# PERFORMANCE OF THE VACUUM SYSTEM FOR SORTEC 1GeV ELECTRON STORAGE RING

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## ABSTRACT

Performance of the vacuum system for SORTEC 1GeV electron storage ring is reported. The vacuum system of the ring was designed so as to pump out the photo-desorption gases effectively and to suppress the trapped ions effectively over the 46m circumference vacuum doughnut. The vacuum system of our storage ring shows remarkable performance as follows. (1)The average pressure of the doughnut was $1 \times 10^{-9}$ Torr with beam current of 200mA and $3 \times 10^{-11}$ Torr without beam. (2)Trapped ion effects were observed and suppressed by applying DC voltage of -400V to clearing electrodes. With the suppression, beam lifetime became longer about 60%. (3)The beam lifetime of 8 hours at 200mA has been achieved at beam dose ( $\int Idt$) of 29 (A·hr).

## INTRODUCTION

The SORTEC Synchrotron Radiation (SR) facility has been constructed at Tsukuba[1]. The SR source consists of a 40MeV electron linac and a 1GeV booster synchrotron as an injector and a 1GeV storage ring. The ring is constructed for the industrial use of SR including X-ray lithography[2]. For the industrial use, beam stability, long beam lifetime and fast start of the ring are indispensable. Our vacuum system of the ring was designed to achieve these requirements by applying (1)antechamber for the bending chamber, (2)electro chemical polishing at inner surface of the vacuum chamber and (3)ion clearing electrode for the suppression of trapped ions.

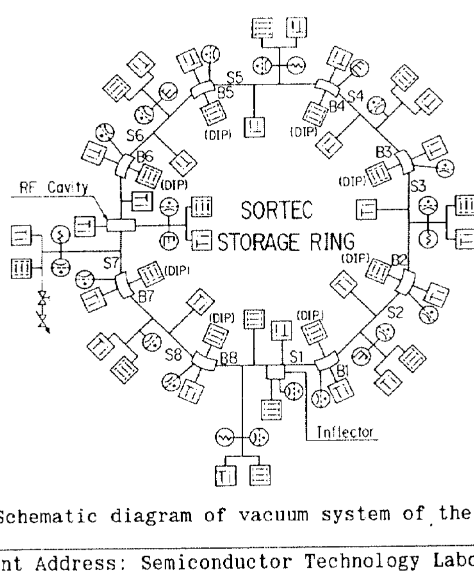


Fig.1 Schematic diagram of vacuum system of the ring.

## VACUUM SYSTEM

A diagram of the vacuum system of the ring is shown in Fig.1. The doughnut consists of eight bending and eight straight sections. Circumference of the doughnut is 46m. Vacuum chambers of the doughnut are mainly made of stainless steel(SS316L,304L) finished by electro chemical polishing at inner surface. The chamber for bending section being considerably spread out from beam orbit forms antechamber, then copious amount of photo-desorption gases can be pump out effectively. Typical bending chamber has three SR ports as shown in Fig.2. The chamber for straight section has inner cross section of 100mm × 38mm race track. The inner wall of the chamber was designed as smooth as possible to prevent the beam instability, also electrodes were equipped for ion clearing.

The bending section is equipped with a 250l/s distributed ion pump and a 1000l/s Ti sublimation pump. The straight section is equipped with a 400l/s sputter ion pump including NEG(Non Evaporable Getter) and a 1000l/s Ti sublimation pump at pumping station located at end of straight section, and a 400l/s Ti sublimation pump at center of the section. In addition, extra pumping system is equipped at an RF cavity. Then, total pumping speed for the doughnut is about 26000l/s.

The ring vacuum is monitored by 8 cold cathode gauges placed at the pumping port of each straight section(S1-S8) and 7 same gauges at each bending chamber(B1-B8) except the forth bending section(B4) where quadrupole mass spectrometer is mounted. Other 3 quadrupole mass spectrometers are installed at pumping station of straight sections, S2, S6, and at the RF cavity to analyze the residual gas components at each region.

