SESAME, A SYNCHROTRON LIGHT SOURCE FOR THE MIDDLE EAST REGION

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Abstract

Developed under the auspices of UNESCO, SESAME (Synchrotron light for Experimental Science and Application in the Middle East) will be a major international research centre in the Middle East/ Mediterranean region to promote science and peace. It will have as its centrepiece a synchrotron light source based on BESSY I which has already been moved to Jordan. During the last years detailed design studies have been performed in order to upgrade SESAME to a 3rd generation light source. According to the new conceptual design report (SESAME IV) SESAME will have energy of 2.5GeV with an emittance of 26.6nm.rad and 13 places for the installation of insertion devices with a length of around 3m are available (around 40% of the circumference). The circumference of the machine will be 128.4m. As injector, the 800MeV Booster Synchrotron of BESSY I will be used with small changes. Jordan is providing a site and funds for construction of the building, which began in July 2003. The new building provides the space for offices, workshops, laboratories and beam lines with a length of up to 37.7m. The circumference of the storage ring allows installing a full energy injector at a later stage. It is anticipated that the first experiments could be performed in 2009.

INTRODUCTION

SESAME will be jointly operated and supported by more as 13 member countries of the Middle East region. As of July 2003, Members of SESAME are Bahrain, Egypt, Iran, Israel, Jordan, Pakistan, Palestinian Authority, Turkey and the United Arab Emirates, with a total population of over 305 millions. SESAME is located in Allan, Jordan, 30 km North-West of Amman.

The scientific program of SESAME includes applications which require hard x-rays up to 20keV. With the first design of SESAME (SESAME I, Green Book, [1]) it was capable of achieving x-rays up to 20keV by upgrading BESSY I from 0.8GeV to 1.0GeV and using 7.5T super conducting wigglers (see table 1).

In order to increase the number of long straight sections, to lower the emittance, to avoid the influence of the 7.5T super conducting wiggler and to increase the hard x-ray beam lines, SESAME was redesigned to a 3rd generation light source with an energy of 2.0GeV (SESAME II, White Book [2]), with this design the layout of the building was fixed.

In order to face the increasing demand of the users (especially after the first users meeting, Amman, October 2002), [3] for higher brilliance and to reach the selenium k-edge with in-vacuum undulators, the nominal operation energy has been increased to 2.5GeV (SESAME III, Yellow Book) [4]. With SESAME II and SESAME III, it was possible to install up to 13 insertion device with lengths of up to 2.75m. The drawback of the SESAME III design was the limited flexibility for the vertical focussing according to the foreseen pole face windings.

To optimise the machine for more flexibility, future upgrade and modifications, the longest possible straights for insertion devices as well beam lines, the location of the machine inside the hall and the lattice were changed (SESAME IV, appendix to SESAME III)

The upgrade steps from BESSY I into SESAME IV are summarised in table 1. The main parameters of the several upgrades are shown in table 2. With the upgrade from SESAME I to SESAME IV the facility was changed from a VUV to a hard-x-ray source.

An overview of the SESAME IV (a description of the building, the optimised lattice, beam dynamic and the design of the main components of the storage ring) are represented here, furthermore the list of the first set of beam lines foreseen for SESAME will be discussed.

THE SESAME BUILDING AND MACHINE

The layout of the building

The SESAME building (see Fig. 1) is under construction since August 2003. The ground floor of the building 85mx85m will accommodate the accelerator complex, the beam lines with the experimental hutches. Furthermore it provides the space for workshops and laboratories for the operation of the facility.

The experimental hall is 60mx60m with an annex from the four sides of 7.5mx30m and it is served by one crane. Offices for the staff and users, library, control room, seminar room…etc are located on the first floor, access to the machine will be by stairs from the first floor near the control room (see Fig. 1).

The machine in the latest design (SESAME IV) is shifted by 6m from the centre of the building to be able to extend the beam lines as much as possible. The layout of the ground floor of the building with the machine inside is shown in Fig. 1.

