SPring-8 VACUUM SYSTEM

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Introduction

The vacuum system consists of two differently- shaped aluminum alloy (A6063-T5 whose strength is equivalent to that of T6) chamber extrusions, two types of absorbers, and the various chamber components such as bellows, flanges and valves.

To achieve a beam lifetime of approximately 24 hours, the vacuum chamber with its pumping system should be designed so as to maintain the beam-on pressure of 1 nTorr or less. The main pumping system is based on non-evaporable getter (NEG) strips, which are used in the straight and bending chamber. In addition to the NEG strips a distributed ion pump is installed in the bending magnet chamber. Lumped NEG pump, sputter ion pump and titanium sublimation pump are used at the crotch and absorber locations.

In a storage ring, the maximum achievable beam current depends greatly on the impedance of the vacuum chamber, its components, and RF cavities. A special technique must be employed to minimize their impedance characteristics. Therefore, our design has been carried out to have a minimum change in the cross section of the vacuum chamber; the vacuum chamber components such as bellows, flanges and insertion device chambers, which introduce a finite impedance.

Our philosophy in the design of the vacuum system is that synchrotron radiation is almost intercepted by the crotches and absorbers placed just downstream and upstream of a bending magnet, and not intercepted with the vacuum chamber all around the storage ring.

The most important task for the vacuum system should be considered as the development of the flanges whose reliability, especially of leakage, is still maintained through the multiple extreme operation like baking.

We report design results of the vacuum system and its current status of development and research.

SR Power density

The SR-induced gas load distribution is mainly based on the percentage of the SR intercepted by the crotch and strip absorber placed just downstream and upstream of the bending magnet from which photons produced.

Figure 1 shows the diagram of a magnetic cell of the storage ring including crotches (CR), absorbers (AB), and magnets. In particular, the crotches, CR 1 and CR 2 are positioned so as to intercept the greater part of the SR power without interrupting the experimental photon beam or interfering with the circulating electron beam. The total SR power, pg. in kW, is given by $26.6E^3BI$, where E is the electron energy in GeV, B the magnetic field in T, and I the electron current in A. For 8 GeV, B=0.61 T and I=0.1 A, the Pg. from 96 bending magnets (BM) in our storage ring corresponds to about 831 kW. Calculation results of SR power and its denisty show that 59.4 % (5.1kW) of SR power from BM1 and 48.3% (4.2kW) from BM2 are absorbed at CR1 and CR2, and these powers correspond to the power densities of 21.9 kW/cm^2 and 26.1 kW/cm^2, respectively.

The absorbers, AB1 and AB4, which are located in front of BM2 and BM1, absorb 31% (2.7kW) of SR power from BM1 and 1.8% (0.2kW) of that from BM2, respectively. 40.4 % (3.5kW) and 5.6 % (0.5kW) of SR power from BM2 are absorbed at AB2 at the beginning and AB3 at the end of the straight section, respectively. Table 1 lists the numerical values. A small fraction of the SR power from BM1 and BM2 is catched up by the following crotch. Furthermore, the SR light that passes out through the slot without being intercepted at the crotch or absorber, is not intercepted on the back side of the slot.

