VACUUM SYSTEM FOR UVSOR STORAGE RING

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The vacuum system of the UVSOR electron storage ring is made of stainless steel and evacuated by sputter ion pumps, titanium sublimation pumps and built-in pumps. The pressure of 10^{-9} Torr is required to maintain long lifetime of the beam. The average base pressure was on the order of 10^{-8} Torr and the e-folding lifetime was only several min in the early days. Following the improvement of the pressure in the past three years routine operation on the ring, it became about 2 hr at the beam current of 100 mA. The improvement is mainly due to the cleaning effect of synchrotron light which desorbs molecules of gases from the surface of the beam pipe. This report describes the performance of the vacuum system and aging effect of the synchrotron light.

Introduction

UVSOR is a 600 MeV electron storage ring dedicated to vacuum ultraviolet synchrotron radiation research in molecular science and its related field. The first beam was stored in November 1983, and experimental studies using the synchrotron radiation from the ring were started in October 1984.[1] The main parameters of the ring are shown in Table I and the symbols in the table will be used in the following sections.

The plane view of the vacuum system of the UVSOR is shown in Fig. 1.[2] It is composed of eight bending, four long and four short straight sections. Almost all vacuum vessels are made of stainless steel. Exceptionally, beam pipes at perturbators for the beam injection are made of ceramics with gold coat (thickness of 100 nm). The vacuum system of the ring is separated from the beam transport line with a polyimide film at the exit of the chamber for the injection septum magnet (inflector). Two outlets of the synchrotron radiation are available from each bending section, and the vacuum system of the ring and each optical beam line are connected via a vacuum interlock system consists of a beam shutter, a manual valve, a tightly closing valve and a fast closing valve. Rughing pumps are four turbo-molecular pumps set inside the ring.

Requirements for Vacuum System

The lifetime of the electron beam in a storage ring of which energy is less than 1 GeV is mainly determined by Touschek effect and scattering by residual gas. Th estimated Touschek lifetime of 600 MeV electrons is 1 hour at the beam current of 500 mA, in the case of the UVSOR. Therefore, the lifetime due to residual gas scattering must be much longer than the Touschek lifetime, say 10 hours. To satisfy this requirement, the pressure at the beam path must be less than 4×10^{-9} Torr under the stored beam condition. Estimated total outgassing rate is $1.4_2 \times 10^{-5}$ Torr l/s for 600 MeV electrons with 500 mA.[2] In order to realize the pressure, the total pumping speed must be more than 3.5×10^{3} l/s. Two sputter ion pumps (IP) with pumping speed of 400 l/s and two titanium sublimation pumps (TSP) with 1000 l/s are located on both sides of each long straight section. Each short straight section is evacuate with an IP with 400 l/s and two TSP with 1000 l/s, and a built-in ion pump of which pumping speed is estimated at 250 l/s is set in each bending section. The RF cavity is evacuated with an IP with 400 l/s and TSP with 1000 l/s. The gross pumping speed for the whole ring is 2.4×10^{4} l/s. The effective pumping speed and the actual outgassing rate is discussed in the following sections.

Table I. Main parameters of UVSOR

Energy	E	600-750	MeV
Mean Radius	R	8.47	m
Circumference	$C(=2\pi R)$	5.32	m
Bending Radius	ρ	2.2	m
Horizontal Tune	Q_H	3.25	
Vertical Tune	Q_V	2.75	
Radio Frequency	f_{RF}	90.1	MHz
Harmonic Number	h	16	
Emittance	ε_T	$8\pi \times 10^{-8}$	m.rad

Effective Pumping Speed

There are orifices and bends between the beam pipe and the vacuum pumps. The pumping speed is reduced considerably by these obstacles. The built-in ion pump is separated by an electric shield with 98 slots of which lengths and widths are 30 and 5 mm respectively. The effective pumping speed of each built-in pump becomes 217 l/s. The beam pipe and the sputter ion pump and / or the titanium sublimation pump are separated by a thin wall with a large hole with diameter of 65 mm and 24 small holes with diameter of 10 mm. The conductance of the holes and the duct is about 250 l/s. Even when the pumping speeds are sufficiently high, the effective pumping speed is limited by the conductance. There are 20 these openings in the whole ring. The total effective pumping speed without built-in pumps