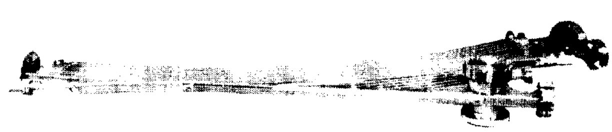

Fig.2 Photograph of typical bending chamber.

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## VACUUM STATUS

Previous to the beam injection, the doughnut had been evacuated with baking at 150 °C for 48 hours, then a base pressure below $5 \times 10^{-11}$ Torr had been achieved. The beam injection into the storage ring began on September 27th 1989.

The first beam was successfully stored with SR light in a day after the first injection. The stored current was 3.5mA with an e-fold lifetime of 10 minutes. The pressure of the ring was degraded to $7 \times 10^{-8}$ Torr by the beam. Then, following two weeks, the beam cleaning was done keeping the maximum vacuum pressure below $1 \times 10^{-8}$ Torr, hence the beam current was limited about 70mA. At the end, normalized pressure rise $\Delta P/I$ (Torr/mA) reached $2 \times 10^{-11}$ (Torr/mA) and the beam lifetime reached over 2 hours at 80mA.

Since then, in parallel with the beam cleaning, optimization of beam was carried out[3] such as adjustment of betatron tunes, correction of Closed Orbit Distortion, detuning of RF phase, and ion clearing. The stored beam current of 200mA with an e-fold beam lifetime of 4 hours, that is our design goal, had been achieved on October 30th only a month later the first beam storage. The average pressure reached $1.2 \times 10^{-9}$ Torr at a beam current of 200mA and $3.5 \times 10^{-11}$ Torr without beam. The normalized pressure rise was $7.6 \times 10^{-12}$ (Torr/mA) at the time. Before these results were obtained, stored beam dose was only 10.7(A·hr).

As the beam dose increases, the normalized pressure decreased continuously and at the end of November, just as two months later the first beam storage, the beam dose reached 29(A·hr) and the corresponding specific pressure was $4.5 \times 10^{-12}$ (Torr/mA). The beam lifetime reached 8 hours at 200mA under the vacuum of $1 \times 10^{-9}$ Torr as shown in Fig.3.

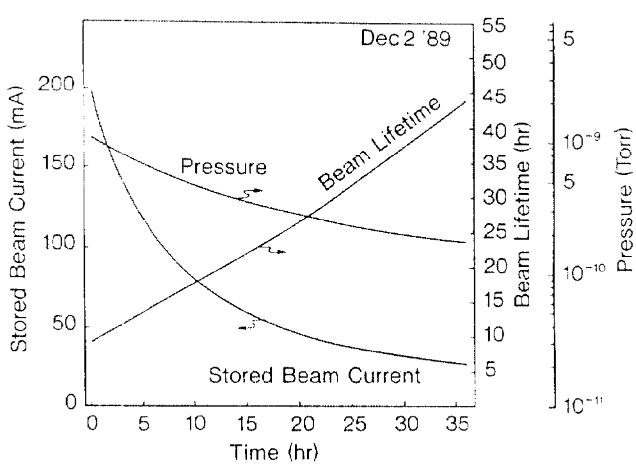


Fig.3 Decay pattern of beam current and corresponding pressure and beam lifetime.

## BEAM CLEANING

SR from the stored beam cleans the inside wall of the vacuum chamber. For the beam cleaning, beam trajectory was undulated occasionally by steering magnets to change the exposed area inside the vacuum chamber[4]. To achieve maximum beam dose, stored beam current was kept near its maximum value by refilling the beam occasionally.

Since the beginning of the commissioning, vacuum data of the ring has been recorded continuously. These results are summarized in Fig.4 against the beam dose.

