Performance of Upgraded SORTEC 1-GeV 500 mA SR Source Facility

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Abstract

At SORTEC, the 1GeV SR source facility has been successfully upgraded. The ultrahigh vacuum of the storage ring was completely recovered. At present, the maximum beam lifetime reached 25 h at 500mA and 80 h at 200 mA. Machine studies are continuing for investigation of the beam behavior at various stored beam currents of up to 500mA, by using the merit of the full energy injection scheme. In this paper, the performance of RF accelerating system, ion clearing effects and vacuum characteristics are described. As a result, It is shown that the lifetime predicted from the theoretical considerations has been almost attained.

I. INTRODUCTION

The reconstruction work for the upgrade, which was performed by shutting down the facility from April 20 through July 20, 1992., 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 which will be requested in order to use for SR lithography , 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. The beam lifetime at 200mA extended 70 h at the before upgrade and the ultrahigh vacuum of the storage ring was completely recovered[1]. At present, the maximum beam lifetime reached 25 h at 500mA and 80 h at 200 mA. Machine studies are continuing for investigation of the beam behavior at various stored beam currents of up to 500 mA, by using the merit of the full energy injection scheme.

II. UPDATE BEAM OPERATION

Figure 1 represents a typical daily operation. The beam lifetime of the ring is 24 h at 1GeV ,500mA of the storage current. After an initial warm-up of 1 h in the morning, a nominal beam current of 500 mA is stored within 10 min. New beams are refilled in one or two minutes only once or twice a day to recover the beam reduction of about 15 % because of long beam lifetime. Table 1 shows main parameters of the storage ring.

Table 1 Main parameters of the storage ring.

<table>
<tr><th colspan="2">Operation mode</th><th>"Flat"</th><th>"Round"</th></tr>
<tr><td>E(GeV)</td><td>beam energy</td><td colspan="2">1</td></tr>
<tr><td>I(mA)</td><td>beam current</td><td colspan="2">500</td></tr>
<tr><td>τ(h)</td><td>beam lifetime</td><td>20 (25)</td><td>60 (80)</td></tr>
<tr><td>f inj (Hz)</td><td>injection cycle</td><td colspan="2">0.31</td></tr>
<tr><td>νx/νy</td><td>betatron tune</td><td>2.20/2.23</td><td>2.143/2.149</td></tr>
<tr><td>βx/βy(m)</td><td>avg. beta function</td><td>4.36/6.55</td><td>4.41/5.93</td></tr>
<tr><td>κ</td><td>coupling of beta func.</td><td>0.1</td><td>1</td></tr>
<tr><td>εx/εy(μm rad)</td><td>emittance</td><td>0.622/0.062</td><td>0.35/0.35</td></tr>
<tr><td>ξx0/ξy0</td><td>natural chromaticity</td><td colspan="2">-2.99/-0.20</td></tr>
<tr><td>ξx/ξy</td><td>chromaticity</td><td colspan="2">2.26/-1.83</td></tr>
<tr><td>α</td><td>momentum compaction</td><td>0.185</td><td>0.184</td></tr>
<tr><td>Δp/p(x10⁻³)</td><td>momentum spread</td><td colspan="2">0.462</td></tr>
<tr><td>L(m)</td><td>ring circumference</td><td colspan="2">45.73</td></tr>
<tr><td>fRF(MHz)</td><td>RF frequency</td><td colspan="2">118</td></tr>
<tr><td>frev(MHz)</td><td>revolution frequency</td><td colspan="2">6.5556</td></tr>
<tr><td>h/B</td><td>harmonics/bunch no.</td><td colspan="2">18/18</td></tr>
<tr><td>Rsh(Mohm)</td><td>shunt impedance</td><td colspan="2">1.35</td></tr>
<tr><td>β(0)</td><td>coupling factor</td><td colspan="2">4.0</td></tr>
<tr><td>U0(keV)</td><td>radiation loss</td><td colspan="2">31.83</td></tr>
<tr><td>Vc(kV)</td><td>cavity gap voltage</td><td colspan="2">100</td></tr>
<tr><td>fs(kHz)</td><td>synchrotron frequency</td><td>46.3</td><td>46.1</td></tr>
<tr><td>P(kW)</td><td>RF power(Max 28kW)</td><td colspan="2">22</td></tr>
</table>

