RECENT PROGRESS OF THE SORTEC SR RING

N.Awaji, M.Kodaira and T.Kishimoto
SORTEC Corporation
16-1,Wadai Tsukuba-shi, Ibaraki 300-42, Japan

H.Tsuchidate and T.Iida
Mitsubishi Electric Corporation
1-1-2 Wadasaki-Cho, Hyogo-ku, Kobe 652, Japan

Abstract

As a dedicated synchrotron radiation source for industry, especially for X-ray lithography, the SORTEC SR ring started to provides SR for internal users from Apr. 1990. Since then, the operation of the ring continued successfully and the performance of the ring improved through machine studies, resulting in the the beam lifetime of 60 hours at the nominal condition. The upgrade of the ring for higher SR intensity is scheduled in spring 1992. As a feasibility study for the upgrade, the high current beam storage experiments are being done at low energy and confirmed the beam storage of 1150mA at 600MeV.

Introduction

The SORTEC SR facility is constructed for the SR related R&D project, mainly X-ray lithography development, and started its operation since 1989. With the adoption of full energy injection scheme based on 40 MeV Linac and 1 GeV booster synchrotron, the storage ring provides an SR stably through 4 beamlines for basic research on X-ray lithography. Table1 summarizes the principal parameters of the facility. For the higher SR intensity, the ring is scheduled to upgrade in 1992 by increasing the beam current from 200mA to 500mA at 1GeV. Currently, various machine studies for the upgrade are being done.

Table 1 Principal Parameters of SR Facility at SORTEC

	Achieved	Planned
Storage Ring		
Energy	1 GeV	1 GeV
Dipole	1.2 T	〃
Critical Wave-length	15.5 Å	〃
X-Ray Power	6.37 kW	15.93 kW
Beam Current	200 mA	500 mA
Beam Lifetime	>60 hr	>20 hr
Natural Emittance	0.51 mm・mrad	〃
Circumference	45.7 m	〃
Synchrotron(Injector)		
Injection Energy	40 MeV	40 MeV
Maximum Energy	1 GeV	〃
Beam Current	50 mA	〃
Circumference	43.2 m	〃
Linac(Pre-injector)		
Energy	40 MeV	〃
Beam Current	60～80 mA	〃
Energy Spread	±0.67 %	〃
Emittance	0.7π mm・mrad	〃

Improvement in the ring performance

Since the first machine operation for internal users in Apr.1990, the down time of the source in the past one and a half years is just two or three days demonstrating the reliability of our facility[1]. By choosing the optimum operating point, in addition to the good vacuum, the beam lifetime extended to 60 hours until now. Figure.1 shows the typical daily operation of the source.

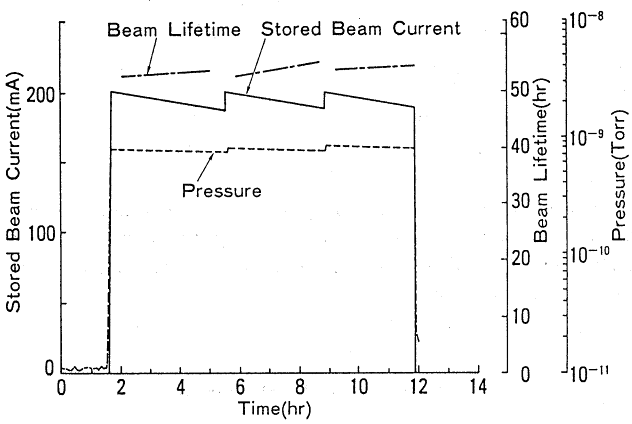

Fig.1 Typical daily operation of the source.

Based on the full energy injection and the long beam lifetime, the "flat top operation" of the stored beam is demonstrated[2]. By injecting 1 or 2 mA beam for each half an hour automatically, the SR intensity can be kept constant within 1% as shown in Fig.2 that is ideal for X-ray lithography. This operation would also be effective with the short beam lifetime mode like high current beam storage since the effective beam lifetime is infinite.

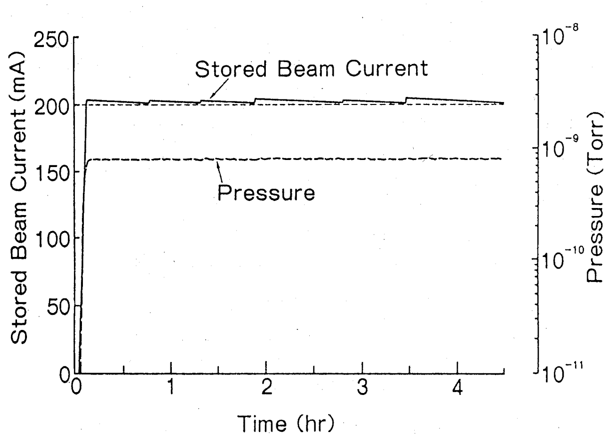

Fig.2 The "flat top" operation of the storage ring.

