5. Layout of the Storage Ring

5.1 Introduction

SESAME, a 2 GeV synchrotron light source with a circumference of about 125 meters and the emittance of 17 nm.rad and a nominal current of 400 mA, is dedicated to deliver photons to different experimental needs of the Middle East region [1].

In this chapter, an overall view of the SESAME storage ring will be presented. After a brief description of the machine, the materials and the manufacturing processes are discussed and followed by some descriptions about the gate valves, bellows and the power absorbers around the ring.

5.2 Description of the SESAME Storage Ring

The design of the vacuum system of SESAME follows the chamber concept of the recently built synchrotron light sources around the world. The machine consists of three main parts: storage ring, booster and the beam lines. Figure (5.1) shows an overview of the machine including the beam lines. The booster is a 800 MeV synchrotron which is filled by a 20 MeV Microtron [2]. The injection in the storage ring is done at 800 MeV and then the energy of the particles is ramped up to 2 GeV. Three kickers are foreseen for the injection process. The RF system of the machine consists of a pair of cavities with a 250 KW klystron system [1].

There are two different types of beam lines on the SESAME machine; 0 degree and 11.25 degrees. The 0 degree beam line is specified for the photons, which are produced by the insertion devices and the 11.25 degrees one is for the synchrotron radiation from the bending magnets. The zero degree beam lines corresponding the dipoles in the downstream of the RF cavities and injection straight section don't exist because there is no place to put the insertion devices there.

Lengths of the beam lines vary by their angle and their position in the building. Figure (5.2) shows the ring which has been placed in the building including all possible beam lines and Table (5.1) presents the length of the zero degree and 11.25 degrees beam lines measured from the source point. The maximum length available for 0^o beam line is 34.1 meters and for the 11.25^o beam line is 30.4 meters measured from the source point, which should be enough for all the experimental needs. Nevertheless, if longer beam lines are needed, the ring position can be optimized to provide longer ones. The angle of 11.25^o has been chosen due to this fact that in the middle of the bending magnet the beam has the minimum possible size.

Table 5.1: Length of the beam lines in one quarter of the ring measured from the source point

Dipole Number	Length of 0^o beam line [meters]	Length of 11.25^o beam line [meters]
Dipole #8	34.1	29.4
Dipole #9	25.8	30.4
Dipole #10	29.5	29.8
Dipole #11	31.1	24.0

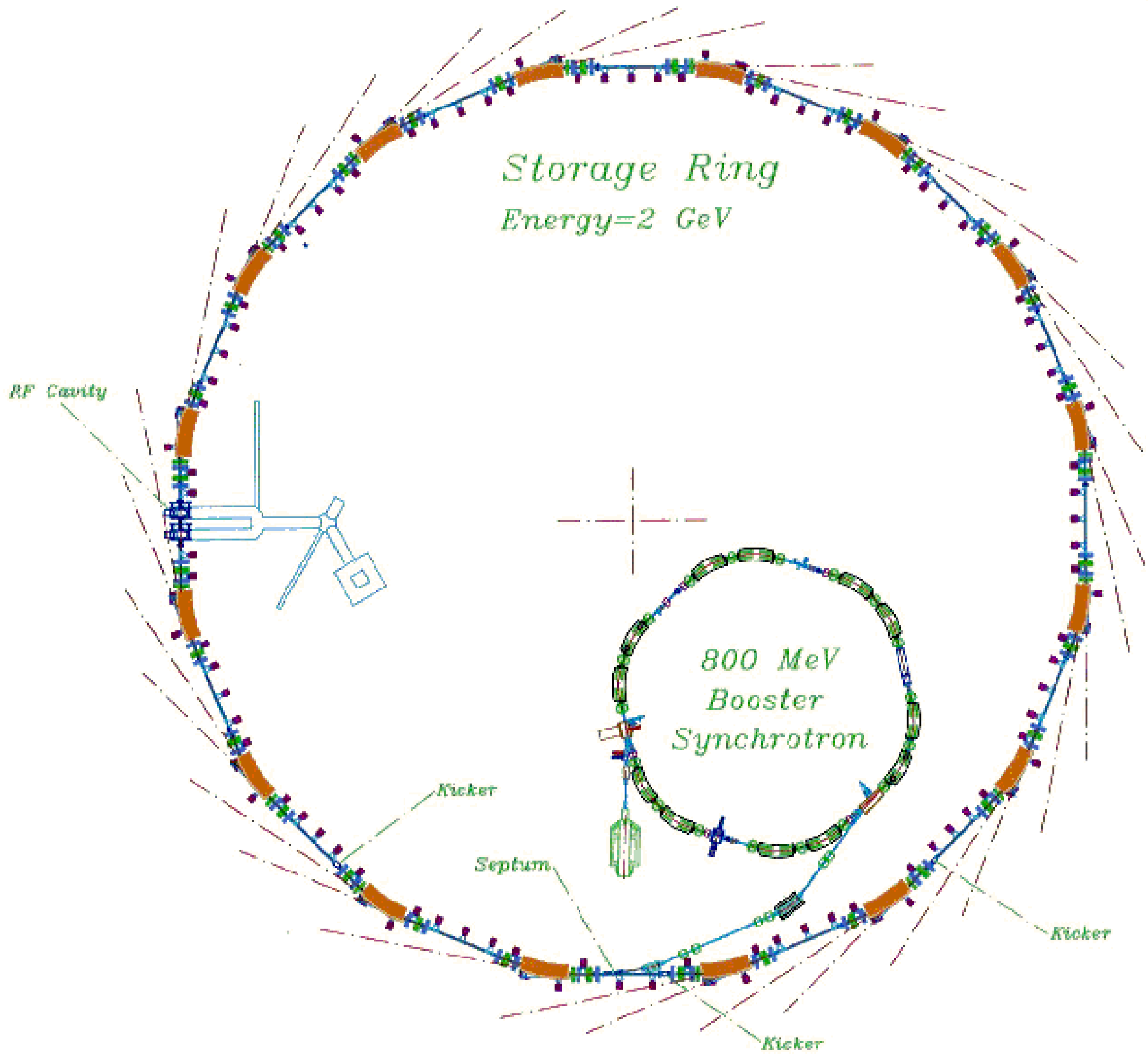

Figure 5.1: An overview of the SESAME machine

Each one of the 8 super periods of the SESAME storage ring lattice contains 2 bending magnets, So there are 16 dipoles in the whole machine, Figure (5.3) shows one super period of the SESAME. The overall circumference of the machine is 119.51 meters, so each super period is about 14.94 meters long.