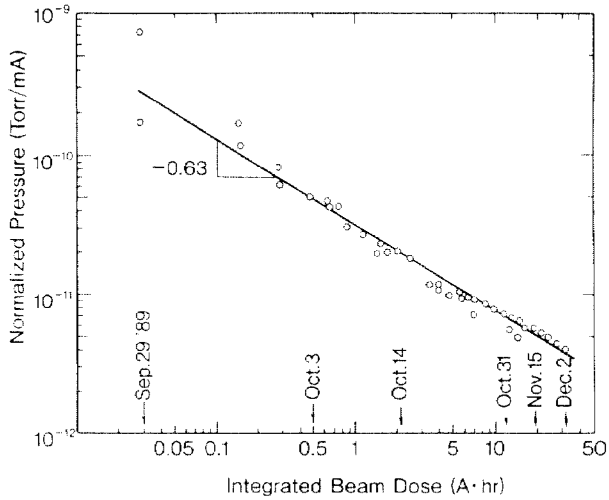


Fig.4 Improvement of normalized pressure rise $\Delta P/I$ (Torr/mA) as a function of beam dose (A·hr).

As the beam dose increases, the normalized pressure rise decreases steadily with the slope of -0.63 that can be compared to the value of -0.61 found for DCI[5] or -0.73 for Super-ACO[6]. In the early stage of beam storage, the pressure rise at bending section was almost 10 times as large compared to the straight section. However, as the beam dose increases, the tendency has changed. The typical normalized pressure at bending and straight section against the beam dose are plotted in Fig.5. The slope of the plot are -0.90 and -0.33 for bending and straight section respectively. The difference of these slope indicates faster beam cleaning for bending section due to the higher photo flux compared to the straight section.

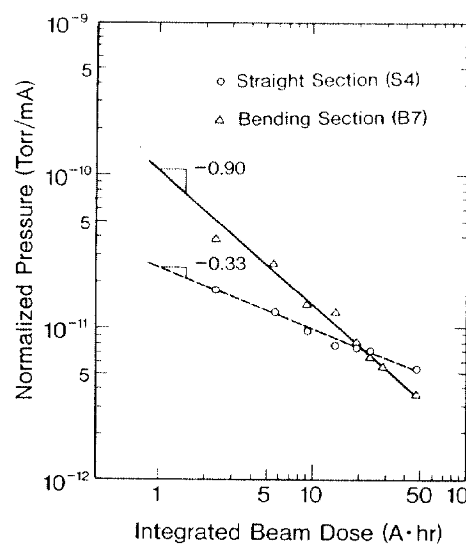


Fig.5 Normalized pressure rise $\Delta P/I$(Torr/mA) for bending and straight section as a function of beam dose (A·hr).

The partial pressure at bending and at straight section are also monitored. Fig.6 shows the mass spectra at each section after 20(A·hr) beam dose with beam current of 200mA. Main residual gas species are $H_2$, C, $CH_{3,4}$, $H_2O$, CO, $N_2$ and $CO_2$. The fact that the water peak observed at bending section is lower than that of straight section might also indicate the effect of direct SR exposure on the bending chamber.

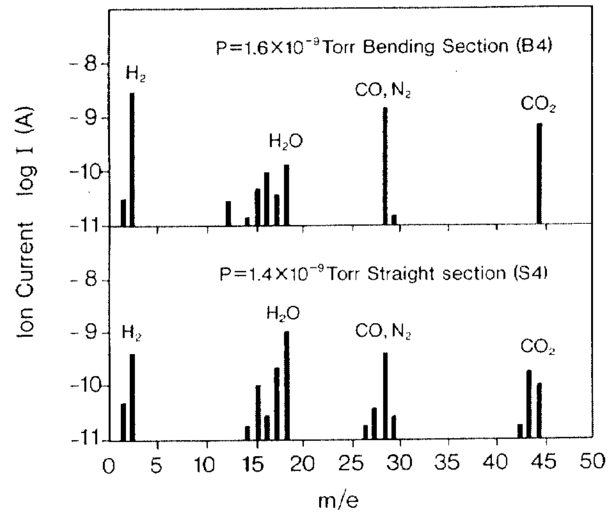


Fig.6 Typical gas spectra at bending and at straight chambers with a beam current of 200mA at a beam dose of 18(A·hr).

## ION CLEARING

Ions trapped in the potential created by electron beam cause some problems like shortening of beam lifetime, blow up of beam size or tune shift. To clear these ions, disk type electrodes have been installed at seven out of eight pumping stations at each straight section where the beam size is minimum at a nominal operating point of the ring.

