THE VACUUM SYSTEM OF SUPER SOR

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Abstract

We present a design of the vacuum system of Super-SOR ring. Two types of beam lines are prepared to extract the synchrotron light from insertion devices (0 deg line) and from bending magnet (4.3 deg line). Design of the vacuum system is considered to avoid from the effects of the heating. These are also designed to suppress the beam instability by the induced wake fields.

INTRODUCTION

The Super SOR light source facility is a 3rd generation vacuum ultra violet (VUV) and soft X-ray light source to be constructed at Kashiwa campus of the University of Tokyo[1]. 1.8 GeV electron beam is planed to be circulating in the main ring with 400 mA beam current (maximum current). This facility aims to generate a highly brilliant light stably on the top-up operation. In order to realize the beam operation with such a highly brilliant light stably, the following properties are required to the vacuum system of the Super SOR main ring. One is to suppress the wake field. Beam instability and the heating by these wake fields will be enlarged by the large impedance section. Another is to avoid melting the vacuum chamber by synchrotron radiation especially from the insertion devices, when the beam current is 400 mA. Final important thing is to achieve the ultra-high vacuum pressure. Fig.1 shows the lifetime as a function of the vacuum pressure. If we need to increase the lifetime longer than 10 hours, the vacuum pressure should be lower than 5×10^{-8} Pa.

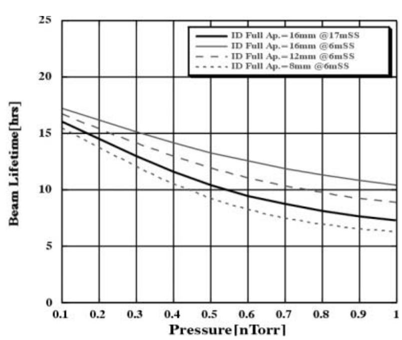

Fig.1. The lifetime vs vacuum pressure on each ID gap. The molecule is mainly assumed to be CO in this calculation. Touschek lifetime is also included.

DESIGN OF VACUUM CHAMBER

General layout

First we introduce the basic design of vacuum chamber. Fig.2 shows the vacuum chamber of the half of one cell.

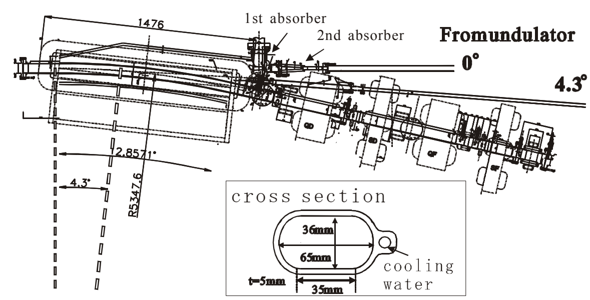

Fig.2. The layout of the vacuum chamber of the upstream of one cell. The squared area shows the cross section of the beam duct of normal section.

The cross section of the vacuum chamber is a racetrack type as shown in Fig.2 except for the ID ducts. The vacuum chambers will be made of Al alloy, except for flanges, bellows and beam position monitors (BPMs). To avoid the heating from synchrotron radiation, the cooling water flows the outer side of vacuum chamber. Two types of beam lines are prepared on the bending section. One is to extract the synchrotron light from the insertion devices (0 deg line). Another is to extract the synchrotron light from bending magnet (4.3 deg line). Because the beam energy is lower than that of SPring-8 (8 GeV energy ring), the divergence angle of the synchrotron light from the insertion devises is very large, especially when we utilize the lower photon energy light (10-30 eV). The gap height inside the chamber of bending magnet (called as the bend chamber) is also important parameter to avoid the synchrotron radiation irradiating the inner gap, which is named as SR-extraction gap here. Then we determined this SR-extraction gap is 20 mm, which is large enough to avoid the radiation heating. Fig.3 shows the cross section of the bend chamber. The SR-extraction gap is open with 20 mm height and the synchrotron radiation goes through this gap. The distributed ion pump (DIP) is equipped on the side of beam chamber. The clearance between the bend chamber and the bending magnet is 2.3 mm, which is large enough to set the bend chamber. The Al frame of the bend chamber has a thickness of more then 5 mm to avoid the deformation by the pressure of the atmosphere.

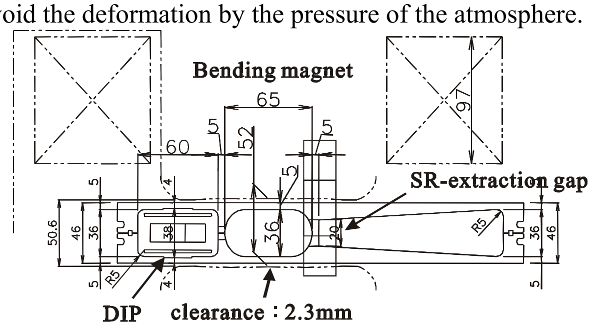

Fig.3. The layout of the cross section of the bend chamber. The DIP is equipped on the side of beam chamber. The inner gap of chamber is open with 20 mm height.