The design of the dipole vacuum chamber is Chamber/Ante-chamber based which means that the electron beam circulates in one chamber and the synchrotron radiation passes through a small gap into the anti-chamber where it is absorbed by lumped absorbers. Since the length of this absorber is short compared to the circumference of the ring, the outgassing is obtained in a shorter time of conditioning. Furthermore the desorbed gases are immediately pumped by a large Ion pump close to the absorber. Figure (5.4) and (5.5) show an overview of the dipole vacuum chambers [3]. The vacuum chamber design will be presented in more details in section 5.5.

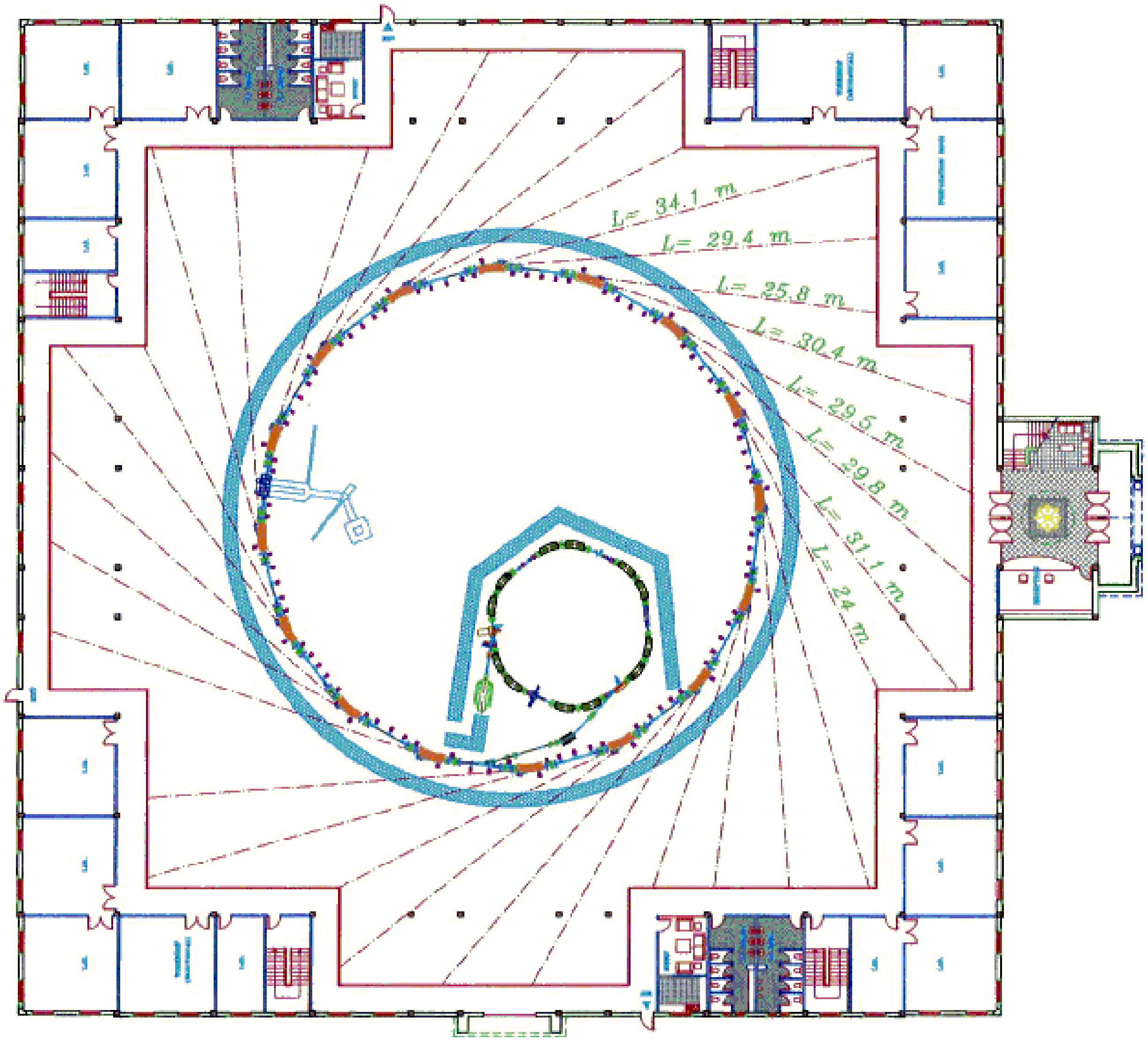

Figure 5.2: An overview of the SESAME machine placed in the building

As one can see on Figures (5.4) and (5.5), the dipole vacuum chamber includes a large pumping port as near as possible to the crotch absorber to pump the outgassing coming out from it due to the radiation. Another pumping port is placed on the other side of the dipole chamber to help keeping the pressure as low as possible. Using Titanium Sublimation Pumps in combination with Ion pumps is advised for dipole chamber. Due to the forces applied on the vacuum chamber from the atmospheric pressure side, it is necessary to use some strengtheners to keep the deformation below the reasonable limits; this has been discussed in more details in section 5.5.

