Performance of the SPring-8 Storage Ring Vacuum System

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Abstract

The installation of the vacuum system of the SPring-8 storage ring was completed during 1996, as was the vacuum control system. Most of the vacuum chambers are made of aluminum alloy. The main pumping system is a mixed one consisting of NEG strips, DIP, SIP, and LNP. In addition to the standard treatments for ultrahigh vacuum components, dust-controlled procedure was adopted in the manufacturing and the installation processes. In the commissioning phase, the photon induced desorption phenomenon was observed. The operation of the vacuum system shows good features of quick beam self-cleaning. The performance of the overall vacuum system is to be described.

1. Introduction

The SPring-8 with a beam energy of 8 GeV and a critical photon energy of 28.9 keV has been undergoing commissioning since March 1997. It will be open to the users with ten beamlines since October 1997.

In the synchrotron light source, due to the large desorption induced by the synchrotron radiation (SR), The dynamic pressure in the electron storage ring vacuum system is very high in the early stage of commissioning, in spite of the fact that a static ultrahigh vacuum environment has been achieved The interactions between the electron beam and the gas molecules desorbed from the chamber surface result in beam loss and emittance growth. Many criteria must be considered when designing the vacuum system of an electron storage ring. The design, fabrication, and testing of the vacuum chambers have been described before [1]-[4].

In this paper, the construction and the commissioning of the SPring-8 vacuum system are described.

2. Vacuum system

The manufacture and installation of the vacuum system of the SPring-8 storage ring was completed in October 1996. The vacuum control system including an interlock system for the purpose of vacuum safety, which was built in order to increase the reliability of the vacuum operation, was also completed at the end of 1996.

A layout of a normal unit cell is shown in Fig. 1. The vacuum chambers of normal unit cell consists of three straight section chambers (SSC's) with an absorber, two bending magnet chambers (BMC's), two crotch chambers (CR's) equipped with an absorber-crotch, two rf-shielded gate valves, one dummy chamber (IDD), four bellows assembled chambers (BEC's). A dummy chamber will be replaced by the vacuum system of the insertion device one by one.

The vacuum chamber materials are mainly aluminum

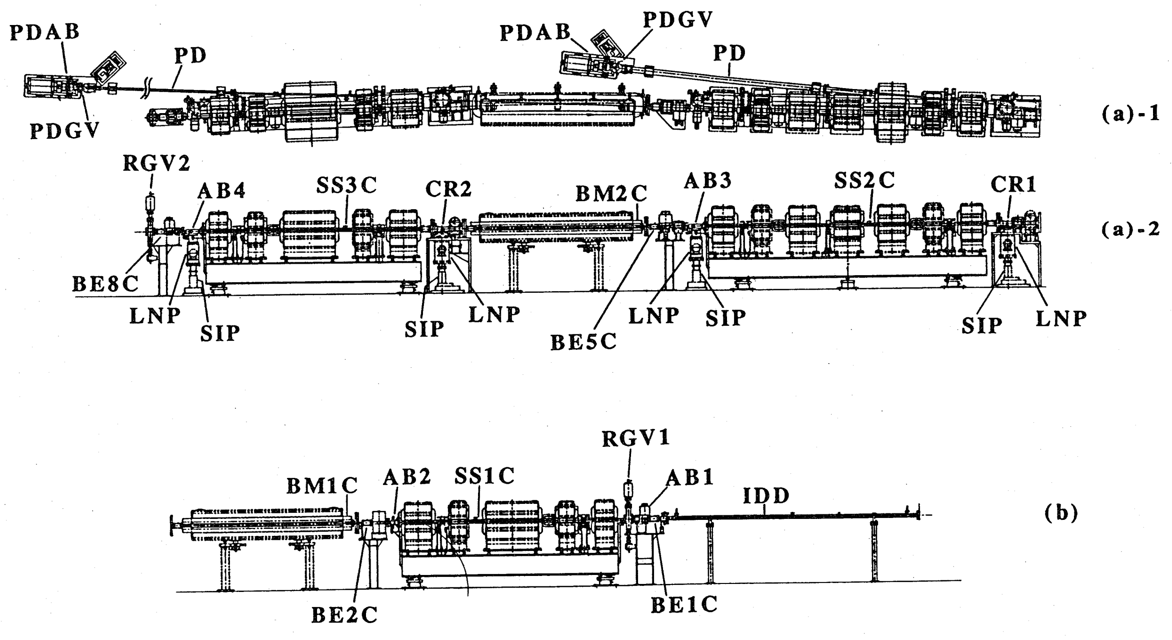

Fig. 1. A layout of the normal unit cell. (a)-1 and (a)-2 are top and side views of the downstream section of the cell, respectively. (b) is the side view of the upstream section of the cell.