The absorption of the synchrotron radiation

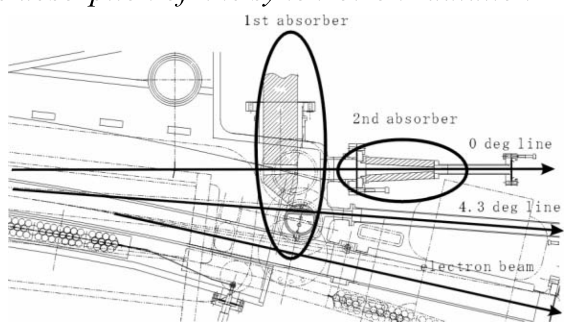

Fig.4 Expanded view of the downstream of the bend chamber.

If there are no absorbers, the synchrotron radiation from insertion devices hits on the light transport beam ducts and then beam ducts are melted. To avoid melting the beam duct, two absorbers are prepared just behind the bend chamber as shown in Fig.4. It is enough to absorb a few kW on these absorbers and to avoid melting the beam duct. We also note that the other components like the BPMs, the bellows and the flanges can be installed without cooling water, because those are hidden from synchrotron radiation by Cu absorbers to avoid the heat load as shown in Fig.5.

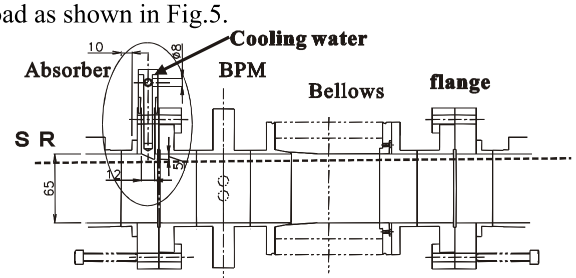

Fig.5. The BPMs, bellows and flanges sit in shade of the absorber from the synchrotron radiation.

The vacuum pressure

A large number of the pumping units are distributed. The DIPs are set on the bend chamber to obtain large pumping speed which is assumed to 500 l/s on each bending section. The titanium sublimation pumps and the sputter ion pumps are installed on the straight section in the main ring. The 300 l/s ion pumps are set on the end of the bend chamber and the 100 l/s ion pumps are set on normal straight sections at every two meters. If the beam current, the beam energy and the molecular desorption yield □ are assumed to be 400mA, 1.8GeV and 1×10^{-6} (molecular/photon), respectively, then the averaged pressure will reached less than 4.6×10^{-8} Pa. Fig.6 is the calculated pressure distribution in the main ring by assuming the above conditions. The vacuum pressure is measured by a few B-A gauges and/or CCGs on an each one cell.

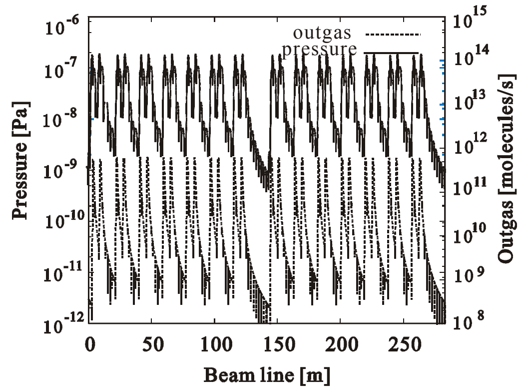

Fig.6. The pressure distribution along the main ring. The horizontal axis shows the positions along the main ring. The solid line shows the pressure distribution. The dotted line shows the outgas distribution.

The reduction of the induced wake field

It is better for the extraction of synchrotron radiation to enlarge the gap height more. On the other hand, it is worse for the circulating electron beam to enlarge the gap height on the grounds that the induced wake field become large. In order to estimate the influence of wake field, we calculate it using MAFIA[2] when the beam goes though the bend chamber with the 20 mm SR-extraction gap. Fig.5 shows the result of calculation of wake field induced in the bend chamber.

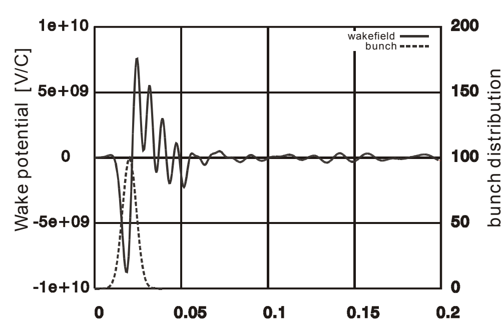

Fig.7. The calculation of wake field when the beam goes through the bend chamber. The horizontal axis shows the longitudinal position s (z – z') [m] along the bend chamber.