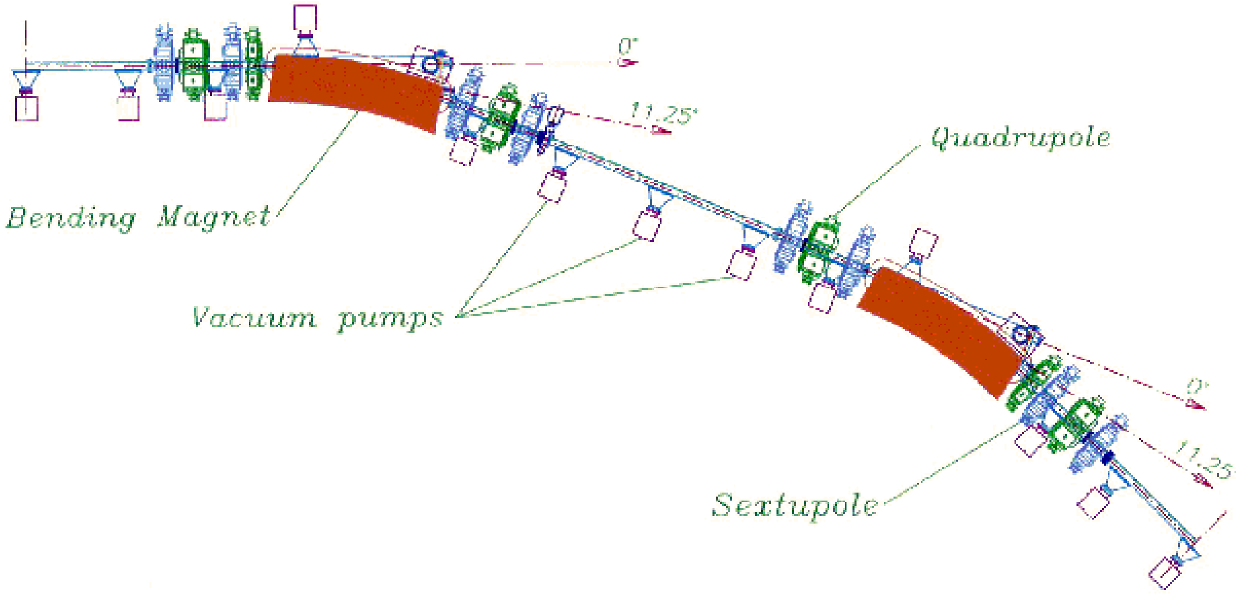

Figure 5.3: One super period of the SESAME storage ring

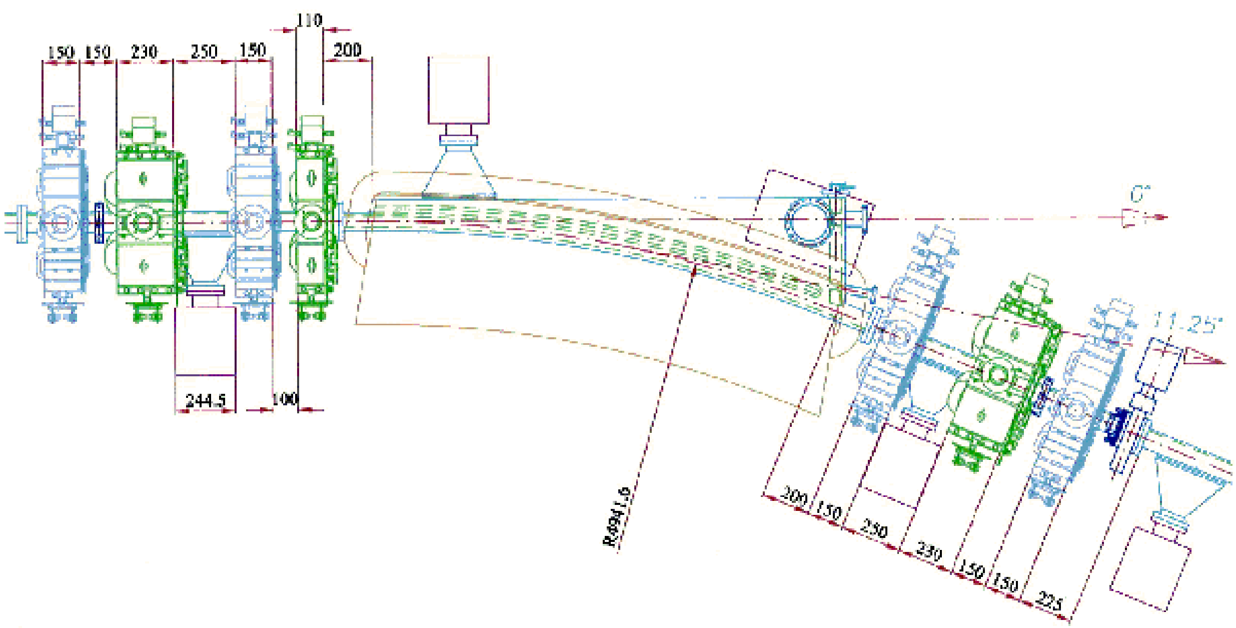

Figure 5.4: Top view of the dipole vacuum chamber, first dipole of the super period