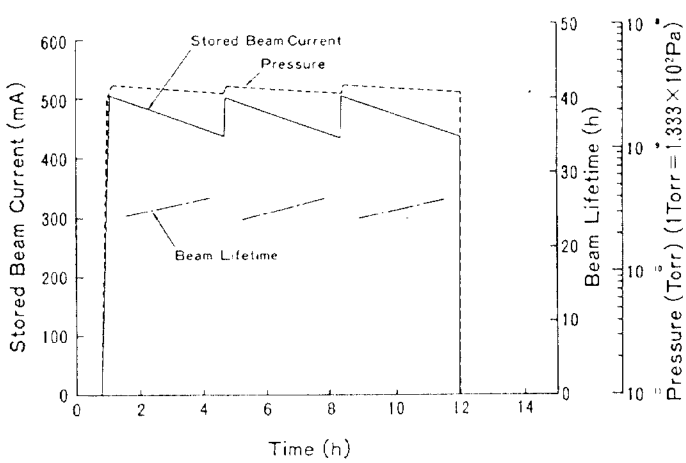

Fig. 1 Typical daily operation.

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III. SALIENT RESULTS OF UPGRADE

A. Optimization of RF Acceleration System

The output power and reflection power were optimized by taking into account the stability of the system. Figure 2 shows the vector diagram and indicates that the peak cavity voltage Vc is a vector summation of the beam loading voltage Vb and generator produced voltage Vg. The cavity voltage Vc was increased from 90 kV to 100 kV by improving the Touschek terms effecting on lifetime [2] and stability of the beam. The condition for phase stability is theoretically given by using the stability factor s [3] as

$$S = Vc \cdot \sin\phi + Vb \cdot \sin\psi > 0$$

The relationship between output power and reflection power were investigated by taking into account a margin of 10 kV (namely s>10 kV). Under this condition,it was also found that coupling constant β would be required 4 and detune angle α for phase stability would be needed 10～20 ° for attaining 500 mA and set up for regular operation.

As a result it was found that the output power of 28 kW was attained and the reflection power of 10kW was absorbed by the circulator of the RF power supply as a result of the RF system test.

Figure 3 shows calculated RF generator produced power Pg, reflected power Pr and stability factor S as a function of beam current at α =20 ° . The measured values of up to 500 mA were compared and agreed well with the calculated values. According to these results, Pg is 22 kW at 500 mA and up to 600 mA can be stored at 28 kW(an upper limit of Pg).

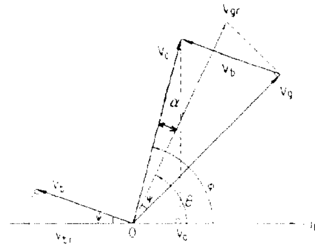

Fig. 2 Vector diagram of an RF accelerating system.

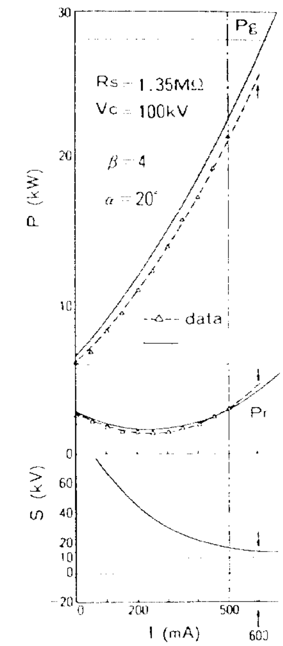

Fig. 3 Pg, Pr and S as a function of beam current.

