IMPROVEMENT OF BEAM LIFETIME AT THE NewSUBARU STORAGE RING

Y. Shoji, A. Ando, S. Hashimoto, NewSUBARU, LASTI, University of Hyogo*, 678-1205, Japan
N. Kumagai, H. Ohkuma, M. Oishi, SPring-8, JASRI, 679-5198, Japan

Abstract

We report on the improvement of beam lifetime of NewSUBARU storage ring since 2001. The upgrading of the vacuum system in 2001 improved an averaged pumping speed by about a factor of 2. After re-surveying the beam loss process, we could inject 7.5 times number of electrons than before. It reduced a time for the beam self-cleaning of the vacuum chamber. The optimisation of the vertical COD and the correction of a modulation of vertical beta function enlarged the effective vertical acceptance. These resulted in an improvement of the beam lifetime by about 50%. The transversal beam shaker enlarged the vertical beam size and improved Touschek beam lifetime. The bunch filling of ring buckets were optimised for longer lifetime.

INTRODUCTION

The 1.5 GeV electron storage ring NewSUBARU [1, 2] has been constructed in the SPring-8 site in 1998. After the beam commissioning the user experiments started in February 2000. The ring is a racetrack type with the circumference of 119 m. It has two 14 m long (LSS) and four 4 m long (SSS) straight sections. The main parameters of the ring are summarized in Table 1.

Since the beginning of the initial commissioning, one of the biggest problems had been a short lifetime because of a heavy gas load due to the synchrotron-radiation–induced gas desorption (PID). A radiation safety condition, which limited the injectable number of electrons to $7.2X10^{12}$ per week, prevented the rapid beam self-cleaning of the vacuum chambers. We operated the machine with a periodic beam injection mode, typically once every 20 seconds, in order to maximize the beam dose under the limitation.

The first upgrading of the vacuum system took place in 1999 [3]. Main part of it was replacement of vacuum chambers of insertion devices. It improved the vacuum performance by about a factor of five and enabled a user operation. The second upgrade took place in 2001 [4], including the reformation of bending chambers and straight chambers. It improved the vacuum performance by about a factor of two.

We also proceeded re-calculation of radiation level and got a permission of operation with a different condition in Nov. 2001. Under the new condition NewSUBARU could accept 7.5 times more electrons. It pushed up the stored beam current during the user operation and enabled a rapid beam self-cleaning.

In 2002 followed the two improvements, the maximization of the vertical ring acceptance [5] and the optimisation of the bunch filling [6]. With the better vacuum pressure the elongation of the Touschek lifetime (τ_T) became to be important. The power upgrade of the RF shaker improved the Touschek lifetime in January 2004.

In the following sections we report on these improvements.

*Previously Himeji Institute of Technology.

Table 1: Main parameters of the NewSUBARU

Energy	0.5 - 1.5 GeV
Injection Energy	1.0 GeV
Circumference	118.731 m
RF Frequency	499.956 MHz
Natural Emittance at 1 GeV	38 nm
Harmonic Number	198
Filling Pattern	Two 80-bunch trains
Maximum Stored Current	500 mA /ring
Betatron Tune ν_x / ν_y	6.30 / 2.23
Linear Coupling	1 %

UPGRADING OF THE VACUUM SYSTEM

The upgrade of vacuum pumps and reformation of vacuum chambers were planned based on calculations described in the other contribution to this conference [4]. The main parts of it were (1) addition of pumping ports (2) use of many TSPs (titanium sublimation pumps) with larger inner diameter to extend pumping speed.

The number of vacuum pumps were 54 for SIP (sputtering ion pump), 77 for TSP and 13 for NEG (non-evaporable getter) pump. After the bake out of the vacuum chambers around the ring, the pressure readings of ccgs (cold cathode gauges) were of the order of 10^{-9} Pa without the beam. Although the life was bad at just after the exposure to the air of the chambers, the chambers memorized the beam dose and lifetime was improved with an increase of beam dose. It improved the vacuum performance by about a factor of two.

NEW PERMISSION OF RADIATION SAFETY CONDITION

New Scenario of Beam Loss

In 2001 we proceeded re-calculation of radiation level using more realistic beam loss scenario. At the same time we decided to add two local radiation shields required by the new radiation safety low expected to start in 2003.

