NewSUBARU Storage Ring

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Abstract

Improvements in this year are briefly summarized. The main features are as follows; The high intensity operation became very stable by the installation of a HOM tuner to avoid beam instability due to the parasitic modes of the RF cavity. The stable top-up operation realized the constant current of ~ 250 mA at 1 GeV.

Introduction

There are eight operating beam lines for the user experiments as shown in Fig.1 (BL-2, 6, 7a, 7b, 9, 10 and 11). The other two beam lines are used for R & D and γ-ray source by laser Compton back scattering (BL-1) and for accelerator beam diagnostics with visible light (BL-12).

The total operation time in 2003 was ~ 2800 hours (user time: ~ 1060 hrs, R&D, machine study: ~ 1400 hrs and remains: tuning). The most remarkable point is that there was no accountable time for machine trouble. (See Fig.2) The storage ring is usually operated in weekdays. Monday and, sometimes, Tuesday are for 1.5 GeV operation. The top-up operation is performed for 1.0 GeV to keep the beam current constant, typically ~250 mA. The day time is ordinarily assigned to users and the remains to machine study and R&D. The beam lifetime at 1.5 GeV has been reached at ~ 6.5 hrs at ~ 300 mA which means practically that the current intensity reduces to the half (~ 150 mA) after 6.5 hrs later as seen in Fig.3 and this gives the lifetime of more than 18 hrs at 100 mA & 1.5 GeV.
**Orbit Stability**

The primary control system of water cooling was improved to keep the temperature change less than $\Delta T < 0.1^\circ$ at the summer shutdown in 2003, then the orbit shift of the electron beam is mainly caused by the temperature change of the ring vault. Figure 4 shows beam position signals at the dispersive and non-dispersive points. Fortunately there are no significant orbit change at the non-dispersive points, which means that the room temperature change mainly causes the circumference change. The ripple of the room temperature comes from the open-close control for the chilled water flow. From this figure we can say for the change of the energy ($\Delta E/E$) and the circumference ($\Delta L: \mu m$) as follows;

<table>
<thead>
<tr>
<th></th>
<th>$\Delta E/E$</th>
<th>$\Delta L: \mu m$</th>
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<tbody>
<tr>
<td>ripple</td>
<td>1.8E-5</td>
<td>3.1</td>
</tr>
<tr>
<td>drift</td>
<td>-1.1E-4</td>
<td>-20 (in 3 hrs).</td>
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**Stability of SR Axis**

The above effect was very drastic on SR axis because most of our beam lines use mirrors of which support are very sensitive to the room temperature. The vertical position of synchrotron light at BL-9 changed as the temperature changed in normal operation as shown in Fig.5-(a). Mechanically closing the water flow at corresponding fan coils, this position became very stable as shown in Fig.5-(b). Though there was still non negligible shift and drift, these are considered as results of unreasonable setting of the measurement system.

**Streak Camera and Ultra Short Bunch**

Beam diagnostics using the streak camera (Hamamatsu Photonics C6860) is very useful and powerful not only for measuring a very short bunch length but also for routine tuning such as the complete synchronization and the complete energy matching between the injector LINAC and the storage ring.

The relative phase of the electron beam to the RF wave was precisely measured by changing the RF voltage. This measurement gives the precise estimate of the linear part of momentum compaction factor ($\alpha_1$) and the relation between the monitored value ($V_M$) and real one ($V_R$) of the RF voltage. We have $\alpha_1 = 1.30E-3$ in usual operation and $V_R = V_M$.

The quasi-isochronous operation realized a very short bunch as shown in Fig.6. This means that the rms bunch length is $\approx 0.48$ mm and opens the possibility to produce coherent radiation in the mm wave region. It should be noted that this is just a observed value and the real length would be smaller after correcting some systematic effects or errors.

**Visibility Monitor and Vertical Emittance**
The vertical beam size was measured by the visibility monitor using interference of visible light. The results are 81 (41) µm in rms at $\beta_y = 19.3$ m without (with) skew quadrupole correction and give the vertical emittances are 0.34 (0.087) nm. The vertical emittance is increased to ~ 1.9 nm at 1 GeV by shaking the beam with quasi-white noise frequencies to reduce the Touschek effect.

**Summary of Efforts for Improvement**

The beam physics and accelerator physics group paid many efforts day by day to improve the storage ring performance. Figure 7 shows the achieved maximum stored current and corresponding typical efforts. The following list are the main improvements and their results.