B. Vacuum characteristics and beam lifetime

Figure 4 shows the dependence of normalized pressure rise $\Delta P/I$ for the straight section and bending section on integrated beam dose since the beginning of operation in 1989. $\Delta P/I$ was almost flat before the upgrade, and however again begins to decrease sharply after the upgrade. The ultrahigh vacuum of the storage ring was completely recovered when the beam lifetime exceeded 70 h, which was the maximum value before the upgrade at 200 mA. It reached 80 h only after 8 months as shown in Fig. 5. These effect may have been caused by installation of a new NEG pump, although closer observation will be needed.

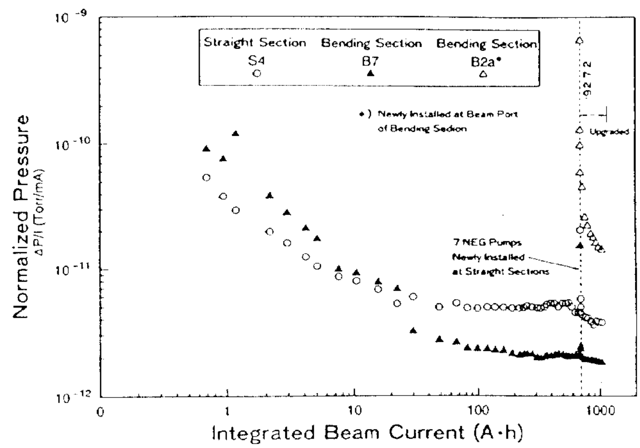

Fig. 4 Change of normized pressure rise $\Delta P/I$

C. Effect due to a trapped ion

To clear an ion, the existing disk-type ion clearing electrode, installed at seven out of eight straight sections. To all electrodes including already installed before the upgrade,applied voltage was increased to 1.5 kV from 500 V. One ion clearing electrode was newly installed at the one straight section previously not equipped with an electrode . A stripe-type ion clearing electrode, was newly installed in each chamber of the NEG pump. When the clearing voltage is decreased from 0V after storing beam current, the beam lifetime is clearly improved at less than some fixed voltage. These threshold voltages are almost proportional to stored beam currents and are higher than those when voltage is increased from lower voltage, for example -1100v or less. Figure 6 shows the clearing voltages showing hysteresis as a function of stored beam currents in three zones: A,B and C. The clearing voltage is required for set up in zone A. Figure 7 shows the beam lifetime as a function of clearing voltage at different beam modes of round beam(No. 2R) and flat beam(No. 2F)as shown in Table 1 and stored beam currents of 200 mA and 500 mA. For No.2R the beam lifetime was improved to 75 h from 20 h at 200 mA and 22 h from 9 h at 500 mA by applying Vic=-1100V previously been used in

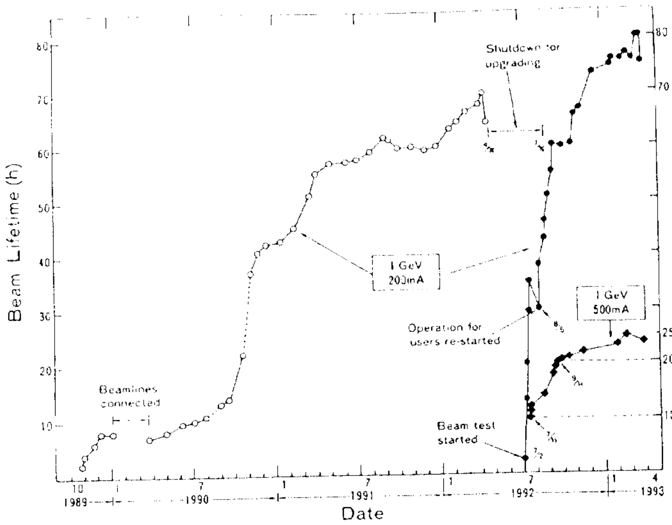

Fig. 5 Improvement of beam lifetime.