On the ring vacuum, the estimated average photo desorption coefficient η of the vacuum duct, 1.5×10^{-6}(molec/ph), demonstrates the effect of photo cleaning[3]. In Fig.3, the estimated pressure profile for the 1/4 sector of the ring is shown for the present duct compared to the initial stage of the vacuum duct. Photo cleaning effect at bending chamber is clearly seen.

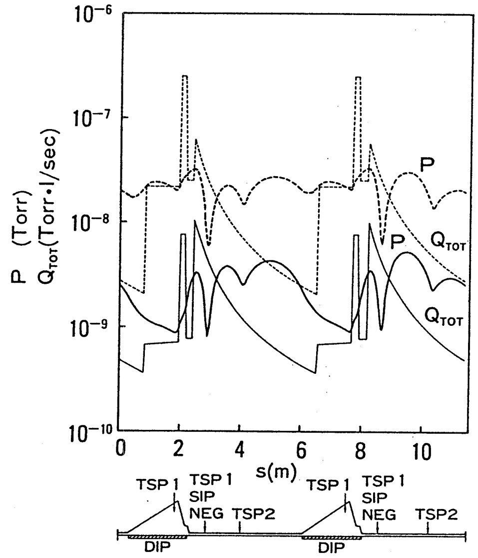

Fig.3 Pressure and gas yield for 1/4 sector of vacuum doughnuts. Solid lines reproduce the recent data whose average η is 1.5×10^{-6}(molec/ph) while dotted lines are for the initial stage whose η is 1×10^{-5}(molec/ph).

The upgrade of the storage ring

The source is scheduled to shutdown for three months from spring 1992. In its new form, the radiation power will increase to 15.9kW by increasing the beam current to 500mA as shown in table1. For the change, the capacity of power supply for RF cavity will be increased from 14kW to 28kW by replacing the power tube RS2012CJ to RS2058CJ (Ziemens) with the modification of RF coupler.

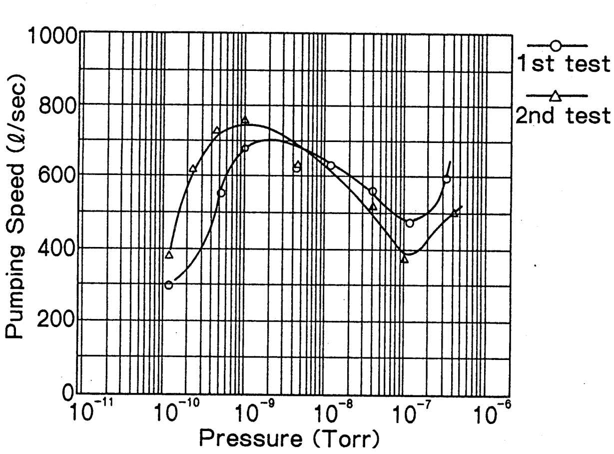

Fig.4 Measured pumping speed of NEG module for H_2.

In addition to the modification of RF system, the pumping speed of the ring will be increased against the higher photo desorption gas. The NEG module (SAES WP-1250, ST707) will be added to remove H_2 at the down stream of the straight section where the pressure is relatively high due to the low conductance as shown in Fig.3. As the basic test, the pumping speed of the NEG module for H_2 in the high vacuum region was measured. The results, shown in Fig.4, satisfy our requesting specification around the 10^{-10}Torr region. After the installation, the beam lifetime expected to be 20 hours at 1GeV 500mA .

High current beam storage experiment at low energy

The beam behavior under high beam current is being studied by decreasing the beam energy. The booster synchrotron is capable to inject the beam from 1GeV down to 400MeV by changing the trigger timing of the kicker magnet. The experiments are done mainly at 600MeV where the limited beam current by the RF power is much high and the secondary effect on beam like instability or the ion trapping are more enhanced then the nominal 1GeV.

The primary problems under high current are the heat up of the ceramics duct and the operational error of the peripheral devices. Applying forced ventilation by fan to the duct, the temperature rise reduced to about half compared to the data without the ventilation. Figure.5 shows the measured data of the temperature rise of the ceramics duct in the saturated temperature region. The noise problems are almost solved by the proper grounding and shielding.