In the old scenario, which had been prepared for the initial stage of beam commissioning, most electrons were lost at the injection septum during the injection tuning. Revised scenario was based on the experience of operation and was more realistic, in which most electrons were stored and are lost at the points of largest dispersion or the points of smallest aperture.

The radiation level was calculated based on the new scenario at typical points in NewSUBARU facility and in SPring-8 cite. A highest radiation in the controlled area was expected at a top of the concrete tunnel of the ring. The calculated level was 0.28 mSv/week, which was smaller than 1/3 of the limit by low, 1 mSv/week.

In November of 2001, the new formal approval of radiation safety was given by the Japanese Ministry of Education, Culture, Sports, Science and Technology. It permits the injection of 7.5 times much electrons (5.4×10^{13} e/w) and storage of 5 times higher beam current (500 mA).

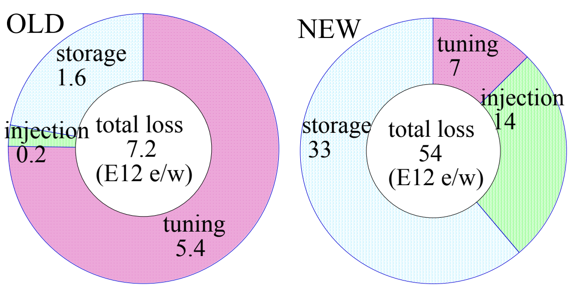

Figure 1: The old and the new scenario about the electron beam loss.

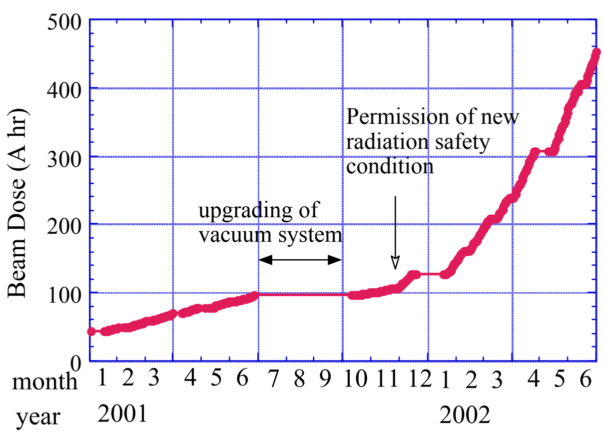

Figure 2: Accumulation of beam dose with time. The increase of beam injection in November 2001 brought a sudden change of stored beam current and rapid beam self-cleaning.

Improvement of Stored Beam Current

At NewSUBARU the stored beam current for the continuous self-cleaning was set at the point where the injected beam and the lost beam were balanced. The increase of number of electrons to be injected pushed up the stored beam current to $\sqrt{7.5} = 2.7$ times higher. It enabled a faster self-cleaning as shown in Fig.3.

OPIMIZATION OF BEAM ORBIT

Rutherford Scattering

The main part of the lifetime comes from the Rutherford scattering of beam with residual gas molecule in vertical direction. Its lifetime, τ_R, is proportional to the square of the inner duct height (a_{YC}) and the inverse of the vertical beta function (β_{YC}) at the critical locations. The critical locations, where a_{YC}^2/β_{YC} took the minimum of the ring, are edges of the bending magnets face to the dispersion free straight sections. There are 12 critical locations in the whole ring, 8 face to the SSS and 4 face to the LSS.

Optimisations of Beam Orbit

We produced a vertical local bump at those critical locations and measured the lifetime with respect to its height (ΔY). The height of the bump was monitored at the beam position monitor (BPM) nearby. Each of them is referred by a named number of BPM nearby, for example as 'BPM16'. Fig.2 shows a typical result of the measurement of beam life varying ΔY.

We optimized the beam orbit at the critical locations and the total beam lifetime was improved from 2.74 hrs to 3.80 hrs (about 40% increase) at 1.0 GeV with the stored beam current of 250 mA.

From the slope of the triangle of Fig.2, we could estimate the contribution of τ_R to the total lifetime τ_0. The result was $\tau_0/\tau_R = 0.64$.