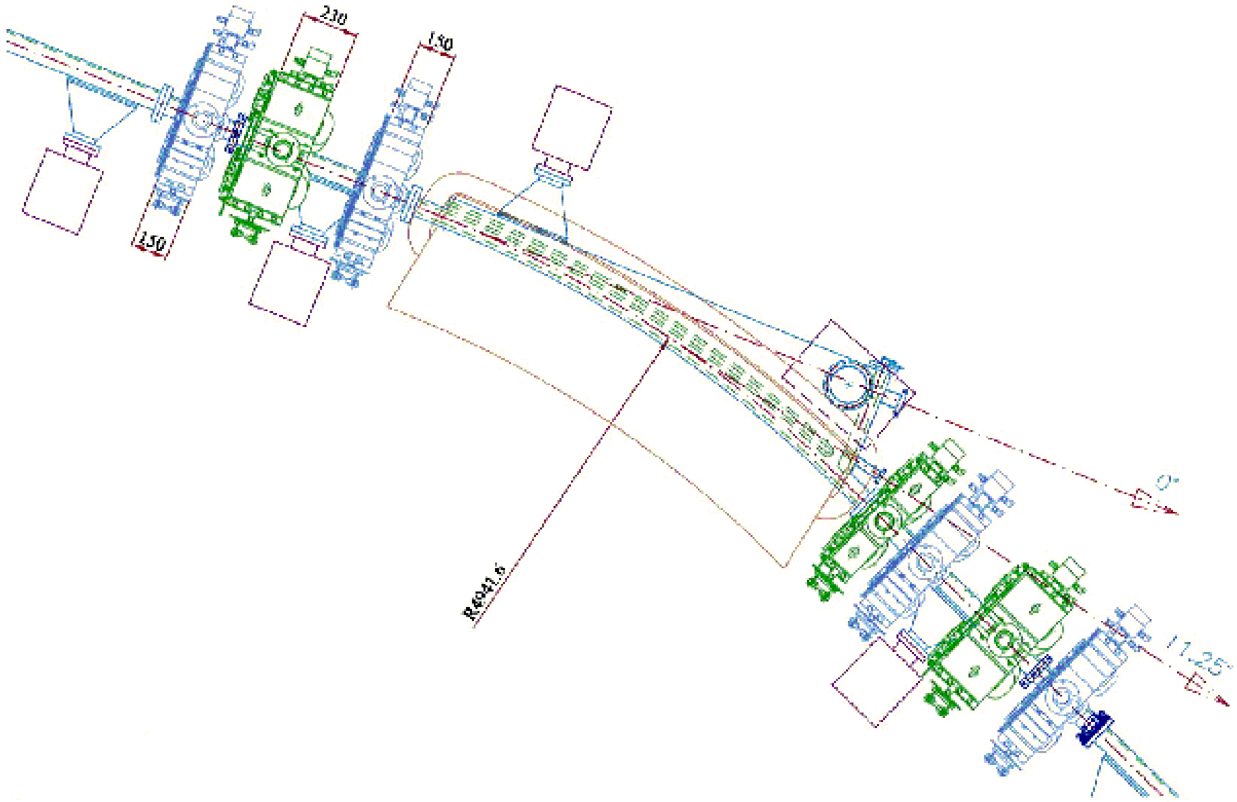

Figure 5.5: Top view of the dipole vacuum chamber, 2nd dipole of the super period

According to the SESAME lattice, two different kinds of straight sections exist, short straight sections with the length of 3.0 m and long ones with the length of 3.12 m. These values are nominal lengths of the straight sections, which means the distance between the last two focusing magnets but the usable length is a bit less than that because of the space needed for flanges, bellows and gate valves. The maximum usable lengths of the straight sections are estimated to be 2.75 m and 2.86 m respectively. In the places where the gate valves are installed this length may be reduced to 2.60 and 2.70 m. Figures (5.6) and (5.7) show the long and short straight sections respectively. Two flanges are foreseen at both ends of the straight sections to provide the possibility to change this vacuum chamber without opening the focusing magnets. This will facilitate the procedure of installation of the future insertion devices. Three pumps, at equal distances, are installed to keep the pressure down in this long chamber, which has a low conductance.

Some straight sections on the ring are dedicated to special purposes, one for the injection, one for the RF cavities and one for the beam diagnostic elements. Another straight section is also reserved for future upgrading of the machine to install a second RF system on the ring. The straight sections, which are used for the RF and injection, have been chosen from the short ones. So finally, there will be 8 long straight sections available on the ring for the installation of wigglers and 4 short ones for Undulators.

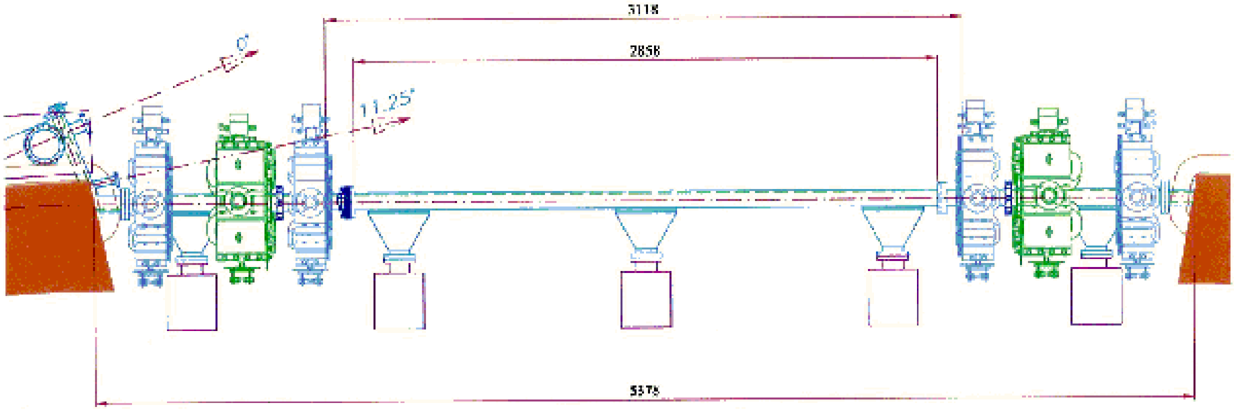

Figure 5.6: Long straight section

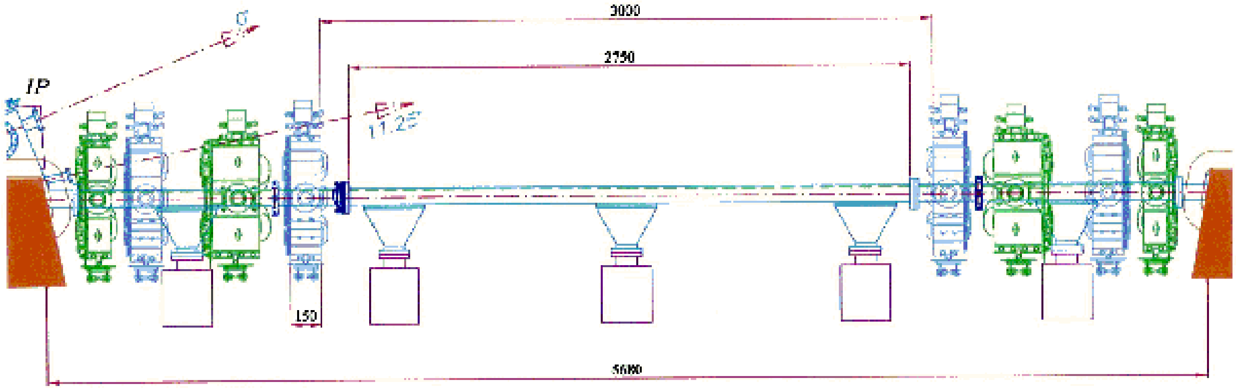

Figure 5.7: Short straight section

5.3 Choice of Material

In UHV (Ultra High Vacuum) systems the materials are normally chosen due to their outgassing rates because in this vacuum region, the main gas load comes from the surfaces. On the other hand the material should be strong enough to withstand the forces acting from the atmospheric pressure to the under vacuum parts. The bending of the vessel walls should not exceed 0.5 mm in the worst conditions [3].