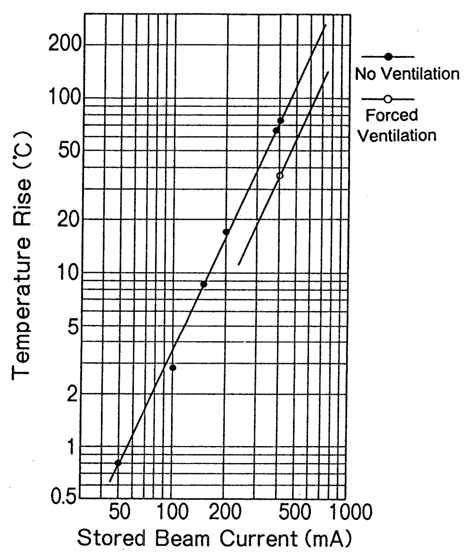

Fig.5 Temperature rise of the ceramics duct in the saturated temperature region.

At 600MeV, beam transport efficiency from the booster to the storage ring is about 5% (max 7%), resulted in about 2mA accumulated beam for each injection since the nominal accelerated beam of the booster is around 50mA. Reasons of the low transport efficiency compared to the typical 10%(max 20%) at 1GeV are the beam loss by the physical aperture in the transport line and the lower capture efficiency of the storage ring. Due to the reasons, the higher injection cycle 0.62Hz is applied rather than nominal 0.31Hz.

During injection, operating point with positive large chromaticity, 5-9 in both horizontal and vertical, and high RF accelerating voltage, 80-90kV, are chosen for stable and efficient beam accumulation. As a result, we succeeded in accumulating the beam 1070mA at Aug.23 and 1150mA in the next day. The measured RF power was 13.5kW and the beam was limited only by the RF power.

Figure.6 represents the typical operation pattern of high current storage experiment. The beam is stable during the storage mode. In the figure, the usual "flat beam" operation mode is applied in the injection mode, while the the "round beam" is applied in the storage mode for the longer beam lifetime[4]. Present beam lifetime at 1000mA is around 3 hours for "round beam" and 30 minutes for "flat beam" that are mainly limited by Touschek lifetime due to low energy as shown in table2.

Table 2 Touschek lifetime τ_T at 1000mA

Beam energy	600 MeV	1 GeV
Flat beam	1.4 (h)	16(h)
Round beam	7 (h)	100(h)

The decrease of beam lifetime, in the figure, at the beam current down to 900mA in the figure may be due to the low ion clearing voltage -1.5kV, that is limited by the power supply, compared to the necessary voltage -1.7kV to cancel out the beam self field. Beam lifetime at 1GeV is mainly determined by beam gas scattering and will be longer compared to 600MeV.

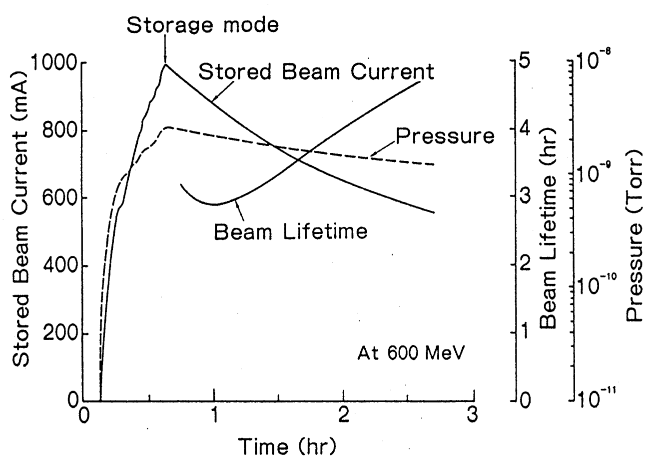

Fig.6 Typical operation of high current storage experiment at 600MeV.

Conclusion

Since Apr. 1990, the ring is providing SR for internal users without serious trouble. The machine performance is being improved and the beam lifetime reached 60 hours at nominal 200mA. The R&D and machine studies for the upgrade of 500mA at 1GeV are being done and the beam current over 1000mA are stably stored at 600MeV that demonstrate the possibility of high current SR source for industry.

Acknowledgement

The authors wish to thank Dr.M.Ohno and Dr.S.Nakamura for the useful discussions. Our thanks are extend to Mr.M.Haraguchi for his help during machine studies.

References

1. M.Kodaira et al., to be published in Proc. of 4th Intern. MicroProcess Conf., Kanazawa, July(1991)
2. M.Kodaira et al., In Proc. of Topical Sym. on Synchrotron Radiation, Jan., Japan(1991)32.
3. N.Awaji et al., Journal of the Vacuum Society Japan, Vol.34,No.10(1991)752.
4. N.Awaji et al.,to be published in Proc. SRI'91, Chester(1991)