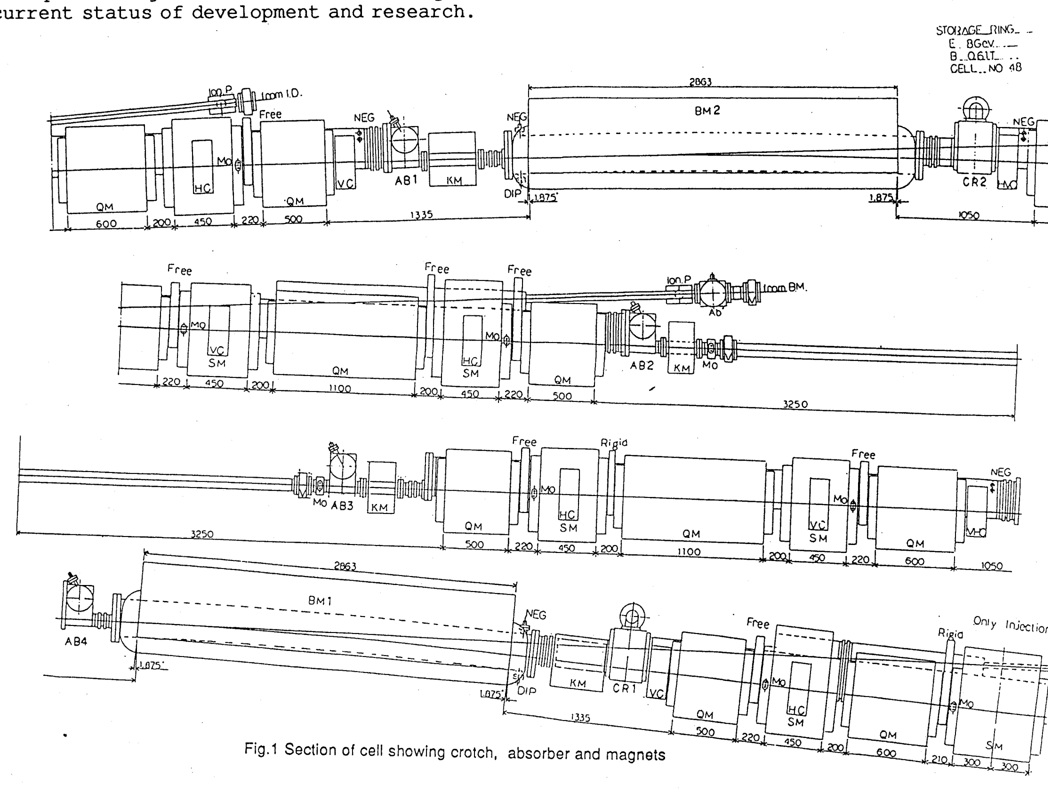

Fig.1 Section of cell showing crotch, absorber and magnets

Table 1 Numerical values of SR powers and its densities

Area	%Absorbed	Absorbed power (kW)	Max.power density (kW/cm^2)
a)BM1 Radiation			
CR1	59.4	5.5	21.9
AB1	31.0	2.9	2.2
CR2	9.6	0.9	0.8
Total	100.0	9.3	
b)BM2 Radiation			
CR2	48.3	4.5	26.1
AB2	40.4	3.8	3.1
AB3	5.5	0.5	0.8
AB4	1.8	0.2	0.4
CR1	4.0	0.3	0.2
Total	100.0	9.3	

Vacuum chamber

In our storage ring, we are considering to use an extruded aluminum alloy (A6063-T5) as the materials of chambers to minimize SR-induced desorption as well as thermal outgassing.The chemical composition of A6063-T5 is 0.55 w/o of Mg, 0.44 w/o of /Si and the balance is Al. This aluminum alloy chamber is extruded in atmosphere of $Ar+O_2$.

A cross-sectional view of the vacuum chamber for the straight sections is shown in Fig.2. The vacuum chamber consists of an electron beam chamber and a slot-isolated antechamber in which NEG strips are installed.

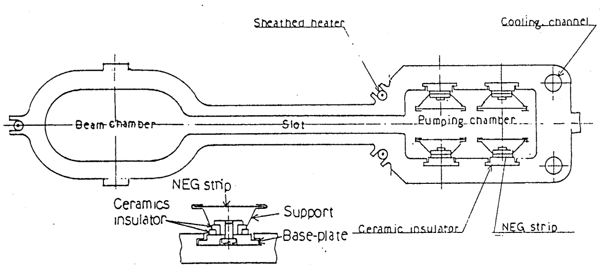

Fig.2 Cross sectional view of the vacuum chamber for the straight sections

The cross-sectional view of the vacuum chamber for the bending magnet is shown in Fig.3. This vacuum chamber consists of a beam chamber, a slot-isolated antechamber and pump chamber. We install a distributed ion pump (DIP) and a NEG strip pump on opposite sides of the beam chamber.

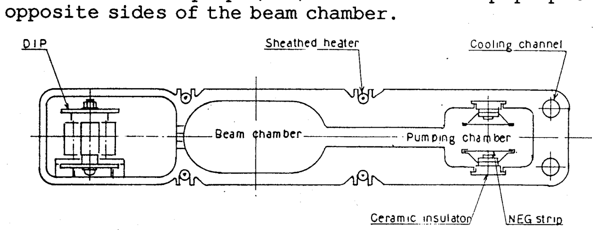

Fig.3 Cross sectional view of the vacuum chamber for the bending magnet

SR is almost intercepted by crotches and absorbers placed just downstream and upstream of a bending magnet, and not intercepted with the vacuum chamber all around the storage ring.