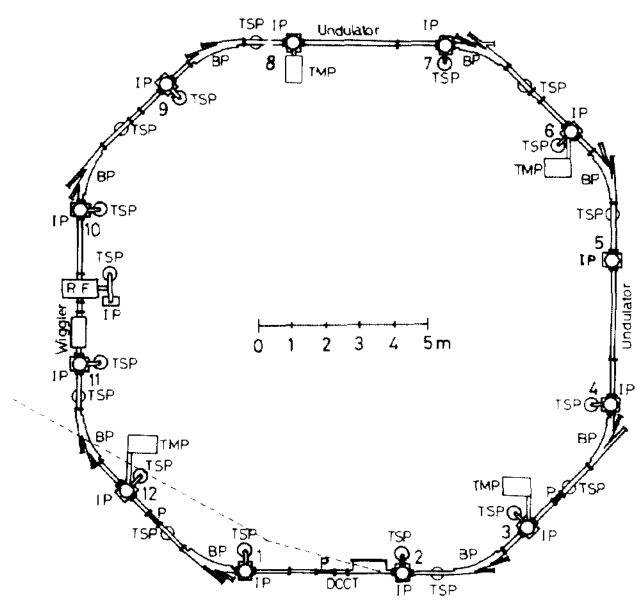

Fig. 1. Plane view of vacuum doughunt of UVSOR. IP: sputter ion pump, TSP: titanium sublimation pump, BP: built-in pump, TMP: turbo-molecular pump, P: perturbator chamber, DCCT: DCCT chamber, I: inflector chamber and 1-12: vacuum gauge.

becomes 5000 l/s (250 x 20), that of built-in pump is 1736 l/s (217 x 8), and the total pumping speed is estimated at about 6700 l/s at the beam position. The pressure gauges are set under the orifices which separate the beam pipe and the pumps. We estimate the effective pumping speed of 1.3×10^4 l/s at the pressure gauge. The best base pressure of 3.1×10^{-10} Torr was recorded in the end of 1986. The thermal outgassing rate of 4×10^{-6} Torr l/s is obtained assuming the estimated effective pumping speed. This value is much larger than expected one. The reason is the insufficiency of the bake-out of the system as mentioned in the next section.

History

Fig. 2 shows the improvements of the pressure and the beam lifetime in 2 years. Some vacuum vessels (for a DCCT etc in 1985, for an undulator etc in 1986) were changed and several new devices (ion-clearing electrodes etc in 1986, a longitudinal feedback electrode in 1986) were installed in the ring in the springs of 1985 and 1986. The vacuum system was baked-out for 2 days after each improvement. Unfortunately, accidents happened immediately after the bake-out, i.e. a glass window for a beam monitor was cracked in a period of an aging with the synchrotron radiation in 1985, and a rod of the ion-clearing electrode dropped in 1986. Moreover, the third accident happened in December of 1986. The air leaked into the beam pipe from a manual valve closest to the ring when a fast closing valve was being changed. It is noteworthy that the recovery was fast when dry nitrogen was put into the beam pipe before the repair (in Apr. 1986) however it is slow when the air leaked (in May 1985 and Dec. 1986). The difference seems to be explained by influence of water got into the beam pipe. The component of water in the residual gas was large after leaks of the moist air. As the vacuum components except pumps were not baked-out after these accidents, the expected outgassing rate was not achieved up to date.

A ripple in the daily data of the base pressure from May 1986, and bumps in Aug. and Oct. 1986 are noticed. As the period of the ripple is one week (Monday for machine study, from Tuesday through Friday for users' time), and the bumps corresponds to the summer and autumn shut- downs, these can be explained by the cleaning effect of the synchrotron radiation, i.e. the radiation desorbs molecules on the beam pipe wall, which behaves like a sublimation pump after that. The base pressure p_0 was slowly improved in these two years, however there has been no improvement in the pressure p_{50} at the beam current of 50 mA recently. The improvement in p seems to result from the cleanig effect stated above.