The longitudinal length of the bend chamber is 1.5 m and the cross section of bend chamber is assumed as shown in Fig.3. The solid line shows the induced wake field by electron beam shown as the dotted line in Fig.7. The bunch length is assumed to be 4 mm ($\square_z$) with a gaussian distribution. When the beam current is 400 mA in the multi bunch mode with 2 ns interval, 0.7 W of the parasitic loss is induced in this chamber. This result shows that this loss is not so high to melt the bend chamber. Another important thing to suppress the wake field is to minimize the impedances of the beam ducts and the vacuum components. All of the beam ducts and the components are designed to connect with smooth transition and good RF contact. Fig.8 shows a prototype model of bellows assembly. The bellows are made of stainless steel and have an RF-shield structure inside of them. The RF-shield structure consists of spring-finger and inner tube of stainless steel. The spring-finger is made of copper-beryllium and is coated with silver to reduce damage due to wearing out.

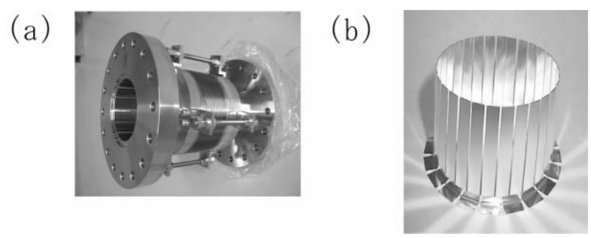

Fig.8. (a) The prototype model of bellows assembly and (b) the spring-finger.

We also take care the wake field by the beam duct of ID's, which are all made of stainless steel. Because of relatively low conductivity of the stainless steel and narrow vertical aperture of the ID duct, the growth rate of the transverse resistive-wall instability becomes large and also heat load due to the parasitic loss is not negligible. Fig.9 shows the calculation of growth rate of SUS and Cu case of insertion devices versus the vertical tune. In Cu case the growth rate is much lower than SUS case.

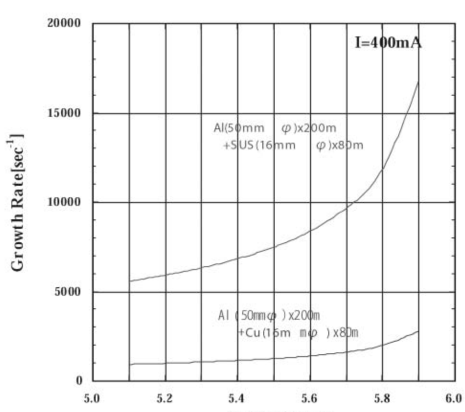

Fig.9. The calculation of growth rate of SUS and Cu case of insertion devices versus the vertical tune

In order to suppress the influence of the resistive-wall impedance, the inner surface of all ID ducts will be coated with Cu[3]. We have fabricated the stainless-steel test duct in Fig.10. The inner surface of this duct is coated with Cu of 100-200 □m thick as shown in Fig.10.

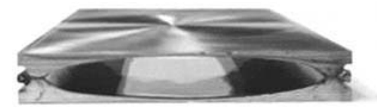

Fig.10. A test model of ID duct. The inner surface is coated with Cu.

It is important to check if this chamber is valid on the ultra-high vacuum condition. Then we try to measure the outgas from Cu-coated duct on the test bench as shown in Fig.11. This measurement is based on an orifice method. Outgas from Cu-coated chamber is measured by the difference between B-A gauge 1 and gauge 2 shown in Fig. 11. From this summer some types of Cu-coated ID chamber will be tested on this test bench.

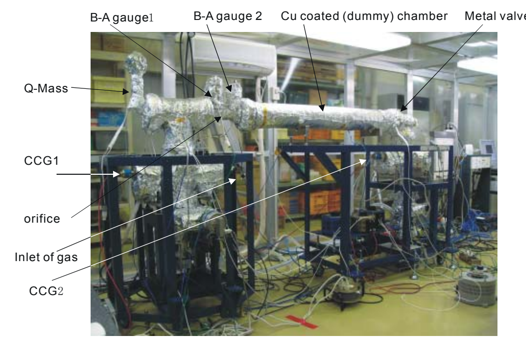

Fig.11. An test bench of measuring the outgas from Cu-coated ID duct in our laboratory.

SUMMARY

We described the design and performance of the vacuum system of the Super SOR ring. To avoid the heating by the irradiation of SR light from ID's, two types of absorbers are set on the downstream of the bend chamber. More than 10 hours of the lifetime will be achieved on these configurations. We note that 10 hours is long enough to operate on the top-up operation. The trials to reduce the wake field are performed by RF shield and Cu-coated duct. Especially it is much desirable to install the Cu-coated duct in order to decrease the resistive-wall impedance if outgas from coating is lower. The outgas measurement from this duct is under studying.

ACKNOWLEDGEMENT

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