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Upgrading to 500mA of the Stored Beam Current at SORTEC 1-GeV Source Facility

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Abstract

At the SORTEC 1-GeV SR source facility for the study of X-ray lithography, the upgrade of the stored beam current to over 500 mA was performed. The RF cavity power supply was increased from 14 kW to 28 kW together with modification of the RF coupler. In addition, the pumping system and the cooling capacity of the storage ring were also reinforced. Reconstruction work and beam tests for upgrade were carried out for 3 months beginning April '92. A stored beam current of 500 mA was successfully achieved within only 2 weeks after the beam operation was restarted. At present the lifetime has reached 25 h. These results are discussed from the aspects of the key issues for upgrading of the stored current and the SR beam aging effects on the time-evolution of the lifetime.

I. INTRODUCTION

The SORTEC SR facility is the dedicated machine which was constructed mainly for x-ray lithography development and has been successfully operating since October 1989 without serious failures. In order to use this system for SR lithography, the exposure time by SR will be required to be as under as that by conventional optical lithography in high throughput requirements.

To reduce the losses of the beamline at the mirror and the Be window and develop a high sensitive resist and so, a maximum stored beam current of 500mA with lifetime of 20h will be required for SR ring [1]. To achieve this requirement, upgrading of the SR ring to 500 mA was scheduled to begin in April 1992. The preliminary machine studies to solve technical problems had been carried out within the capacity limits of existing SR ring in parallel with the regular operations since November 1990 [2].

II. MAIN ITEMS OF THE UPGRADE [3]

For the upgrade of the stored beam current to 500 mA, the nominal capacity of power supply for RF cavity was increased from 14 kW to 28 kW by replacing the main power tube RS2012CJ with RS2058CJ. The RF coupler was also replaced to accommodate the increase of nominal capacity of the RF power supply. Figure 1 is a photograph of the upgraded RF power coupler and RF power supply.

In addition, the vacuum system of the storage ring was reinforced by increasing the pumping speed against the higher photo desorption gas under increased beam current. The ultrahigh vacuum pump using NEG modules (SAES WP-1250, ST707) (NEG pump) was newly added to remove H_2 at downstream from of the each straight section where the pressure is relatively higher than that in the each bending section.

The ion clearing voltage to cancel out the beam self field was needed to minimize the reduction of beam lifetime and the increase of beam instability due to extension of beam current. The nominal voltage of power source applied by the existing disk-type ion clearing electrode, installed at seven out of eight straight sections, was increased to 1.5 kV from 500 V. A clearing electrode was newly installed at the one straight section previously not equipped with an electrode. The stripe-type ion clearing electrode, instead of the existing disk-type, was newly installed in each chamber of the NEG pump. The diagram of the vacuum system of the ring is shown in Fig. 2.

The temperature rise due to the increase of beam

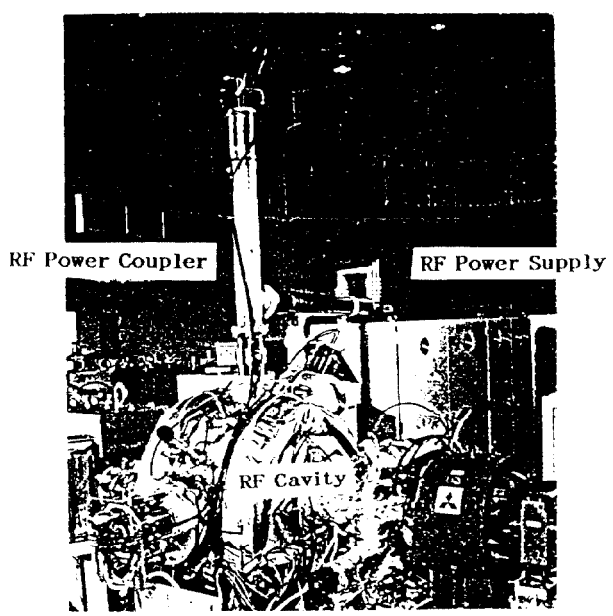

Fig. 1 Photograph of RF coupler and RF power supply.

