NewSUBARU Storage Ring
Ainosuke Ando, Satoshi Hasimoto and Yoshihiko Shoji

Abstract
Present status of the NewSUBARU storage ring is summarized. The machine performance is now in the better level than those of the designed. The efforts for this achievement will be described in another activity reports.

Main Achievements in this year
The design goal of the beam current and the beam lifetime were successfully achieved as shown in Table 1. The operation energy for the user time is 1.0 GeV or 1.5 GeV. The RMS of the closed orbit distortion (COD) in user time are 6 µm in horizontal and 8 µm in vertical at both 1.0 GeV and 1.5 GeV.

Table 1  Main Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>1.0 ~ 1.5 GeV</td>
</tr>
<tr>
<td>Circumference</td>
<td>118.731 m</td>
</tr>
<tr>
<td>RF frequency</td>
<td>499.957 MHz</td>
</tr>
<tr>
<td>Natural emittance</td>
<td>38 nm @ 1 GeV</td>
</tr>
<tr>
<td>Filling pattern</td>
<td>Successive 80 + 80 bunches</td>
</tr>
<tr>
<td>Maximum current</td>
<td>50 mA/bunch &amp; 500 mA/ring @ 1 GeV</td>
</tr>
<tr>
<td>Lifetime</td>
<td>14 hours @ 100 mA &amp; 1.5 GeV</td>
</tr>
</tbody>
</table>

1.5 GeV Operation
At the initial stage of the 1.5 GeV acceleration, there were strong instabilities due to higher order modes in the cavity. These are now completely avoided by changing the detuning angle of the cavity from -5 degree to -20 degree and there is no significant beam loss during acceleration. The RMS COD is also corrected to the same level as at 1 GeV.

The beam decay and the lifetime are shown in Fig. 1.

COD shift
The horizontal COD shift due to the temperature change of the cooling water was ~ 60 µm at the dispersive BPM (~ 50 mm/°C). This means that the change of circumference is ~6 µm/°C. Now the control parameters of the water cooling are optimized so as to the temperature change is less than ±0.1°C, then the horizontal COD shift is almost negligible in taking account of the accuracy as seen in Fig.2. The observed
vertical COD shows typical behavior due to random kicks as seen in the figure. This is understood at present by the reading errors or accuracy of the vertical position.

The high frequency components of the orbit oscillation were measured by spectrally analyzing of the

![COD Variation during Air Temperature Change](image1)

![Spectra of SR Monitor @2002-10-17](image2)

SR monitor (visible light of SR). There is no significant oscillation due to the ripples of the magnet power supplies.

**Fig.2 COD shift against room temperature**

**R & D**

1. **Very Short Bunch**

   Toward generating the coherent radiation in mm wavelength region, the very short bunch operation has been tested by reducing the momentum compaction factor. The preliminary result is shown in Fig. 4. The bunch current is very weak and almost 1/10,000 of those of normal operation. Even the number electrons in a bunch is only $3 \times 10^5$. The strength of the coherent radiation is corresponds to those of incoherent one from $10^{11}$ electrons.

   The obtained rms bunch length is 2.4 psec and this is the world shortest bunch in a storage ring.

2. **Negative $\alpha_p$**

   The operation of $\alpha_p = -1 \times 10^{-3}$ has successfully performed with the injection efficiency of ~70 % (without beam center correction in the beam transform line). The appearance of energy widening, bunch lengthening and head-tail instabilities are completely different from those at positive $\alpha_p$. The quantitative research is possible only at NewSUBARU in the world and our analysis will contribute the development of beam physics.

**Summary of the efforts for improvement in this year**

The beam physics and accelerator physic group paid many efforts day by day to improve the storage ring performance. Figure 5 shows the achieved maximum stored current and corresponding typical efforts. The following list are the main improvements and their results.

![Typical Events & Achieved Maximum Current](image3)

![Fig.5 Maximum current and typical efforts](image4)
(1) RF system

a) HOM (Higher Order Mode of cavity) suppression by temperature and detuning angle
   The transverse HOM near 792 MHz excites the horizontal coupled bunch instability 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 temperature of cooling water for cavity was carefully adjusted to avoid these HOM's, but it was very difficult to obtain a stable condition. Now the operation frequency of the cavity is a little bit lowered by changing the detuning angle (-5 degree to -20 degree) and almost HOM free operation is achieved. The additional tuner (HOM-tuner) will be introduced in the next year and the more stable operation will be performed.

b) Adjustment of the klystron power supply
   The analog signal for interlock of the klystron power supply was very noisy and fault turn off of the power supply occurred very often. No fault turn off is achieved 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 realize 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.

(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 lifetimes 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. This adjust controls 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) Realize and keep the very high injectio efficiency of almost 100 %.

(6) Precise parameter search for 1.5 GeV acceleration

(7) Control system

a) Automatic COD correction
   The COD are easily realize to keep 6~ 8 µm in rms just by one button operation. 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. The sign of the beam energy drift due to the air temperature change was observed even when there was no COD drift. 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.