The most common material, which is used in the most of the world accelerators is stainless steel which has good mechanical properties, weldability (TIG and electron beam) and low outgassing rate. For the SESAME storage ring Stainless Steel 316 LN (Z2 CND) is proposed for the main chambers including dipoles, multipoles and straight sections. The relative permeability of the material should not exceed 1.005 ($\mu_r \leq 1.005$) for the raw [3],[4].

The absorbers of the synchrotron radiation on the ring should be made of a material with a high thermal conductivity. In this case, OFHC[1] copper, ASTM C 10100 is proposed for distributed crotch absorbers. The parts for which the rate of radiated power is higher, GLIDCOP is proposed. This material has better mechanical properties in high temperatures compared to OFHC copper and is suitable for high power crotch absorbers. For more information about the materials, which are used in the vacuum system and their properties, please refer to the chapter 7, *The vacuum system of SESAME*.

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[1] - Oxygen Free High Conductivity

5.4 Multipole Vacuum Chambers

Multipole vacuum chamber of the storage ring consists of two parts, which are electron beam welded together: chamber body and the distributed power absorber. The chamber body has been made of 2 mm thick stainless steel sheets which are formed by folding procedure. The internal size of the chamber is 30x70 mm according to the optical needs of the machine. Figure (5.8) shows the cross section of the multipole vacuum chamber.

Distributed power absorber is placed on the outer side of the ring in the multipole vacuum chambers and the straight sections to absorb the power radiated from the dipole magnets and the insertion devices. To have a good power absorption, it is necessary to use a material with high thermal conductivity; OFHC copper has been used for this purpose. A ribbon of the OFHC copper has been attached to the stainless steel water-cooling channel using explosion bonding techniques.

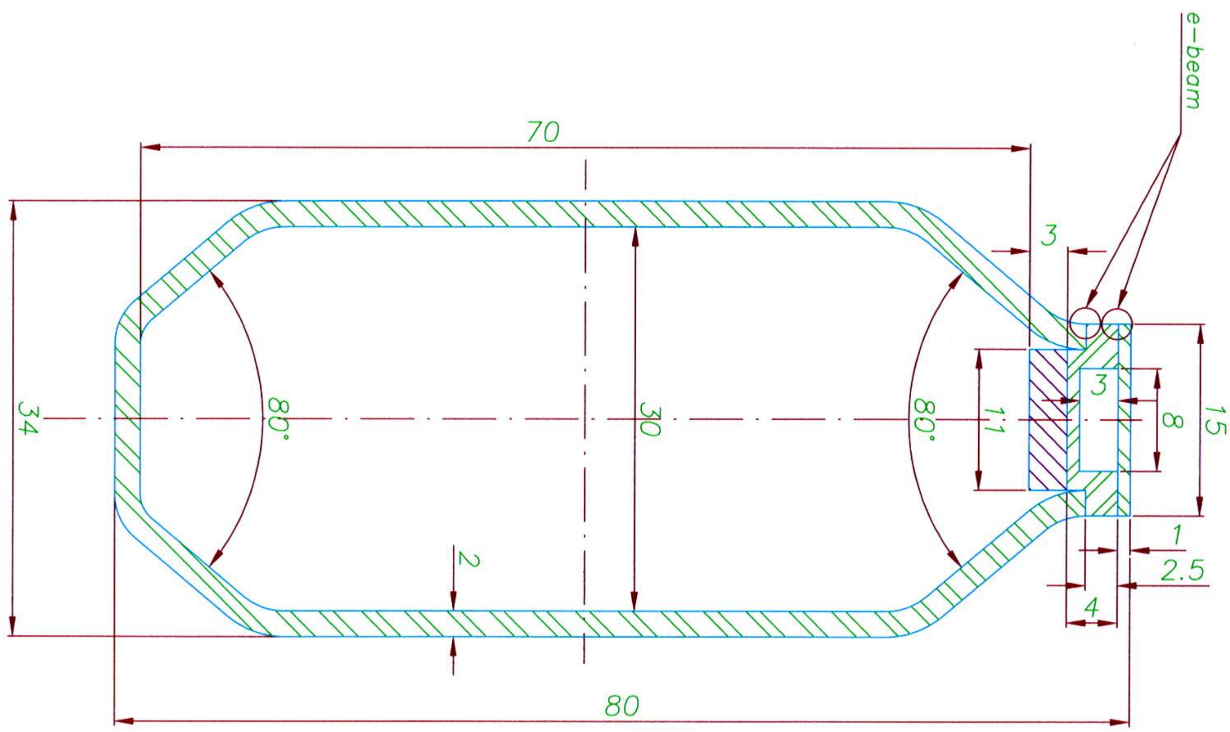

Figure 5.8: Cross section of the multipole vacuum chamber

5.5 Dipole Vacuum Chambers

The design of the dipole vacuum chamber is based on the chamber/ante-chamber design, which is well known and fully developed in the recent radiation sources around the world. Figure (5.9) shows a schematic cross section of the dipole vacuum chamber. It consists of two stainless steel plates, which are preformed by deep drawing procedure and a 7 mm thick outer wall. The two plates are first electron beam welded together from the internal side, and then this sub-assembly is welded to the outer wall from the external side. Because of the large surface area of the dipole vacuum chamber, the thickness of the stainless steel sheet used in this part is 3 mm to prevent the large deformations due to the forces acting via the atmospheric pressure. In any case, it is necessary to reinforce the chamber from outside using some blade-type strengtheners, which are welded, to the chamber to keep the deformation bellow 0.5mm everywhere. The strengthener plates should be connected to the chamber using point-welding method to prevent banana effect on the chamber.