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The layout of the machine

The lattice of SESAME IV (see Fig. 2) is a TME-optic [5], this gives the smallest emittance and the highest percentage of the circumference for the insertion devices. With SESAME IV up to 40 % of the circumference can be used for the installation of insertion devices. The symmetry of the machine is 8, with 2x22.5º combined function bending magnets for each cell. The gradient bending magnets (gradient = 2.38 T/m) perform the main vertical focussing. The changing of the vertical focussing will be done with a separated quadrupole, adjacent to the bending. Two families of quadrupoles perform the horizontal focussing and two families of sextupoles are needed for good beam dynamics behaviour. The arrangement of the magnets within the unit cell is shown in Fig. 3.

The main parameters of SESAME IV are shown in table 3. The natural emittance is 24.9 nm.rad leading to beam cross section in the straight section of σ(x)=700µm, σ(y)=26µm (2% coupling) [6]. With a pressure value of 10^{-9} mbar expected by the end of the conditioning of the machine, the lifetime of the beam expected to be in the range of 15 hours.

Table 1: The upgrading steps from BESSY I to SESAME VI

Name	**Description**	**Reference**
BESSY I	The original design of BESSY	
SESAME I	Upgrading of BESSY I to 1 GeV by changing the lattice from TBA to DBA, modification of the bending magnets and increasing the circumference from 62m to 100.8m	NIM A 467-468(2001) 55-58
SESAME II (White Book)	Upgrading of SESAME I to 2 GeV. All components the storage ring and the lattice are new. The injector is the same as for BESSY I	AIP Conf.-Proc. 680 (2003), S.965 EPAC 2002
SESAME III (Yellow Book)	Upgrading of SESAME to 2.5 GeV by introducing the pole face windings for changing the focusing in the vertical direction. The circumference is the same as for SESAME II.	PAC 2003 SRI 2003
SESAME IV (Appendix)	Introduction of a separated vertical focusing quadrupole by an eccentric location of the storage ring and increasing the circumference.	ISRP9 EPAC 2004 APAC 2004

Table 2: The main parameters for the different upgrading versions of SESAME. The beam area is 2*π*σ(x)*σ (y). (No. = number, ID =Insertion Device)

Name	**Energy (GeV)**	**Circumf. (m)**	**No. of Straights**	**No. of ID**	**Length of ID (m)**	**Emittance (nm.rad)**	**Cross Sect. σ(x)* σ (y) (mm*mm)**	**Beam Area (mm^2)**
BESSY I	0.8	62	4	2	2.7	55	0.4*0.12 0.34*0.023	0.30 0.056
SESAME I	1	100.8	6	4	1*5.4 3*1.85	55	0.72*0.076 0.46*0.021	0.34 0.061
SESAME II	2	124.8	16	13	5*2.4 8*2.6	16.7	0.66*0.014 0.51*0.021	0.058 0.067
SESAME III	2.5	124.8	16	13	5*2.4 8*2.6	24.2	0.73*0.02 0.73*0.02	0.092 0.092
SESAME IV	2.5	128.4	16	13	5*2.5 8*2.55	24.2	0.95*0.019 0.70*0.026	0.11 0.11

Figure 1: The layout of the ground floor of the SESAME building and the storage ring in the eccentric location, showing the beam lines from the 13 insertion device and from the bending magnets.