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current was the primary problems and was solved as follows. The temperature rise of the ceramics duct facing a bump magnet was reduced to one half by forced ventilation by a fan. The temperature rise around the SR port was also suppressed by adding local water cooling pipes.

III RECONSTRUCTION WORK

The reconstruction work for the upgrade was performed by shutting down the facility from April 20 through July 20, 1992.

The replacement work for the RF power supply and RF coupler was performed. The RF power coupler was installed with the antenna loop at the bottom set at an optimum angle to obtain a coupling constant β of 4.

The installation of the RF coupler and NEG pumps was performed carefully by filling the vacuum duct of a ring with dry N_2 gas.

The vacuum components, which had been previously degassed by baking for 48 h at 250 ℃ before installation, were degassed again in the vacuum duct for 48 h at 150 ± 10 ℃ in a vacuum. Figure 3 shows the pump-down curve of the storage ring. The NEG pump was reactivated during baking to minimize contamination of the duct. After completion of these procedures the average base pressure decreased continuously and reached 3.6x10-9 Pa (2.7x10-11 Torr) at straight sections and 4.9x10-9 Pa (3.7x10-11 Torr) at bending sections.

Regarding the RF accelerating system, the relationship between generation power and reflection power was optimized by setting a stability requirement. As a result of this, it was confirmed that on 500 mA operation, the generation power is 28kW and the reflection power of 10kW which is absorbed by the circulator of the RF power supply.

IV. RESULTS OF BEAM OPERATION

The beam operation of upgraded facility was restarted on July 2. The improvement of the stored beam current from start of beam operation to the achievement of required 500 mA is shown in Fig. 4. On the first day of the beam operation a current of 200 mA was stored with the lifetime of 2.5 h. Figure 5 shows the brief history of the beam lifetime. The required current of 500 mA is achieved with the lifetime of 10h on July 14 only 12 days after the start of beam operation.

Since August 5, 1992 the storage ring has been providing SR again for the inner users who first started to use at 200 mA. The beam lifetime extended steadily according to the increase of integral dose by inner users and our machine studies. Figure 6 shows the improvement of beam lifetime as a function of time-integrated beam current in comparison with the data from first beam operation in 1989 until the start of upgrading work and the data after the upgrading. The $I \cdot \tau$ after upgrading is about 5 times as large as $I \cdot \tau$ from initial beam operation at the same integrated beam current in spite of interruption of the

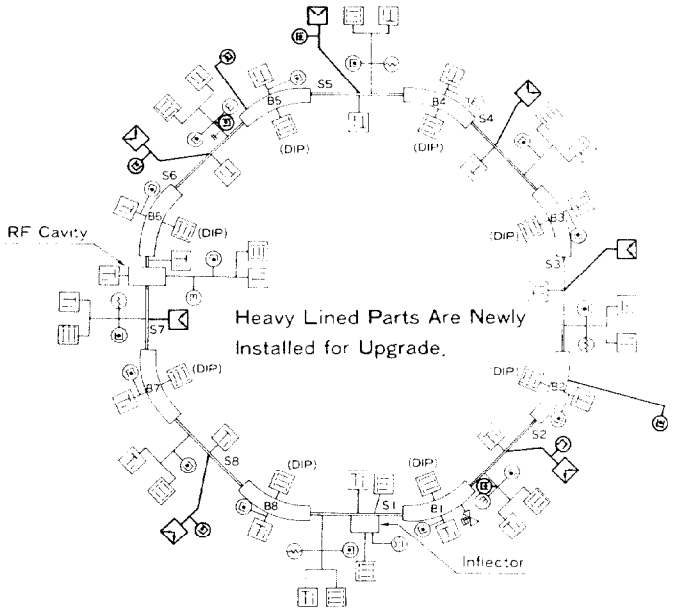


Fig. 2 Schematic diagram of vacuum system ofthering.