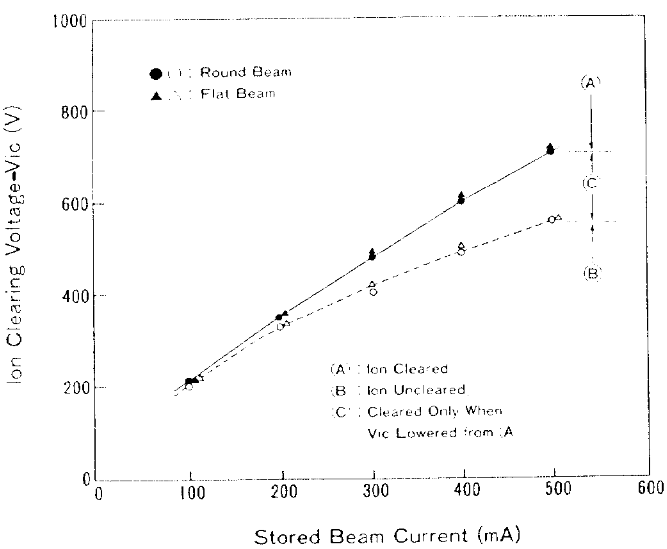

Fig. 6 Clearing voltage as a function of beam current

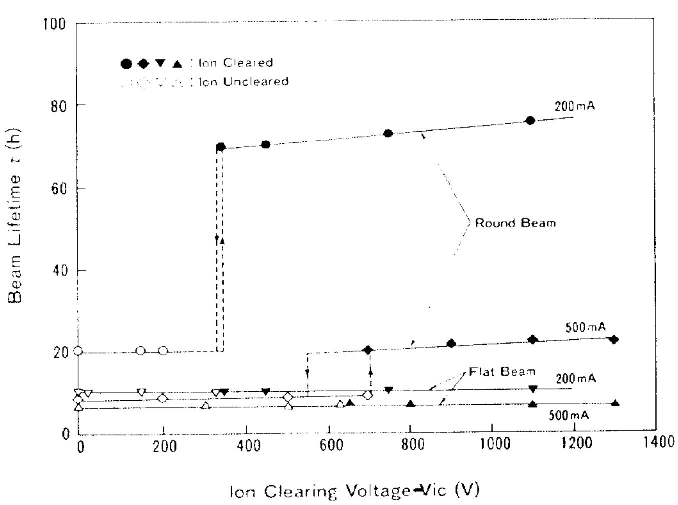

Fig. 7 Beam lifetime as a function of clearing voltage at different beam modes

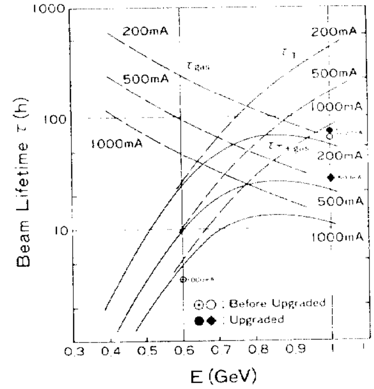

Fig. 8 Comparison of measured beam lifetime and cal culated one.

regular operation. When ions are cleared, average pressures in the vacuum duct of the ring being increased. However for No.2F, the beam lifetime was not clearly confirmed to have been changed. It was nearly 10 h at 200 mA and 6 h at 500 mA at either Vic=0 or -1100 V in spite of average pressures in the ring being increased when Vic=-1100 V.

D. Beam lifetime

Figure 8 shows the beam lifetime calculated for the round beam based on the Touscheck lifetime and beam-gas lifetime for different beam energy and current. In the figure,the measured beam lifetime at 1GeV-200 mA and 1GeV-500mA are compared and agreed well with the calculated values.
The lifetime at 600MeV-1000mA tested before the upgrade are also shown.

IV. CONCLUSION

The performance of the upgraded 1-GeV 500 mA SR ring is presented. The performance of RF accelerating system, ion clearing effects and vacuum characteristics was presented. The measured beam lifetimes are compared and agreed well with the calculated values predicted by preliminary R&D and machine studies. As a result, the SR source facility has attained top levels all in beam current, beam lifetime and x-ray power as a dedicated SR source for industrial use.

V. ACKNOWLEDGEMENT

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VI. REFERENCE

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