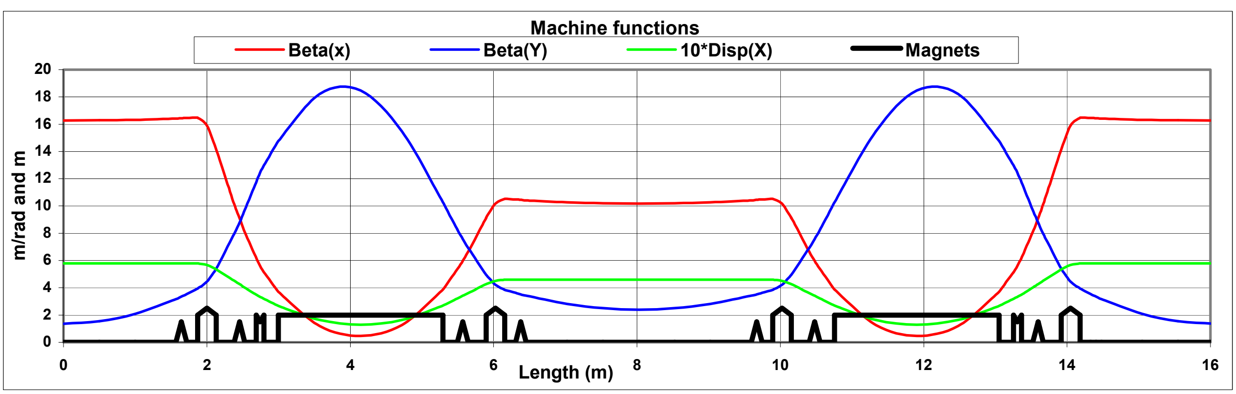

Figure 2: Machine functions within the unit cell of SESAME.

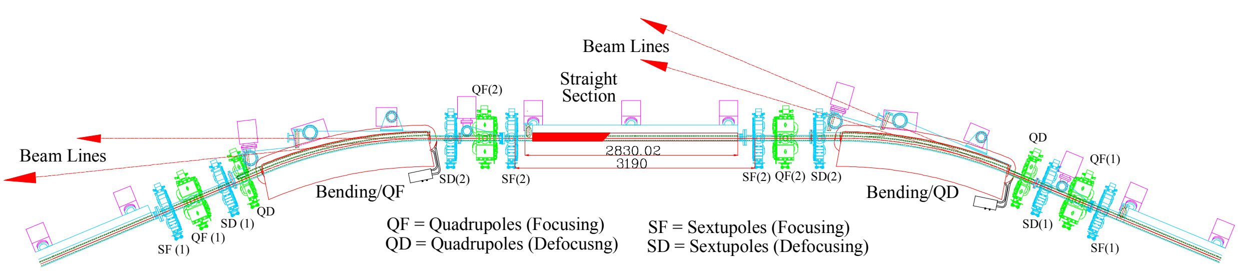

Table 3: The main parameters of SESAME.

Energy (GeV)	2.5
Maximum Beam Current (mA)	400
Bending Flux Density (T)	1.425
Circumference (m)	128.4
Emmittance (nm.rad)	24.9
Length of the Insertion Devices (m)	2.75
Beam Cross Section (Straight Section), (μm)	700*26
Straight Sections for insertion devices (m)	13

The beam dynamics

The physical aperture of the machine without any multipoles in the magnets has a huge value, in the horizontal direction up to 70 mm and in the vertical direction up to 15 mm. For the multipoles in the magnets we took the values from the magnets of SPEAR III. The multipoles of the bending magnets don't have any influence to the dynamic aperture, because the beta function within the bending magnets are pretty small.

The dynamic aperture with the multipoles of the quadrupoles and sextupoles for the nominal energy as well energy deviations of +/-3% are given in Fig. 4 and 5. The available physical aperture is presented too. The energy acceptance of the machine will be, according to the layout of the RF-system not larger as 2 %.

The main components of the machine

The upgrade of BESSY I storage ring from 0.8 GeV into 2.5GeV will allow use of only few components of BESSY I storage ring for SESAME storage ring, however the original BESSY I injector will be used after few modifications, instead of the 10Hz white circuits, 1 to 3Hz fast power supplies will be used, with the new power supplies the energy of the injector could be increased from 800MeV into 1GeV, the 20MeV microtron of BESSY I will be used as a pre-injector for the SESAME machine, a new transfer line between the booster synchrotron and the storage ring will be installed.