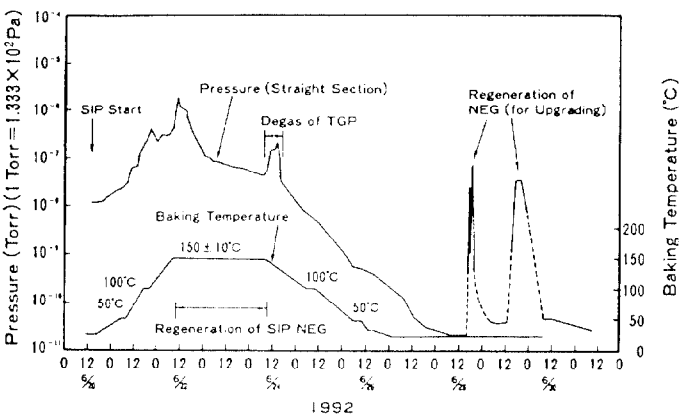


Fig. 3 Pump-down curve of the storage ring.

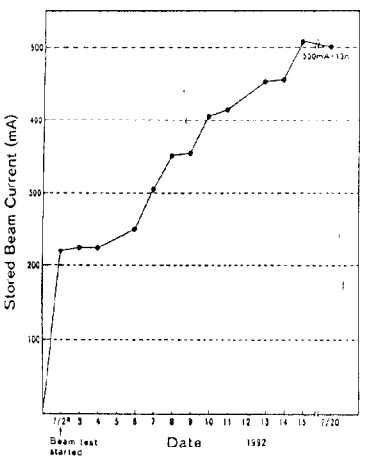


Fig. 4 Improvement of the stored beam current from start of beam operation to 500 mA.

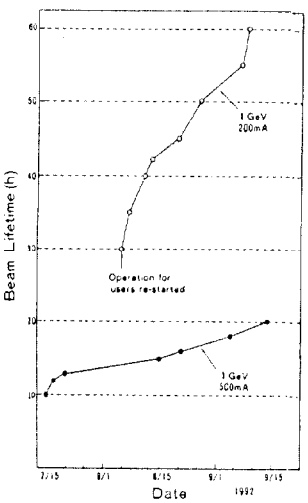


Fig. 5 Brief history of the beam lifetime.

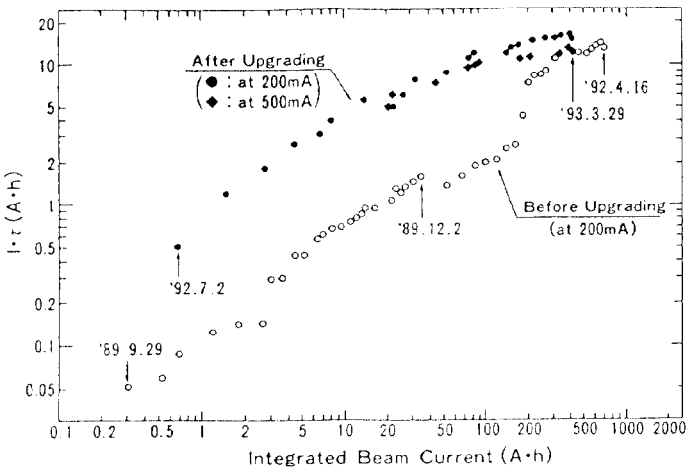


Fig. 6 Improvement of beam lifetime as function of integrated beam current.

