VACUUM PERFORMANCE OF PLS ELECTRON STORAGE RING*

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Abstract

The storage ring vacuum system for the PLS has been commissioned and operated since September 1994. The system is now in normal operation and an average vacuum of about 1×10^{-9} Torr at 100 mA, which is the design value, is now achieved with the beam lifetime of 15 - 20 hours. At the first commissioning, the system was pumped by SIPs only without in-situ bakeout. The specific pressure rise due to the photon induced gas desorption was 2×10^{-7} Torr/mA initially and gradually reduced with the accumulated beam dose. Before opening to users, the improvments were made by accumulating beam dose and by enhancing the pumping speed to reduce gas scattering in order to give sufficient beam lifetime for the users.

1 INTRODUCTION

The vacuum system for the Pohang Light Source(PLS) storage ring is designed to maintain a beam on operating pressure in the nano-Torr range in order to achieve a beam lifetime of 5 hours or more. This level of vacuum can be easily achieved in a baked all metal vacuum system. In a storage ring, however, it could not be easily obtained due to the gas loads from the interactions between photons coming from diopole magnet arcs and the chamber surfaces. In the PLS, these interactions are localized at the discrete photon stops at which the gas loads are dealt with the large capacity vacuum pumps. The pumping speeds were distributed according to the amount of intercepted photons. The vacuum system is mainly pumped by combination pumps which consist of lumped non-evaporable getter(NEG) pumps and sputter ion pumps(SIPs). They offer the total pumping speed of about 30,600 l/s for the storage ring.

The storage ring is made up of 24 sector vacuum chambers and 10 straight section vacuum chambers. The PLS sector vacuum chambers were made using machined A5083 while straight section chambers were made using extruded A6063 aluminium alloy.

The vacuum system underwent two operation phases according to the storage ring commissioning [1]. At the storage ring phase I commissioning, the vacuum system was pumped by SIPs only without NEG actvation and without bakeout. This was because the long alignment time needed and dynamic pressures between 10^{-8} and 10^{-7} Torr are adequate for phase I operation. Their nominal pumping speed for the storage ring were about 5,300 l/s. After the system was vacuum-baked followed by NEG activation, resulting in the total pumping speed increment and hence the reduction of specific pressure rise with beam. The beam lifetime was then increased to many hours at 100 mA. In this paper the performance of the PLS vacuum system is reported as well as the commissioning of the vacuum system.

2 VACUUM SYSTEM PERFORMANCE

2.1 Vacuum System Operation

After the completion of installation of vacuum system on June 7, 1994, the storage ring vacuum chambers had been pumped down using SIPs for about two months. Before the first beam injection on September 1, 1994, the ultimate static vacuum reached to about 8×10^{-9} Torr. With beam stored, the pressures increased abruptly due to the photon induced gas loads. The amount of gas loads is proptional to the beam energy, beam current and the molecular desorption yield so that at the early stage of operation, the gas loads mainly depend on the molecular desorption yield. The pressure rise were measured as high as 2×10^{-7} Torr/mA initially and reduced to 1×10^{-9} Torr/mA at the end of phase I commissioning.

After achieving the goal for the phase I commissioning, efforts were made to improve beam lifetime in two ways, i.e., by enhancing the pumping speed during machine maintenance periods and by accumulating beam dose to reduce the gas scattering. Firstly, RF shielded bellows which connect the sector chamber I and II were replaced to reduce chamber impedance. The storage ring vacuum system was then vacuum-baked at about 90°C for 48 hours followed by lumped NEG activation in order to enhance the pumping speed, and hence to reduce the specific pressure rise, resulting in the total pumping speed increment from 5,300 to 30,000 l/s for the storage ring. The average static vacuum was then low 10^{-10} Torr.

In order to control the chamber deformations, the mild bakeout was performed at 80-100°C using hot water circulating in the copper tubes embedded in the chambers. The rate of pressure rise due to photon induced gas desorption reduced immediately after NEG activation according to the pumping speed increment.

After three month maintenance from January to March 1995, the phase II commissioning began on April 4 and ended on July 21,1995. During this period, the beam was stored as high as possible at overnight in order to clean up

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the photon irradiating surfaces by accumulating the total beam dose. As a result, the beam lifetime has increased from several tens of minutes at the end of phase I commissioning to about 150 minutes at the early stage of phase II commissioning and finally to about 10 hours with 100 mA beam current at the end of machine commissioning.