Beam Loading Effect

Photons radiated from high energy electrons desorb gas molecules trapped on the vacuum chamber walls. Therefore, the pressure depends strongly on the beam current and the electron energy. Fig.3 and Fig. 4 show the dependence of the pressure on the stored beam current at the injection energy (600 MeV), and the energy dependence at the beam current of 100 mA. These experiment were done on 30 June 1986 (A in Fig. 2). Numbers in the figures correspond to pressure gauge numbers shown in Fig. 1. The desorption rate Ng (1/s) is witten by

$$Ng \; 4.8 \times 10^7 E N D \eta (1 \; (\lambda_c / \lambda_\alpha)^{1/3})/C \qquad (1)$$

where E (MeV) is the electron energy, C (m) the circumference of the ring, N the number of stored electrons, D the number of molecules desorbed by an electron, η the number of photoelectrons emitted by a photon, and λ_c and λ_α are the critical wavelength of the ring and the threshold wavelength of the photoelectron emission. Fig. 4 shows that vacuum walls at various places in the ring have not an indentical value of $D\eta$, even if the places have the same periodocity. It is one of the reasons that the desorption rate is a function of the surface coverage which is determined by the previous gas exposure, the treatment of the surface and the previous bake-out history. For example the beam pipe for the straight section III where the vacuum gauge 7 and 8 are set is the newest pipe installed in 1986, therefore $D\eta$ which is proportional to the gradient of line in Fig. 4 is large. As each history of vacuum chamber is not

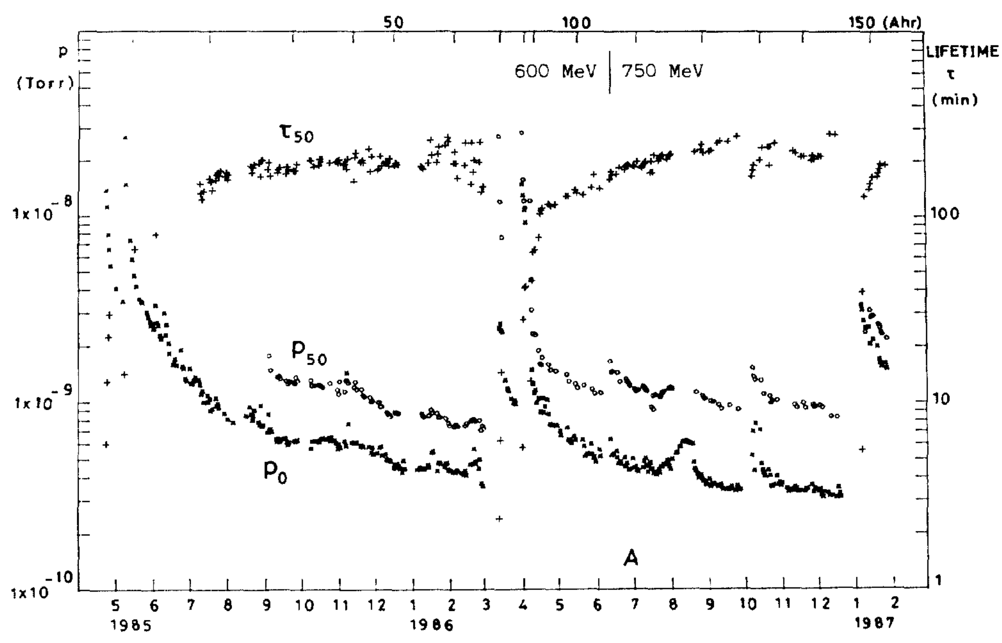

Fig. 2 Improvements of pressure and lifetime. P_0: base pressure, P_{50}: pressure at 50 mA and τ_{50}: lifetime at 50 mA. Horizontal axis shows date and integrated beam current (Ahr).

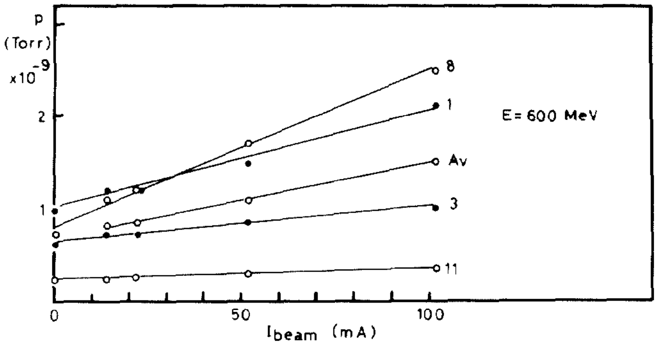

Fig. 3. Dependence of pressure on beam current.