The effect of ion clearing was surveyed by applying negative DC voltage to the electrodes. Shrunk of the beam size by applying the voltage was clearly seen on TV monitor of SR. The beam lifetime changed drastically by applying voltage to the electrodes. However, in spite of the longer beam lifetime, vacuum pressure actually increased. The effects are illustrated in Fig.7. These phenomena might indicate the effect of ions swept out by the electrodes.

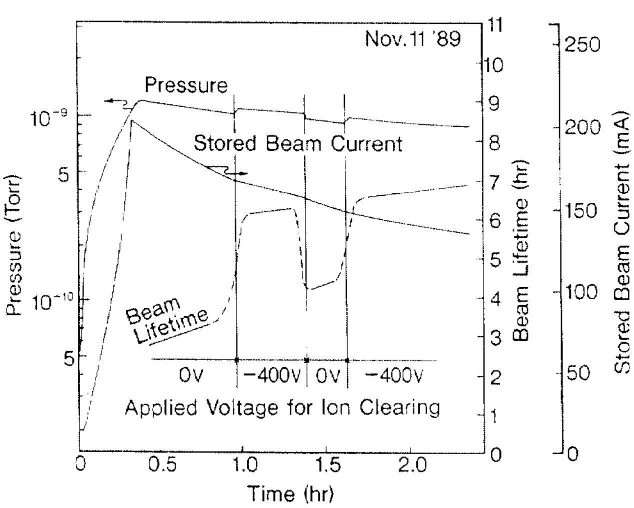


Fig.7 Stored beam current and pressure versus time for the different applied voltage on clearing electrode at a beam dose of 20(A·hr).

Fig.8 shows the dependence of the beam lifetime on applying voltage. In the figure, beam current is refilled to evaluate the beam lifetime at the same beam current. From the figure, clear dependence of beam lifetime on applying voltage can be seen. Applied voltage above 400V has also tried but the effect was almost the same. Anyway, the ion clearing turn out very effective to achieve long beam lifetime that is important especially for the fast start of the ring.

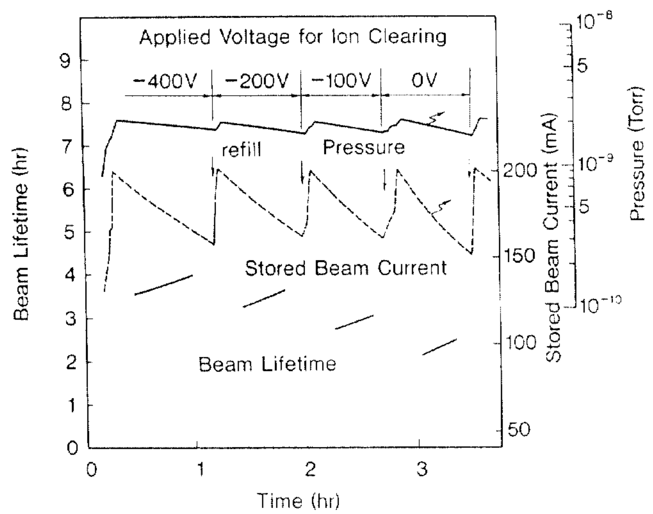


Fig.8 Stored beam current, pressure and beam lifetime versus time for different applied voltage on clearing electrode at beam dose of 10(A·hr).

## SUMMARY

The vacuum system for SORTEC 1GeV electron storage ring was designed to achieve long beam lifetime in a early stage of commissioning. An antechamber of the bending section and electrode for clearing the trapped ions are installed for the purpose. As the result (1)the designed pressure and beam lifetime at nominal beam current are achieved only in a month after the first beam storage in the ring, (2)ion clearing is effective to get longer beam lifetime, then the beam lifetime of 8 hours with a beam current of 200mA was achieved at a beam dose of 29 (A·hr), only in two months after of its first storage. These results have confirmed that our vacuum system suits for the fast start of the storage ring that is essential for the industrial use of synchrotron radiation.

## REFERENCE

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