On september 1, 1995, the facililty finally bagan to open to users. During the user service mode, there was a machine shut down due to the water leaks on October 19, 1995. The water leaks occurred at the copper to stainless steel brazing of the cooling channel in the strip photon absorber. After the two leakaging absorbers were replaced with new ones, the vacuum system of the first and second superperiod was reconditioned and the machine resumed to store beam on Nobember 13, 1995. The strip absorbers which can develop water leaks will be replaced later.

2.2 Dynamic Pressure

The specific pressure rise due to photon induced desorption has been measured as a function of the integrated stored beam current (AH[amp.hrs]). The measurments have been based on the average pressure and the total pumping speed. Figure 1 shows the reduction of pressure rise with respect to the accumulated beam dose. At the very first stage of commissioning, the specific pressure rise was as high as 2×10^{-7} Torr/mA at 6×10^{-5} AH with the beam energy of 1.4 GeV and gradually reduced due to the beam cleaning effect. At the end of 1.4 GeV operation, the pressure rise reduced to 4×10^{-9} Torr/mA at 0.4 AH. With the beam energy of 2 GeV, the pressure rise varied from 6×10^{-9} Torr/mA at 1 AH to 1×10^{-9} Torr/mA at 7 AH where the system was pumped by SIPs only. After NEG activation, the pressure rise reduced immediately to 1×10^{-10} Torr/mA at 12 AH which indicates that the total pumping speed increased to approxmately 30,000 l/s. Finally, it reached to 3×10^{-11} Torr/mA at the end of machine commissioning. Globally, the reduction of the specific pressure rise with the accumulated beam dose has followed closely to the expected value, $(AH)^{-0.7}$. After NEG activation, however, the beam cleaning effect may have a steeper slope than -0.7 because it reflects the total effects of the cleaning of the photon irradiationg surface and of the gradual decrease in pumping speed of the lumped NEG pumps.

The molecular desorption yield was roughly estimated to be about 6.6×10^{-4} mole/ph at 1 AH with the beam current of 17mA, 2GeV. The value depends largely on the status of the surface of the photon stop and the measured value exceeded the expected value, 9×10^{-5} mol/ph.

The effect of the replacement of photon absorbers on the pressure rise is also shown in Figure 1. Shortly after the beam on(1 AH), the beam lifetime returned to its previous value.

2.3 Residual Gas Composition

Due to the chamber surface conditions and the distribution of pumping speed, the residual gas compositions were slightly different from location to location. However, typical gas compositions at various stages of system operation are shown in Table 1. Gas compositions varied greatly with the pumping speed variations for individual gas, with/without bakeout, and with/without dynamic gas loads. With beam stored, the residual gases were increased at all times in order of H_2, CO, CO_2, CH_4 and small fraction of Ar. The water vapor, which does not desorb directly due to the photons, was always a major residual gas because of insufficient chamber bakeout. The PLS gas compositions are typical as an all metal UHV system even with beam stored.

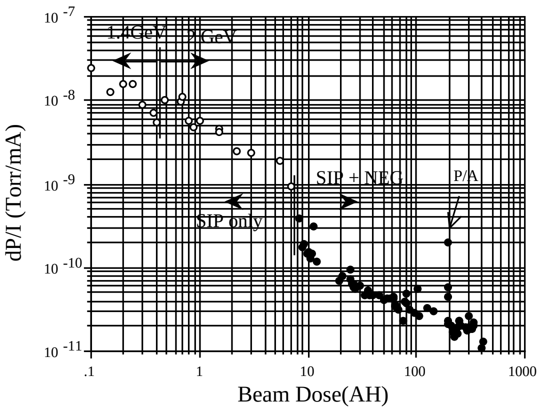

Figure 1: Reduction of pressure rise with respect to the accumulated beam dose. The arrow marked P/A points to photon absorber replacement.

Table I Typical gas compositions(%)

	No B/O, SIP only		BO, with NEG	
	w/o beam	w/beam	w/o beam	w/beam
P_{av}(Torr)	1×10^{-8}	2×10^{-7}	5×10^{-10}	1×10^{-9}
H_2	$73 \sim 77$	79	38	68
CH4	$2 \sim 4$	3	9	5
H_2O	$12 \sim 14$	1	16	6
CO	$4 \sim 8$	12	15	16
CO_2	$1 \sim 2$	5	22	5

2.4 Pressure Distribution

The ressure distributions were measured using ion pump currents and/or ion gauges. Unfortunately a number of ion pumps could not be used to measure the dynamic pressures because of the scattered photons or photoelectrons.