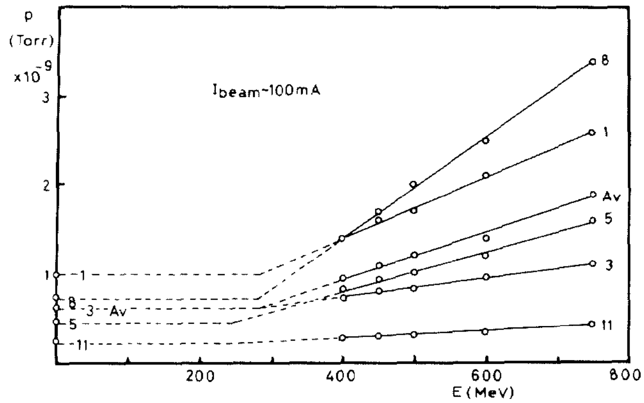

Fig. 4. Dependence of pressure on electron enrgy.

recorded unfortunatley, we evaluate $D\eta$ averaged over the ring. Eq. (1) can be rewritten as

$$Q \quad 0.03\, I_b D\eta\, (E \; E_\alpha) \tag{2}$$

using parameters shown in Table I, where Q (Torr l/s) is the outgassing rate, E_α the energy corresponding to λ_α and I_b the beam current. Fig. 4 shows that the E_α is about 280 MeV, and the gradient of the line corresponding to the average pressure in Fig. 3 is about 8 x 10^{-9} Torr/A. Thus the $D\eta$ of 10 x 10^{-6} can be obtained, assuming the effective pumping speed of 1.3 x 10^4 l/s. The expected $D\eta$ was not achieved due to the lack of the bake-out.

Lifetime

The beam lifetime of the UVSOR is determined by the Touschek effect and the scattering by the residual gas as mentioned above. The measured lifetime τ_A of the beam at 100 mA is about 1.8 h and the estimated Touschek lifetime τ_T is about 7 h. The lifetime τ_S due to a residual gas of 3 h was obtained using

$$1/\tau_A \quad 1/\tau_S + (e\;1)/\tau_T \tag{3}$$

and this figure corresponds to the pressure of 3.7 x 10^{-9} Torr. Fig. 3 and 4 show that the pressure at 600 MeV, 100 mA is 1.5 x 10^{-9} Torr. As this is the pressure at the gauges, the effect of the obstacles between the beam pipe and the pumps must be considered. The pressure at the beam position is estimated at 3 x 10^{-9} assuming the effective pumping speed of 6700 l/s. The estimated pumping speed is consistent with the observed lifetime.

Ion-trapping Effect

Ion - trapping effect is one of the serious phenomena related to residual molecules in the beam pipe. They are ionized by the circulating beam and trapped in it. As the force on the electron beam in the electric field due to the ions is focusing for both horizontal and vertical planes, the tunes shift from the designed operating point. When the operating point approaches to dangerous resonance lines, the lifetime becomes short or the beam quality becomes bad. DC clearing electrodes and an RF electrode were installed to clear trapped ions, and the density of ion can be reduced considerably with these systems.[3,4]

References

<1> T. Kasuga, H. Yonehara, T. Kinoshita and M. Hasumoto,"Present status of UVSOR", in Proceedings of the 1985 Particle Accelerator Conference..., 1985, pp.3409-3411.

<2> K. Sakai, H. Yonehara, E. Nakamura and M. Watanabe, " Vacuum system of UVSOR , " in Proceedings of the 5th Symposium on Accelerator Science and Technology..., 1984, pp.232-233.

<3> T. Kasuga, H. Yonehara, T. Kinoshita and M. Hasumoto, "Ion-trapping effect in UVSOR storage ring," Jpn. J. Appl. Phys. vol. 24, pp. 1212-1217, Sep. 1985.

<4> T. Kasuga, "Ion-clearing system of UVSOR storage ring," Jpn. J. Appl. Phys. vol. 25, pp. 1711-1716, Nov. 1986.