Bakeout and cooling

To achieve the temperature for the NEG activation, a heating current of 60 A is required and the corresponding power dissipation is 4mx345 W/m(=1380 W). This thermal load can be easily removed by the water cooling system, which is designed for load up to 5 kW/m. This can be achieved by flowing water at about 2 m/s in two channels of 10 mm-diameter.

Bakeout of the chamber is achieved by inserting flexible sheathed heaters in three channels for the straight section chamber and in four channels for the bending magnet chamber, which can bring the chamber temperature up to 150°C. The chamber is thermally insulated with kapton films to reduce heat losses. The chamber components such as gauge, valve, bellows and RF cavity are baked using electrical heating tapes.

Crotch feature

We design a new type crotch, in which particles such as photoelectrons, reflected photons, and SR-induced outgasses from the crotch are efficiently trapped. This crotch was also designed to reduce RF impedance, introduced owing to the crotch.

Our crotch, which is shown in Fig.4, consists of two watercooled copper (OFHC-classl) absorbers which get thermal load from the SR, and highly concentrated pumps : a lumped NEG pump of about 2500l/s which consists of 14x getter wafer modules (Saes getters-WP1250), a 400l/s SIP and an approximately 1000 l/s TSP.

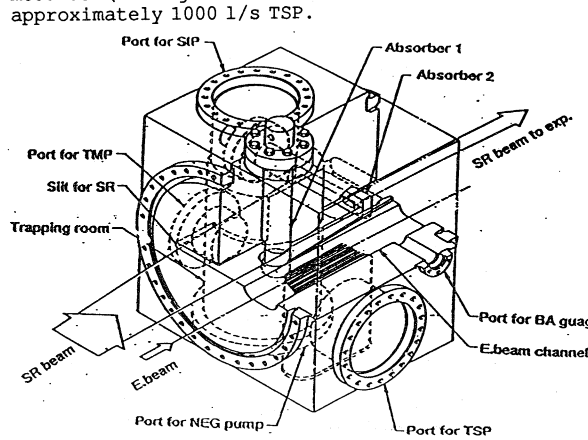

Fig.4 Isometric view of the crotch

A main body of the crotch is also made of copper (OFHC-classl) because its photo-electron yield under SR irradiation is lower compared to that from other materials. A flange at the crotch is made of an aluminum alloy-pure alluminum-copper clad plate (by explosion method or bonding). The body consists of two rooms : one is for an electron beam passageway, which was fabricated to match a cross-section of an electron beam chamber, thereby minimizing heighter order mode losses (or reducing RF impedance). The other is for trapping particles. The trapping room is indirectly connected to the beam chamber by a slit having low conductance. SR-induced outgassing form the crotch is locally pumped before the gas molecules have a chance to bounce into the beam chamber. This is accomplished with three different pumps described above. An SR beam form bending magnet enters the trapping room through the slit and strikes absorber's 1 (AB 1) and (AB 2). Not only AB 1 and AB2 on which SR beam strikes directly but also the main body is made of OFHC, because (1) SR-induced desorption is caused by photo-electrons which bounce in the space around AB 1 and 2 at random, (2) photo-electorons are produced by reflected photons besides the photons which strike AB 1 and AB 2 directly.

Chamber components and mounts

In the design of chamber components, special effort must be given to minimize their impedance characteristics because, in the storage ring, the maximum achievable beam current depends greatly on their impedance. Therefore, the components must be designed such as to avoid as much as possibly any change in the cross section. To minimize the impedance of the chamber components, the gaps between flanges must be reduced, the bellows must be shielded by a RF contact and a step change in the cross section of the vacuum chamber must be provided by means of a tapered transition. Our policy for the design of the vacuum system is : 1) The number of flanges and bellows should be as small as possible. 2) Monitors are mounted directly on the vacuum chamber without a special monitor chamber. 3) A valve and bellows are connected with flanges. 4) The connection between a kicker chamber and main vacuum chamber should be done with flanges for maintenance. 5) Crotches and absorbers are fixed to have advantages in the mounting of the chamber. 6) Exchange of NEG assembly and DIP should be possible for maintenance. 7)Weldment around the storage ring should be kept down to the least.