Figure 2 shows typical pressure distributions along the sector vacuum chambers in a superperiod(1/12 of the SR). The pressures were measured with four ion gauges located in a position that indicates average chamber pressure per chamber. Figure 2(a) and (b) show the static pressure distributions with SIPs only before bakeout and SIPs with NEG activated after mild baking, respectively. Fig. 2(a) shows the uniform pressure distributions. The pressure in the straight chamber was relatively low in spite of low effective pumping speed because the chamber (extruded A6063) has lower thermal outgassing rate than that of sector chambers I and II (machined A5083). After bakeout followed by NEG activation, however, the static pressure(Fig2(b)) was not uniform due to the pumping speed distributions.

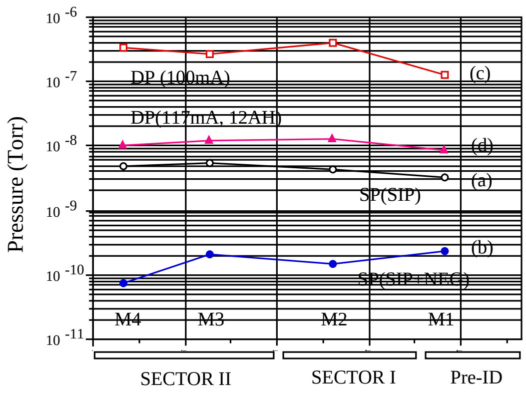

Figure 2: Pressure distributions along the sector chambers

With beam stored at the early stage of the system operation, the pressures were largely increased in sector chamber I and II. The pressure in the straight chamber was about 3 times lower than that of sector chambers because of low photon induced gas desorption. This is shown in Fig 2(c). As the integrated stored beam current increased, the pressure distributions tended to become uniform(Fig 2(d)).

2.5 Beam Lifetime and Pressure

The measured beam lifetime during the phase I commissiong were less than 50 minutes at 100mA due to gas scattering. However, after chamber bakeout and NEG activation, the beam lifetime has increased immediately to about 150 minutes at the early stage of phase II commissioning, on April 13, 1995, and finally to about 10 hours with 100 mA circulating beam at the end of machine commissioning. This is shown in Fig. 3. Now it is considered that the gas scattering gives minor effect on the beam lifetime. At present operating conditions, (i.,e., total dose more than 400AH) Touschek effect is a dominant factor that determines the beam lifetime.

2.6 Recovery after Venting

Figure 4 shows typical pump down curve after the chamber exposed to atmospheric pressure. The relatively quick recovery could be obtained using a procedure that includes SIPs' body heating, 1 hour NEG activation at 450°C and around 24 hour pumping down. It usually takes two or three days. After the recovery or after 1 AH of accumulated beam dose in case of the photon absober replacement, the beam lifetime was almost the same as before the venting.

3 SUMMARY

The performances as well as the operaton of the vacuum system for the PLS storage ring have been described. With relatively large photon induced gas loads, the vacuum system reached to its designed value, of the order of low 10^{-9} Torr, after the accumulated beam dose of 50 AH. The pressure is still being reduced gradually and gives little effect on the beam lifetime.

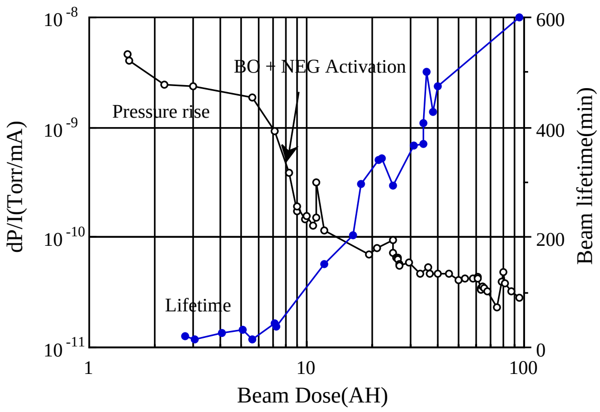

Figure 3: Beam lifetime as a function of beam dose. Data obtained with 100mA stored beam.

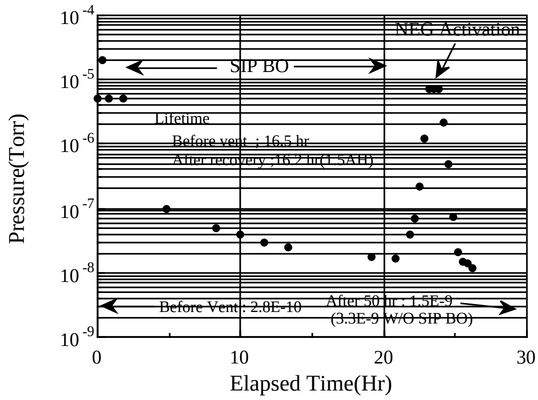

Figure 4: Pump down after air exposure

4 REFERENCES

[1] M. Yoon, et al, In these proceedings.