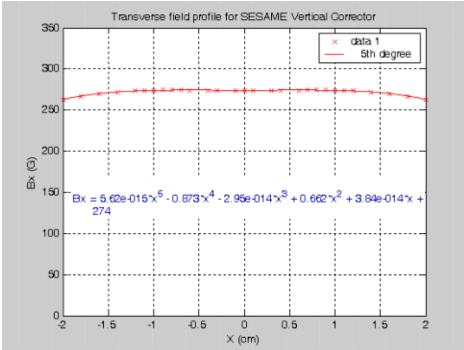

Figure 7: Transverse field profile within ±2cm for the Vertical corrector.

Let us point out that for the horizontal corrector, one could have only the top and bottom coils. In this case the transverse field quality was not very good and we used 4 additional coils to improve the field quality.

In table.3 the magnetic and electric parameters of SESAME corrector magnets are listed.

Table 3: Parameters of SESAME Corrector magnets.

	Horizontal Corrector	Vertical Corrector
θ @ 2.5 GeV (mrad)	0.500	0.500
Magnetic field (T)	0.042	0.042
Effective magnetic length (m)	0.10	0.10
Ampere-Turns per pole	1080(2) +540(4)	905 (4)
Turns per Coil	100+50	100
Conductor size (mm)	Φ 2.65	Φ 2.65
Magnet Resistance (Ω)	0.639	0.648
Magnet Inductance (mH)	15.9	22.5
Current (A)	11	9.1
Total Voltage (V)	7.03	5.9
Total Power (W)	77.4	54

SKEW QUADRUPOLES

By properly rearranging in the SF sextupole the electrical connections of the additional coils it is possible to transform the horizontal corrector into a Skew Quadrupole. The field profile for the B_x and B_y components are shown in fig.8. It shows the field behaviour in the region close to the magnetic center is much more linear and the gradient (T/m) for the x and y plane are 0.75(T/m) in a region of ±6mm off center[4].

QUADRUPOLES AND SEXTUPOLES

32 focusing quadrupoles with a maximum gradient of 19 T/m and magnetic length of 30 cm, 32 defocusing quadrupoles with a maximum gradient of 19 T/m and magnetic length of 10 cm, 32 focusing sextupoles and 32 defocusing sextupoles with the maximum differential gradient of 300 T/m^2 and magnetic length of 10 cm have been employed in the SESAME ring. For quadrupoles and sextupoles a design identical (apart from the length) to the one adopted for ANKA has been chosen [5].

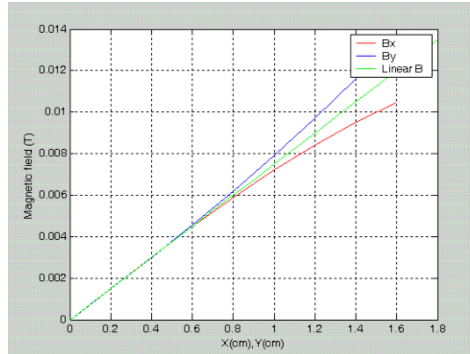

Figure 8: B_x and B_y components for the Skew Quadrupole configuration.

PULSED MAGNETS

The injection process from booster to storage ring takes place in the horizontal plane. The microtron and booster are installed inside the main ring, so the injected beam comes from the inner side of the straight section. The injection scheme (four kickers closed orbit bump) foresees the septum with two kickers in a long straight section, while the other two kickers will be positioned in the two adjacent short straights. The septum magnet is direct driven C magnet (laminated iron) in air. A 9mm vacuum pipe is used for the incoming beam. The kickers have a window frame yoke (ferrite) around a ceramic chamber. The main parameters of the injection septum magnet are given in Tab.4.

Table 4: Parameter list of Septum magnet

Deflection angle (degree)	8
Field Strength (T)@ 800MeV	0.75
Magnetic length (m)	0.5
Septum thickness (mm)	2.5
Magnet Aperture (mm^2)	10x25
Pulse length (μs)	250
Copper resistance (mΩ)	0.81+0.17
Inductance (μH)	1.57
Current (A)	5930
Voltage (V)	175

REFRENCES

[1] G.Vignola et al. “SESAME Lattice” Tech. Note, O-1, Dec. 2004

[2] G.Vignola et al. “SESAME status” EPAC06, Scotland

[3] S.Varnasseri “Dipole Magnet Design for SESAME” Tech. Note, M-1, Aug. 2005

[4] S.Varnasseri “Corrector Magnets for SESAME” Tech. Note, M-2, Feb. 2006

[5] G.Vignola et al. “SESAME in Jordan” PAC05, USA