A new vacuum chamber made of stainless steel will be used, also copper absorbers distributed after each dipole are going to be used to absorb the unused radiation, an antechamber design for the vacuum chamber is foreseen for SESAME, an estimated pumping speed of 32000L/s from ion pumps and titanium sublimation pumps will allow a pressure of 1 nTorr to be achieved by the end of the commissioning stage.

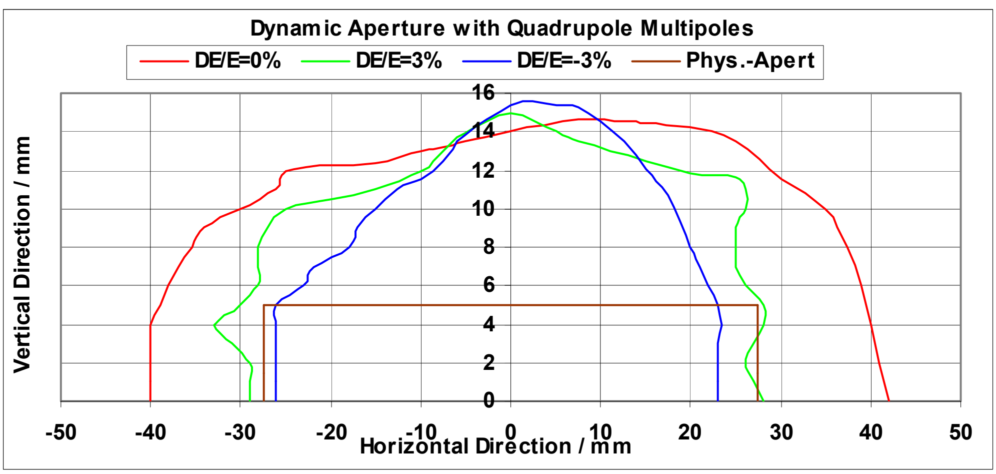

Figure 4: Dynamic aperture of SESAME IV including the multipoles of the quadrupoles.

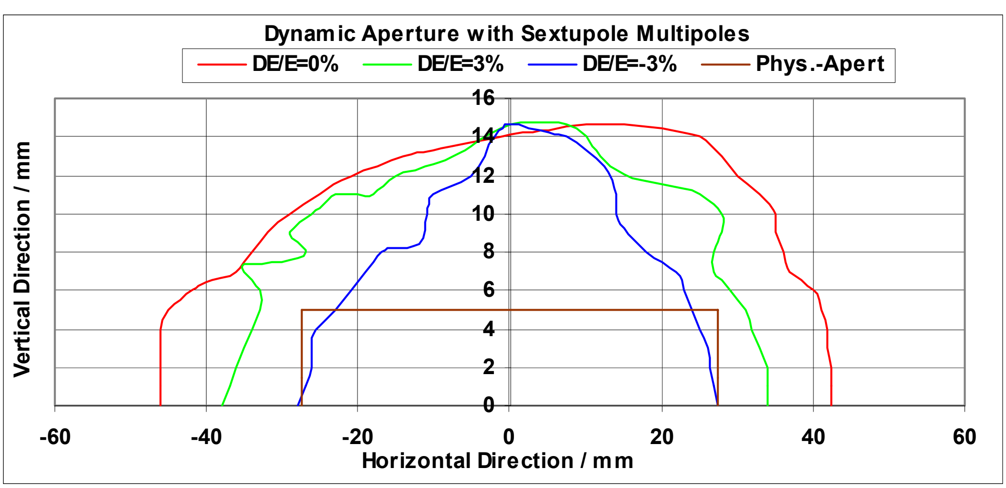

Figure 5: Dynamic aperture of SESAME IV including the multipoles of the sextupoles.