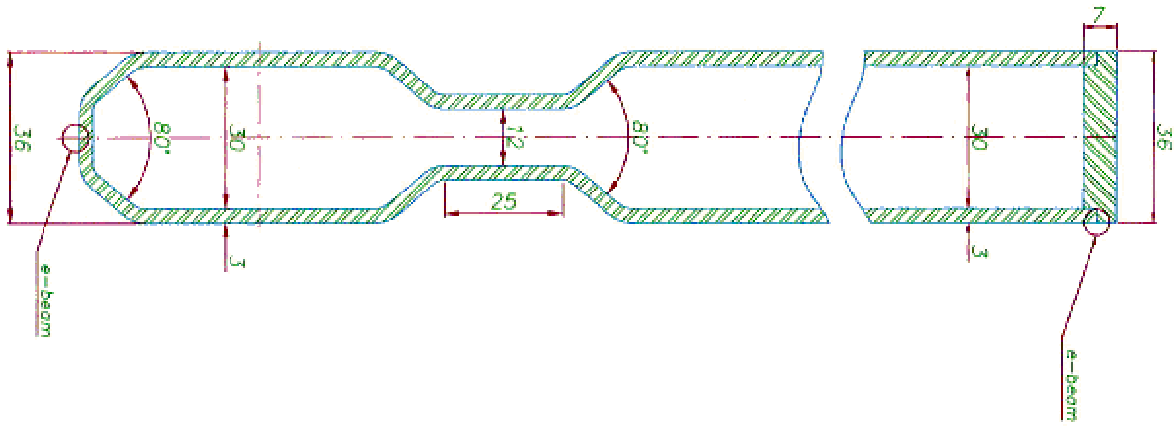

Figure 5.9: Cross section of the dipole vacuum chamber

5.6 Bellows and Gate Valves

The main reasons to have the bellows in the vacuum system are to make mounting procedure easier and absorb the mechanical tensions due to the thermal expansions of the chamber. They are also useful in modifying the accommodation of manufacturing errors. It is recommended to use RF shielded bellows to prevent sudden changes of the cross section of the beam chamber. One RF shielded bellows per straight section (16 in the whole machine) are foreseen for the SESAME storage ring. Figure (5.10) presents a sketch of such a bellows [4].

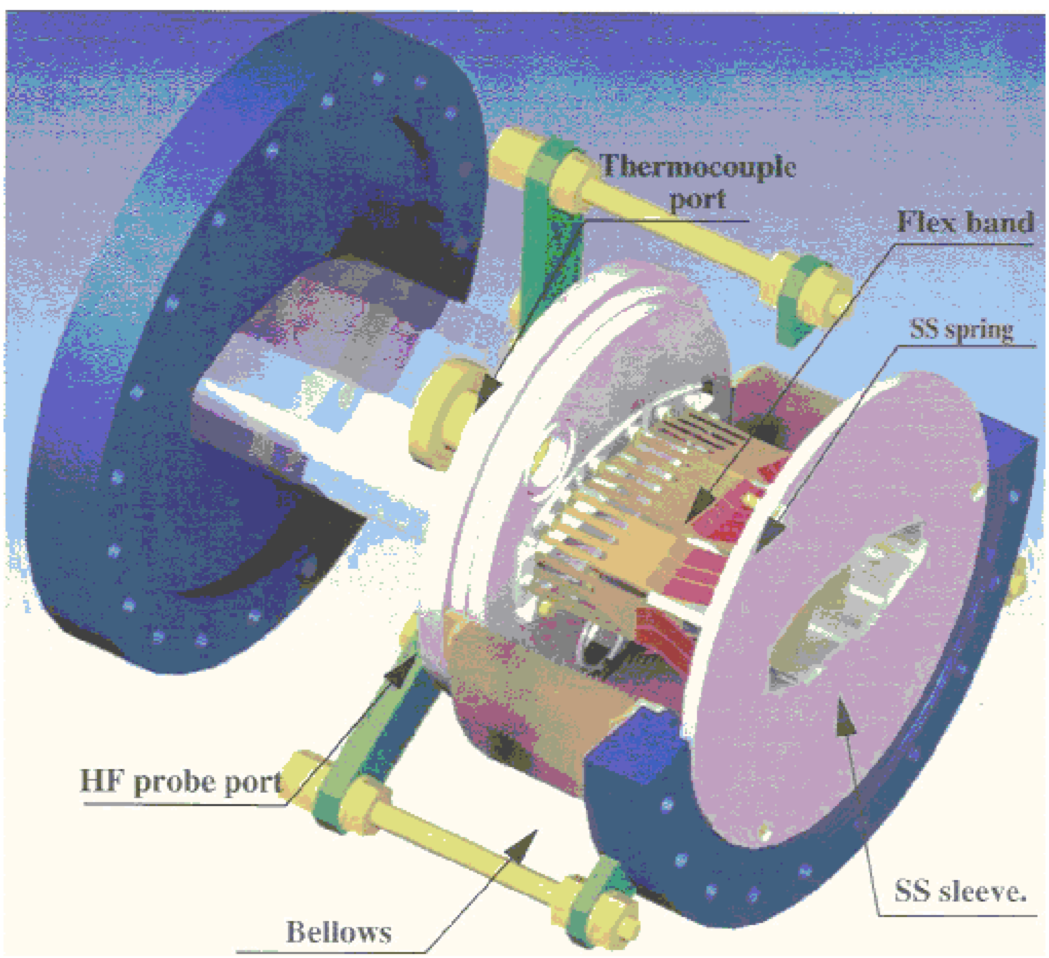

Figure 5.10: Schematic view of an RF shielded bellows

Gate valves are mainly used to divide the machine in smaller sectors. It is so possible to prevent the air effecting all the ring in case of a leak. The best design for the gate valves contains an RF shield which is commercially available from the market. 5 Gate valves are foreseen for SESAME storage ring, 2 at both ends of the RF cavities and 3 others to divide the machine into 4 sectors. Each sector contains 4 dipoles, which means that in case of a leak, or any necessary maintenance operation ¼ of the machine should be vented.