(1) RF system

a) HOM (Higher Order Mode of cavity) suppression by "HOM-Tuner"

The transverse HOM near 792 MHz excites the horizontal (transverse) coupled bunch instability (TCBI) with the ordinal setting of sextupole magnets and limits the maximum stored current at ~ 80 mA. Also ~990 MHz HOM becomes very strong and causes abrupt beam loss when the RF voltage is ~ 300 kV before 1.5 GeV acceleration. The additional tuner, say, "HOM-Tuner" was installed in the summer shutdown period in 2003 to control HOM frequency independently of the main acceleration mode. Then the ~ 792 MHz TCBI has been almost completely avoided. The ~ 990-MHz-HOM- instability has been avoided by setting the RF voltage around 240 kV in the energy of less than 1.3 GeV.

b) Adjustment of the klystron power supply

The analog signal for interlock of the klystron power supply was very noisy and fault turned-off of the power supply occurred very often. No fault turn-off appears after careful adjustments.

c) Double ALL feedback

The feedback circuits of amplitude stabilization both for the cavity and the klystron work very stably, in particular, at very high beam current (more than ~ 300 mA).

d) Optimize the input coupling constant to the cavity

The storage ring is now often operated at the stored current of ~ 300 mA. The initial coupling constant ($\beta$) was ~ 2.6 supposing the beam current of ~ 100 mA. This constant was changed to ~ 5.6 to obtain more stable operation of the RF system for higher beam current.

e) Phase modulation in PLL feedback

The Touschek effect becomes not negligible at ~1 mA / bunch. The reduction of the line density is the key to enlarge the beam lifetime against this effect. The phase modulation in the phase lock loop is the most effective way for this purpose and results in the ~ 30 % increase of beam lifetime . But the modulation with the frequency $2*\nu_s$ ($\nu_s$ : synchrotron oscillation frequency) causes irregular longitudinal distribution of the electron beam which results in the reduction of brilliance, though it is most effective in increasing beam lifetime. Therefore this modulation is not used in the normal operation.

(2) COD optimization by the aperture survey

The aperture survey by steering magnets found a kind of the golden orbit and resulted in the ~ 10 % increase of beam lifetime. This was done with the tight collaboration with the beam line group.

(3) $\beta_x$ and $\beta_y$ correction by trim windings of quadrupole magnets

The careful analysis of the COD generated by a steering magnet and the insertion devices suggest the significant distortion of $\beta_y$ caused by the systematic error in the one family of quadrupole magnet (QB).

The correcting pole windings were added and then the beam lifetime was increased by ~ 10 %.

(4) Optimization of correcting sextupoles magnets

The adjustment of chromaticity was very important and sensitive to keep higher current than ~ 300 mA. The harmonic sextupoles were also adjusted to avoid transverse instabilities by controlling the amplitude dependent tune shifts. Both the optimization of sextupole magnets and the HOM control are the key for the stable operation with high beam current.

(5) Very high injection efficiency of almost 100 %
The complete synchronization has been kept between the SPring-8 LINAC and the NewSUBARU storage ring\(^6\).

(6) Precise parameter search for 1.5 GeV acceleration

(7) Control system

a) Automatic COD correction

The COD are easily corrected to the magnitude of 6–8 µm in rms just by one button action with keeping the revolution frequency constant. This is very useful for the user time to keep the SR axes stable.

b) Simultaneous observation of air and water temperature

The systematic analysis of the drifts in COD and SR axes became possible as described above. The more accurate orbit control is going to be implanted.

c) Improvement of the database of the storage ring

The model machine in the database should be the same as the real storage ring. This is the key to realize a very small and/or negative \(\alpha_p\) lattice to obtain a very short bunch. The database has been updated mainly by adjusting the effective lengths of magnets comparing measured Twiss parameters with calculated ones.

Acknowledgement

The authors would like to thank Mrs OGATA Y., SASAKI I. and YAMAMOTO N. for improving the utilities and all the SPring-8 stuffs for the stable operation of the NewSUBARU facility.

References

[1] on courtesy of NIIBE M. and SUGISAKI K.
NewSUBARU Storage Ring

**Main Parameters**
- Circumference: 118.731 m
- Lattice: modified DBA \( \sqcup 6 \)
- Straight Sections: 4 m \( \sqcup 4 \) + 15 m \( \sqcup 2 \)
- Injection Energy: 1.0 GeV
- Maximum Energy: 1.5 GeV
- Bending Radius: 3.22 m
- RF Frequency: 499.955 MHz
- Harmonic Number: 198
- RF Voltage: < 140 kV
- Betatron Tunes: 6.30 / 2.23

**Typical Operation Parameters at 1 GeV**
- Mom. Comp. Factor: 1.35 E -3
- Natural Energy Spread: 4.7 E -4
- Natural Emittance: 38 nm
- Natural Bunch Length: 20 psec (rms)
- Maximum Current: 500 mA (multi-bunch)
- Maximum Current: 50 mA (single bunch)
- rms COD in (x/y): 6 / 8 \( \mu \)m

**Critical Photon Energy from Bending Magnet**
- 2.3 keV @ 1.5 GeV, 0.67 keV @ 1.0 GeV

**Beam Optics in 1/4 - Ring.**
- \( \beta_x \), \( \beta_y \)
- \( D_x \), \( D_y \)
- \( \alpha_p \approx 1.3 \times 10^{-3} \)

\( s \) : from the Center of Long Straight Section (\( D_x \): Horizontal dispersion)