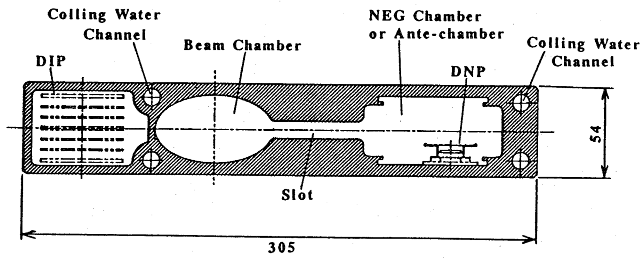

Fig. 2. The cross section of the bending magnet chamber (BMC).

alloys to benefit from their low outgassing rate, high thermal conductivity, low radio activity, and so on. The SSC and the BMC are made of A6063-T5 aluminum alloy by extrusion with the cooling channels on the both sides. The SSC consists of a beam chamber and a slot-isolated antechamber in which a pair of non-evaporable getter (NEG) strips, allowing for distributed pumping are installed. The BMC includes a rectangular pump channel in which a distributed ion pump (DIP) is installed, abeam chamber and a slot-isolated antechamber in which a NEG strip is contained. The beam chambers of the SSC and BMC are extruded with the same cross section in an ellipse 70 mm in width and 40 mm in height. Figure 2 shows the cross section of the BMC.

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 the order of 10^{-7} Pa or less with a circulating beam of 100mA. In our vacuum system, synchrotron radiation is almost intercepted by the crotches and absorbers placed just downstream and upstream of bending magnets. An only photon emission for energies less than 10 eV with a angular spread larger than 1.5 mrad in the vertical plane is intercepted by a slightly part of 10 mm photon beam slot walls of chambers.

The main pumping system is based on NEG strips which are used in the SSC's and BMC's to evacuate the scattered molecules, and lumped NEG pump (LNP) for evacuating mainly SR-induced gases at the crotch and absorber location.

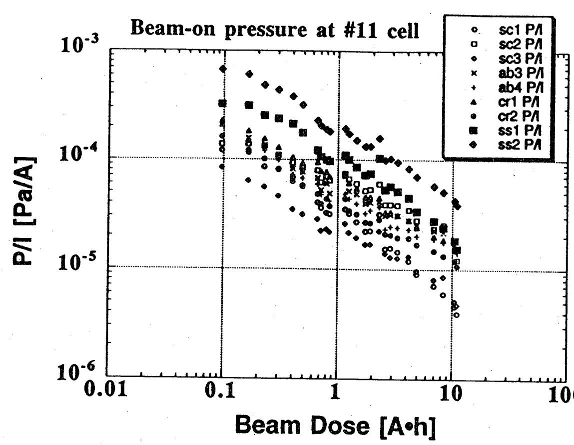

Fig. 3. The pressure per Ampere of the electron beam current versus the accumulated beam dose at several points in the unit cell.

In addition to the NEG strip, a DIP is installed in along-side the beam chamber of the BMC. A sputter ion pump (SIP) which assists the LNP is also used. The vacuum system is divided into 48 unit cell by rf-shielded gate valves and was installed and evacuated section by section. During chamber baking and NEG activation, we use the movable-type rough pumping system which consists of a rotary pump (RP) with a fore-line trap and a turbomolecular pump (TMP). The RP's are used to evacuate the vacuum system from atmosphere. The TMP's are turned on when the pressure reached the 1 Pa region. All of the SSC's, BMC's and IDD's were 150 °C prebaked in advance of the chamber installation in the storage ring tunnel in order to remove chamber warps which were caused by the construction process and welding. The NEG pumps were activated at the last stage of pre-baking procedure. Residual pressure after the pre-baking was the order of 10^{-8} Pa or less. All of the installation works were accomplished in a clean room or clean booth. After the installation of the vacuum system in the storage ring tunnel, the 140 °C baking of the vacuum system and the NEG activation were done once again, section by section.

The photon absorbers are made from Glid-Cop (Al and Al_2O_3 dispersion strengthened copper) because of high allowable thermal stress of 60 kg/mm^2, compared to 10 kg/mm^2 of OFHC. The absorbers have the structure in which particles such as reflected photons, photo-electron and SR-induced outgases are efficiently trapped. SR-induced outgases are evacuated locally by the high capacity pumping system before the outgases have a chance to bounce into the beam chamber. The part of the photon beam power from a bending magnet of 10.5 kW, about 6.6 kW (34 kW/cm^2) is irradiated at the photon absorber of the crotch and the remaining beam power deposited at the absorbers placed downstream of the crotch.