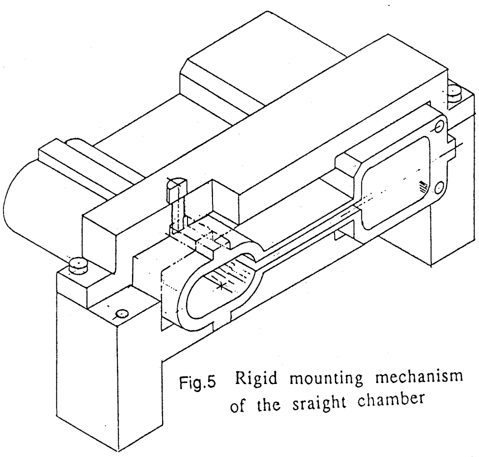

Fig.5 Rigid mounting mechanism of the sraight chamber

The chamber for a straight section is installed with two mounts, a crotch and an absorber as shown in Fig.1. One mount is completely rigid and does not allow chamber movement in any direction even during chamber bake cycle (see Fig.5). The other mount allows the chamber thermal expansion or contraction only in the electron beam direction, but not the vertical by means of a special mechanism (see Fig. 6). This mounting method should be able to insure a displacement of the vacuum chamber less than the accuracy of 0.1mm required for the beam position monitor.

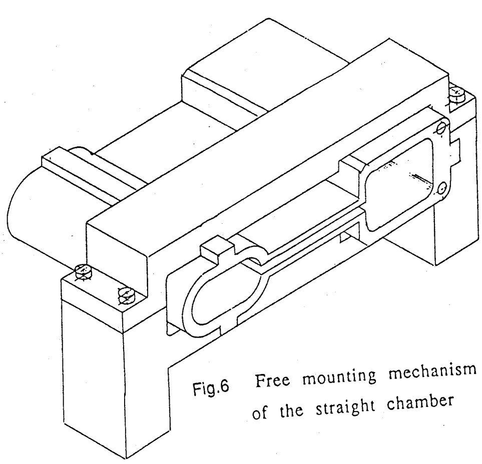

Fig.6 Free mounting mechanism of the straight chamber

Pumping system

A gas load in the vacuum system depends on SR-induced gas desorption and thermal desorption. Sr-induced gas desorption decreases with an integrated photon flux. This is directly related to the integrated electron beam currents. The gas load, Q, can be expressed by[1] $Q=2.7 \times 10^{-4} D^{-2/3}$ Torr/s for 0.1 A at 8 GeV, where D is the integrated electron beam current in Ah unit. The total thermal gas load is 8.5×10^{-5}Torr l/s. In this estimation. we considered an extruded aluminum alloy as a chamber material and an oxygen-free copper as a crotch material. For the outgassing rate of these materials, we assumed 5×10^{-12} l/s cm^2. (Our measurement results is 2×10^{-13} Torr l/s.cm^2). The total inner surface area of the chamber and crotch is 1.7×10^7 cm

Main pumping system

Our main pumping system per cell of the ring is based on NEG strips that are used in both straight and bending chambers. DIP is only installed in bending chambers. DIP is only installed in a bending magnet chamber. Lumped NEG pump, SIP and TSP are used at the crotch and absorber locations. The pumping of the SR-induced outgassing from them is locally accomplished with these three pumps. Thus, the main pumping system is a mixed one, which consists of NEG strips, DIP, SIP, TSP and lumped NEG pump.Calculation result of a pressure gradient profile over one cell is shown in Fig.7.

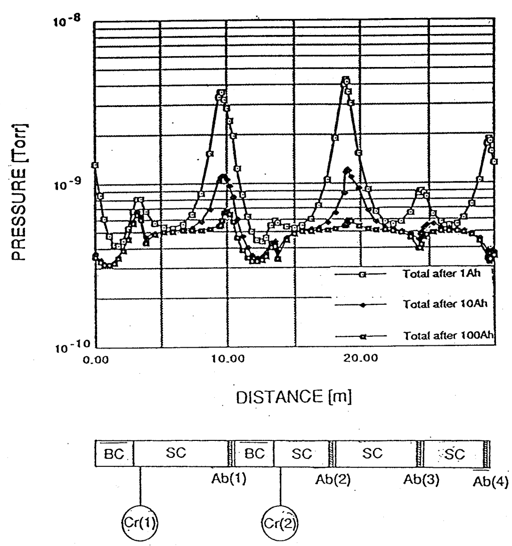

Fig.7 Pressure gradient profiles after the integrated stored current of 1, 10, 100 Ah

From this figure, we can find that an average pressure decreases with an increase in the integrated stored current.

After 100 Ah, the average pressure is approximately 0.2 nTorr, and a beam lifetime of about 24 hours is expected to be achieved easily.

References

1. ESRF Draft B (The Red Book) P.157