5.7 Synchrotron Radiation and Absorbers

Each electron storage ring has a power loss due to the synchrotron radiation. This power hits the walls of the vacuum chamber and causes temperature rise. Lumped and distributed absorbers are then necessary to remove the produced heat from the system. Total radiated power over the machine circumference can be calculated using the Equation (5.1).

$$P_T = 88.5\frac{E^4 I}{\rho} \qquad (5.1)$$

P_T : Total radiated power over machine circumference [Watts]
E : Energy of the particles [Gev]
I : The beam current [mA]
ρ : Bending radius [m]

So for SESAME storage ring with E=2 Gev and I=400 mA and ρ=4.94 m the radiated power in all circumference is 114.6 [KW] which means 18.24 [W/mrad]. The lumped absorbers in the dipoles and the distributed absorbers along the straight sections absorb this power.

If *d* shows the distance between the source point and a surface normal to the photon beam, the linear power density can be calculated by Equation (5.2). Figure (5.11) shows the different parameters, which have been used in the Equation (5.2).

$$P_l = \frac{P_T}{2.\pi.d} = \frac{P_T}{N.\rho.\alpha} \text{ , N: number of bending magnets} \qquad (5.2)$$

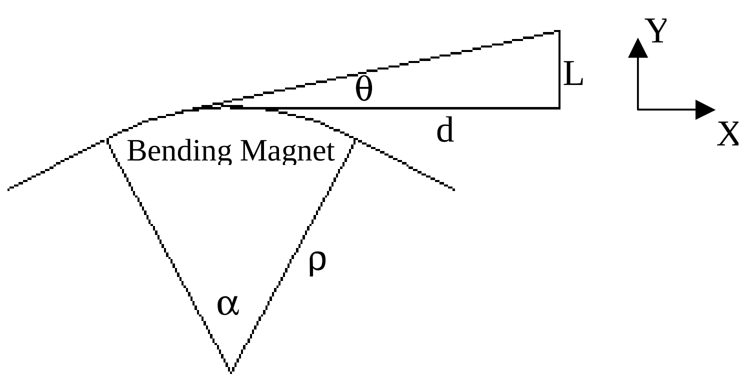

Figure 5.11: Different parameters of the Equation (5.2)

The crotch absorber on the SESAME dipole magnet is shown in Figure (5.12) in more details. The power absorbed by this absorber is shown in the Figure (5.13). The figure shows that the maximum heat load on the crotch is around 35 W/mm. In this case SLS type crotches can be used without any problem because they can withstand heat loads up to 50 W/mm. Figure (5.14) and (5.15) show sketches of this kind of crotch absorbers.