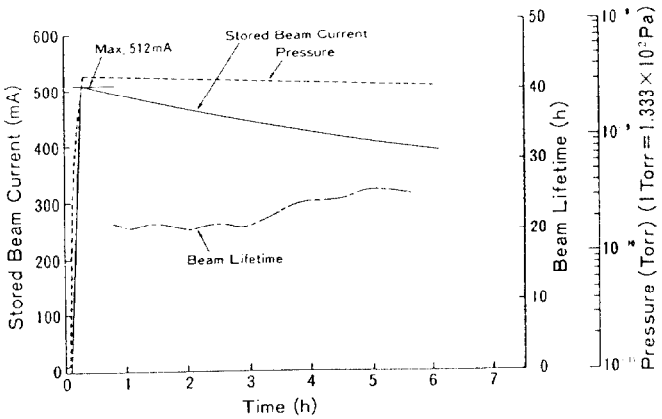
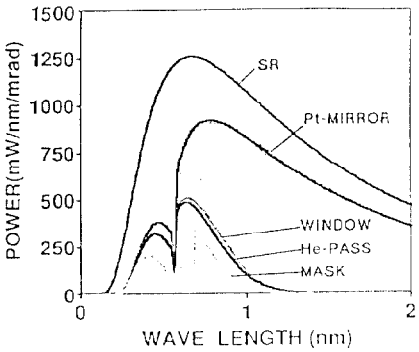


Fig. 7 Typical operation of the facility

Table 1 Main parameters of SR facility at SORTEC.

		Designed	Achieved
Storage Ring			
Energy	Get	1	1
Dipole Field	T	1.2	1.2
Critical Wavelength	nm	1.55	–
X-Ray Power	kW	15.9	15.9
Beam Current	mA	500	500*
Beam Lifetime	h	>4	>22**
Natural Emittance	mm·mrad	0.51	–
Circumference	m	45.7	–
Synchrotron (Injector)			
Injection Energy	MeV	40	40
Maximum Energy	GeV	1	1
Beam Current	mA	30	50
Circumference	m	43.2	–
Linac (Pre-Injector)			
Energy	MeV	40	40
Beam Current	mA	>30	60~80
Energy Spread	%	<±1.5	±0.67
Emittance	π mm·mrad	<3.8	0.7

* max. 512 mA
** max. 25 h (80 h at 200 mA)



(SR 1GeV 1.2T 500mA)
(Pt-mirror 21mrad) (Be 35 μm)
(He 0.1MPa 0.3m) (SiN 2μm)

Fig. 8 SR spectrum at 1GeV-500mA SORTEC ring.

vacuum and replacement of the components. This remarkable extension of the lifetime after upgrading mainly depends upon the memory effects of beam duct cleaned by beam dose over a long period. The highest stored beam recorded so far at 1 GeV is 512mA on Oct. 22 ,1992, as shown in Fig. 7. The SR ring is filled to 500mA within 10 min. The beam lifetime at 500 mA is 21 h. At present, the maximum beam lifetime reached 25 h in February.

Table 1 summarizes the designed and achieved performance. As a result of the upgrade of the stored beam current to 500 mA from 200 mA, synchronous radiation power was increased by two and a half times. The power density per horizontal angle of 1 mrad ranging from 0 to 2 nm was 1470 mW /mrad. Figure 8 shows the spectrum of synchrotron radiation for the upgraded 1-GeV 500 mA ring.

V. CONCLUSIONS

The works for upgrading has been completed successfully as scheduled with high performance beyond our expectations. As a result of the success of upgrading to 500 mA with over 20 h, the SORTEC 1-GeV SR source has attained top levels all for beam current, beam lifetime and X-ray power as a dedicated SR source for industrial use.

VI. ACKNOWLEDGEMENT

The authors wish to thank all of their colleagues at SORTEC Corporation and Mitsubishi Electric Corporation. The success of the upgrade to 500 mA was the result of their efforts through preliminary studies and reconstruction work. Also, the authors wish to express deep thanks to the many people who provided useful suggestions.

VII. REFERENCE

[1] T.Hosokawa and T.Kitayama,Oyo Buturi(In Japanese) Vol..60,703(1991).
[2] N.Awaji,M.Kodaira,T.kishimoto,T.Iida,Y.Kijima and H.Tsuchidate, EPAC92,Vol.1,pp.304-306(1992).
[3] M.Kodaira,N.Awaji,T.Kishimoto,O.Asai and M.Haraguchi, EPAC92,Vol.1,pp.203-205(1992).