The RF system will be built up in stages, first two cavities with a power up to 250kW will allow SESAME to operate at 2GeV and two wigglers, then another RF cavity will be installed with an over all power of 500kW this will allow SESAME to operate at 2.5GeV and up to 6 wigglers and with a current of 300mA, the final stage is by adding another RF cavity to the storage ring, with an other all RF-power of 750kW, then it will be possible to run SESAME at 2.5GeV with 6 wigglers and a current of 350mA.

EPICS will be adapted as a control system for SESAME; the same control system will be used for both the machine and the beam lines.

A completely new diagnostics system will be installed for SESAME.

Few power supplies from BESSY I can be used for SESAME (mainly for the booster synchrotron).

THE FIRST SET OF BEAM LINES AND CHARACTARISTIC OF SYNCHROTRON RADIATION

Through extensive consultation, scientific workshops and the first SESAME user meeting, six beam lines are being planed for the first phase for different applications include MAD Protein Crystallography, SAXS and WAXS for polymers and proteins, Powder Diffraction for material science, UV/VUV/SXR Photoelectron Spectroscopy and Photoabsorption Spectroscopy, IR Spectroscopy, and XAFS. Most of the applications require hard x-rays up to 20 keV photons, the description and energy range of these beam lines are presented in table 4. The brightness of the emitted radiation of a 400mA stored beam from different sources are presented in Fig. 6. [7]

Table 4: The first set of beam lines at SESAME.

No.	Description of Beam Lines	Energy Range
1	MAD protein crystallography (undulator)	7.5–15 keV
2	Small angle X-ray scattering (undulator or wiggler)	5.0–15 keV
3	Spectroscopy of gases and solids (undulator)	0.05–2 keV
4	EXAFS (2.5 Tesla multipole wiggler)	3–25 keV
5	Powder diffraction (2.5 Tesla multipole wiggler)	3–25 keV
6	Infrared spectroscopy	0.01– 1 eV

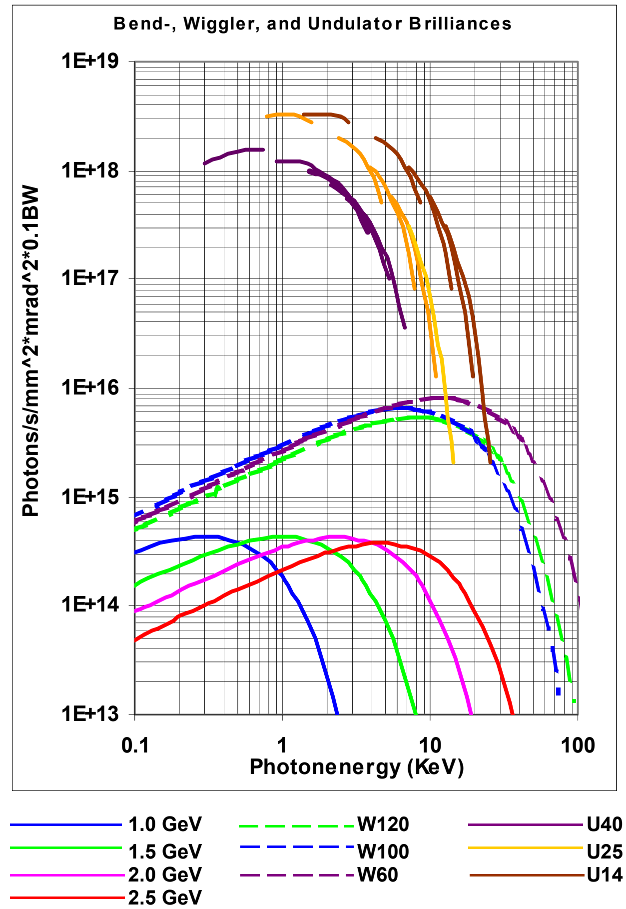

Figure 6: Brilliance of the synchrotron radiation emitted from the stored beam in the bending, wigglers and undulators.

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