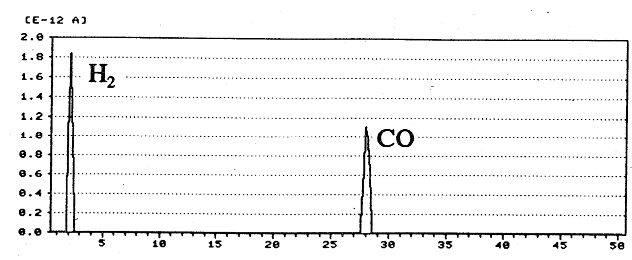

Fig. 4. Quadrupole mass spectrum for a beam current 1.1 mA at accumulated dose of 10.9 Ah.

3. Commissioning

The averaged pressure readings of the storage ring are $\leq 1\times10^{-8}$ Pa without electron beam, 5×10^{-7} Pa at a beam current of 18 mA. After a continuous cleaning by the SR, the pressure rise due to the photon induced desorption (PID) effect was significantly reduced. Figure 3 shows the curves of the pressure per Ampere of the electron-beam current (P/I) at various position of unit cell versus the accumulated beam dose. The value of P/I decreased by about two orders of magnitude after an accumulated beam dose of 11Ah. It shows the beam self-cleaning effect on the vacuum chamber. A mass spectrum at beam current of 1.1 mA and a dose of 10.9 Ah is shown in Fig.4. The dominant desorbed gases are H_2 and CO.

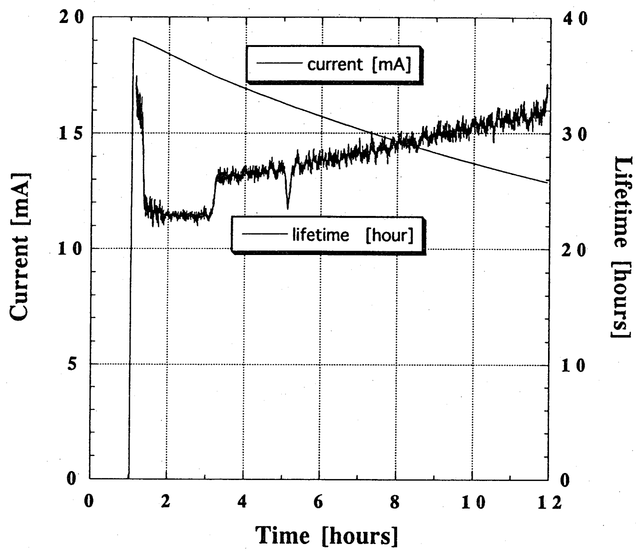

Fig. 5. The beam current and the lifetime of the typical operation.

An accumulated dose of 11Ah and a lifetime of 35 hours at 19 mA current were achieved after four months' operation. Figure 5 shows the electron beam current and beam lifetime on the typical operation. The gap of the insertion device has been closed down to 8 mm of the minimum gap of the standard in-vacuum type undulator of the SPring-8, the beam lifetime is reduced due to narrow gap of the insertion device.

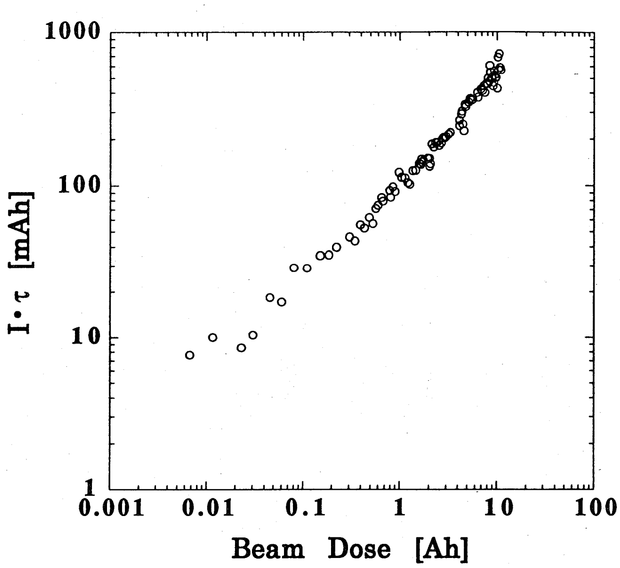

Fig. 6. The product of the beam current (*I*) and beam lifetime (τ) versus the accumulated beam dose.

Figure 6 shows the product of the electron-beam current (I) and the beam lifetime (τ) versus the accumulated beam dose. The relationship can be described by the following formula:

$$I\tau \sim 110 \left(\int I\,dt \right)^{0.65} \quad \text{mAh.}$$

The trend of the Iτ curve is determined by scattering of the electron beam by the photo-desorbed gas resident in the ring vacuum system.

In the summer shut-down period, all of the NEG strips and LNP were re-activated. The beam-on pressure was reduced by about one second, and then the beam lifetime increased. About 70 hours beam lifetime was achieved at 18 mA of the beam current..

References

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