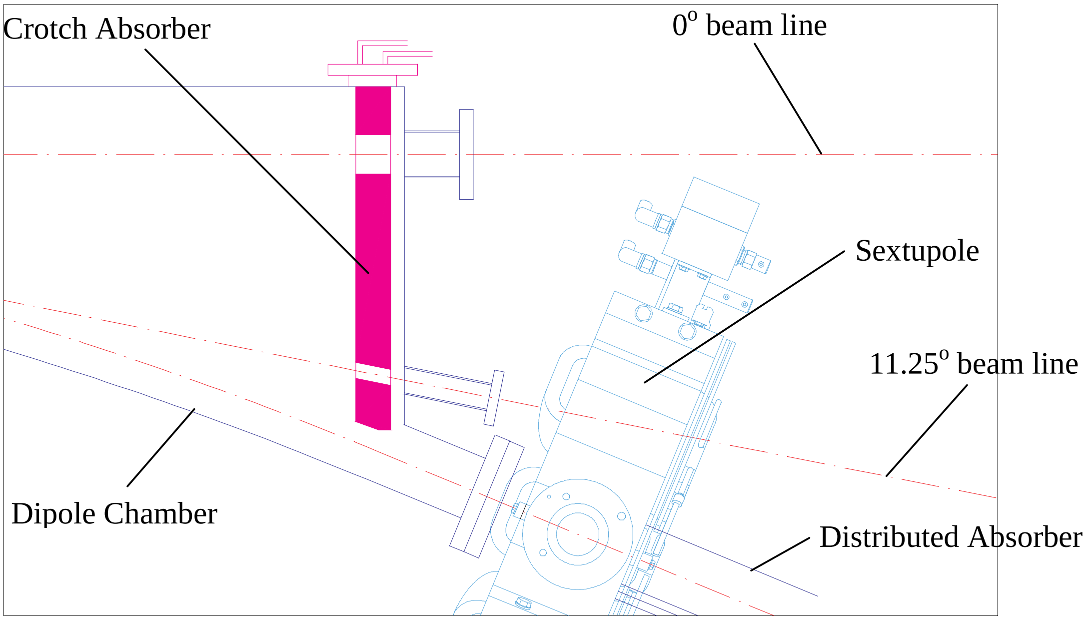

Figure 5.12: The crotch absorber on the dipole magnet

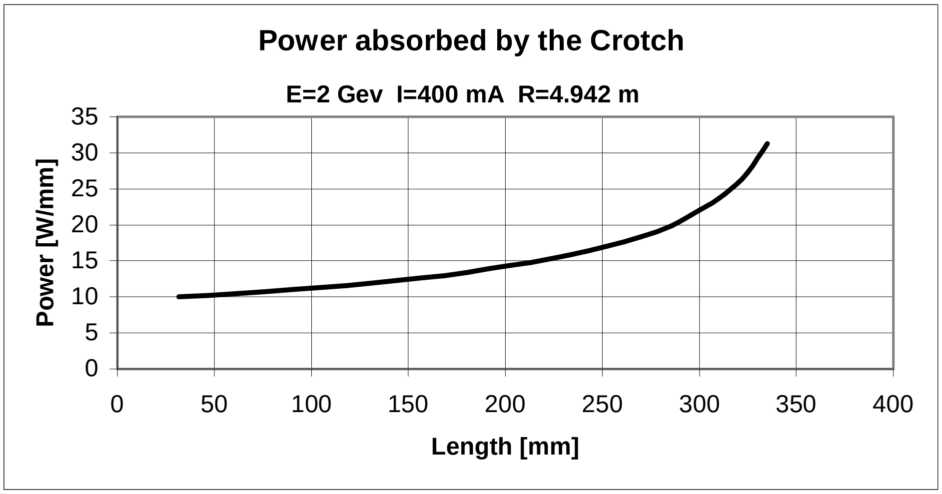

Figure 5.13: Power absorbed by the crotch in the dipole

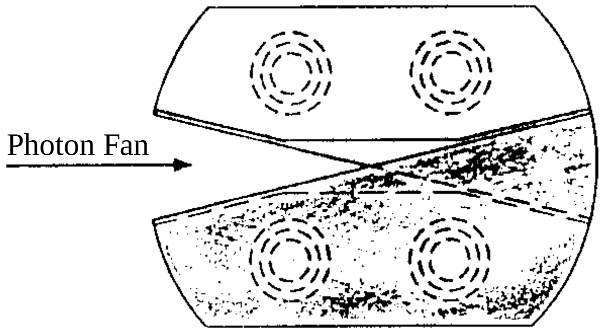

Figure 5.14: Cross section of the crotch absorber

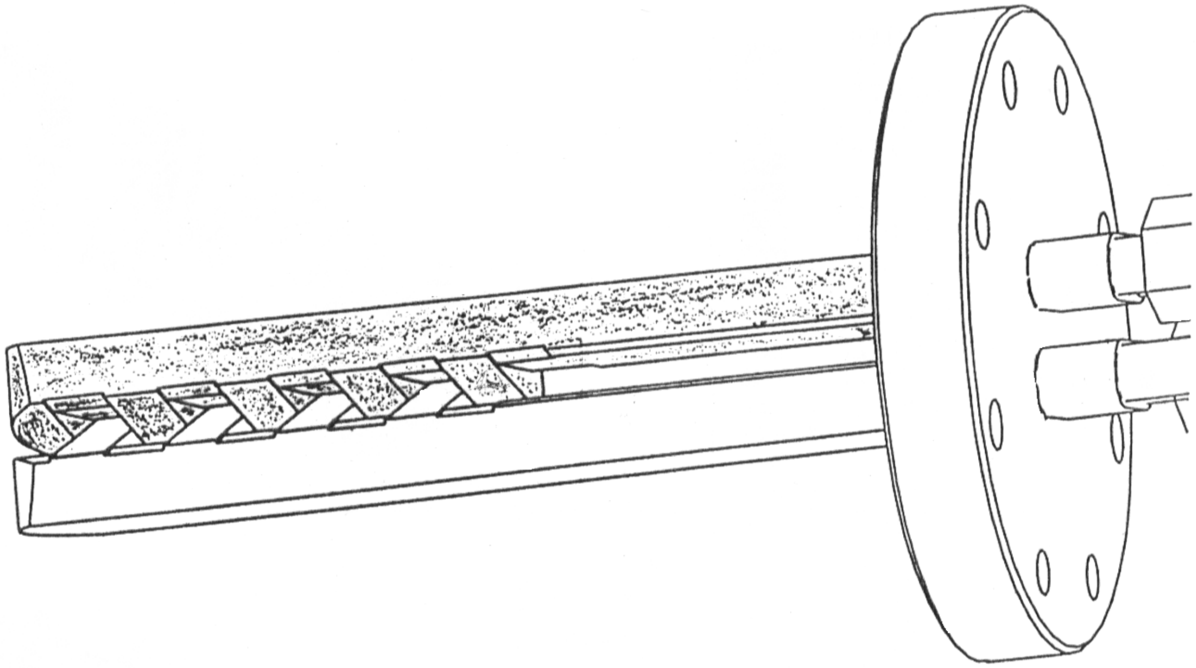

Figure 5.15: An overall view of the crotch absorber

The power absorbed by distributed absorber in the straight section has been shown in the Figure (5.16). The figure shows that the maximum heat load is around 2.6 W/mm, which is in the permitted range for these kind of absorbers.

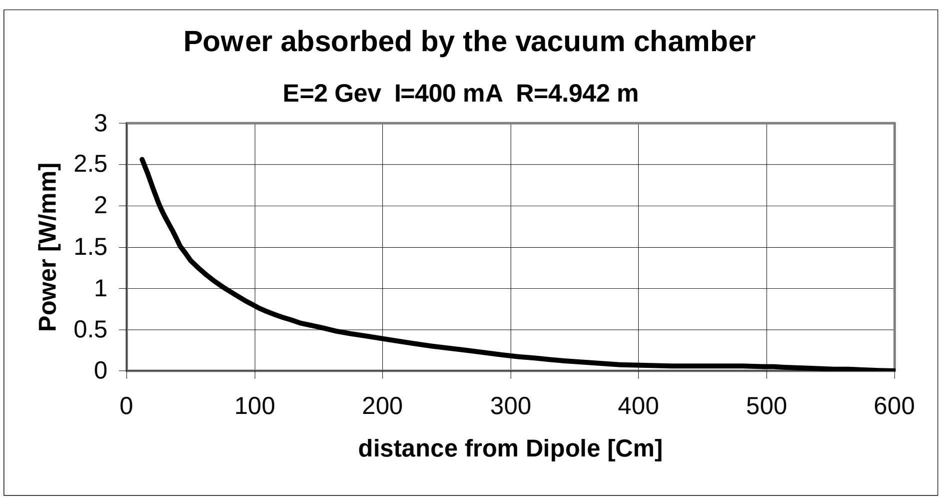

Figure 5.16: Power absorbed by the distributed absorber in the vacuum chamber

References

[1] D. Einfeld, SESAME, First Draft of Conceptional Design, version 8, March 2002.
[2] SESAME A Proposal for a Synchrotron Radiation Source in the Middle East, Oct. 1999
[3] E.Huttel, D. Einfeld, *"The vacuum system for the synchrotron radiation Source ANKA"*
[4] SOLEIL, *"Rapport d'Avant Projet Détaillé"*, Jun 1999