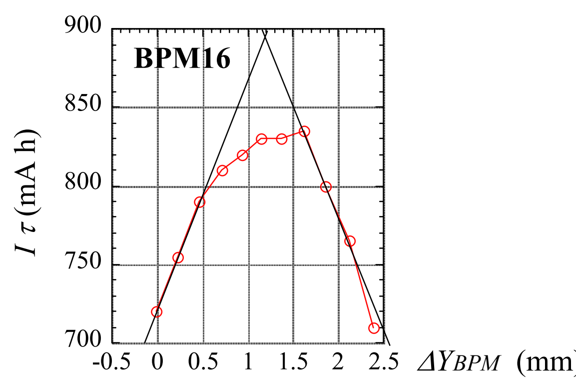

Figure 3: A typical result of the vertical aperture survey at 1.0 GeV. Vertical axis is the beam current times the lifetime. About 15% improvement of the lifetime was obtained by the 1.2mm displacement of vertical position at BPM nearby (ΔY_{BPM}). The slope at the flattop was thought to be an effect of the spill of the local bump orbit.

Modulation of Vertical Beta Function

After the optimisation of the beam orbit there should be no flattop at any critical location if the ring was perfect. However there still existed flattops at many of locations. Fig. 4 shows a plot of the flattop width with respect to the vertical betatron phase. The width propagated around the ring like a modulation wave of beta function with harmonic number of 4, roughly the twice of vertical betatron tune (ν_Y=2.2).

The estimated modulation amplitude of the beta function was $|\Delta\beta_Y/\beta_Y|_{max}$ = 15%. We applied a correction of asymmetric modulation of the beta function (amplitude of 7%) using trim windings on the quadrupole magnets. Finally we obtained about more 5% improvement of the total lifetime.

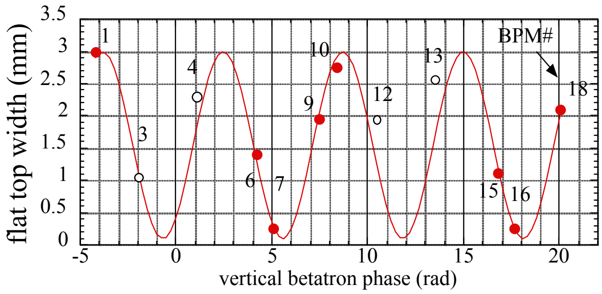

Figure 4: Flattop width of the aperture survey vs. the vertical betatron phase. The line is a 4th harmonic sinusoidal wave. The shaded circles and clear circles are critical locations face to SSS and LSS, respectively.

RF SHAKER

In January of 2004, the power supplies of the RF shaker (fast strip-line beam deflector) were upgraded from 10 W/channel to 50 W/channel. The shaker deflects the beam vertically with white noise and enlarges the vertical beam size in order to obtain longer Touschek lifetime (τ_T). The total beam lifetime was improved by about 20% at 1.0 GeV by the upgrading. Fig. 5 shows the beam lifetime versus the beam size at a light source point.

In the user time the power of the shaker is lowered when there is a user who needs a sharp synchrotron radiation.

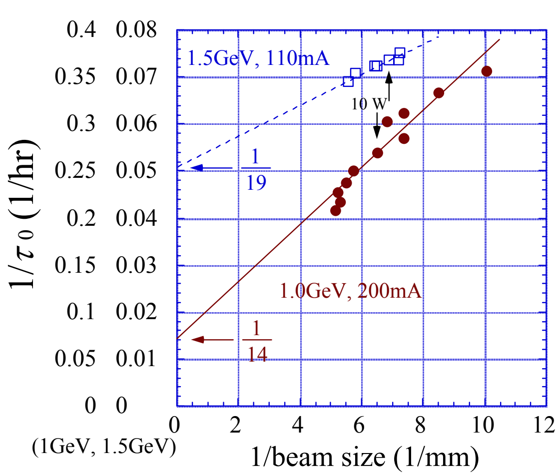

Figure 5: Vertical beam size (σ) versus the beam lifetime at 1.0 GeV (circle) and 1.5 GeV (square). The points at [1/beam size] = 0 are considered to be $1/\tau_R$.

From the plot of Fig.5 we estimated the contribution of τ_T and τ_R. The results were τ_T/τ_R = 3.1 at 1.5 GeV, 100mA, and τ_T/τ_R = 2.0 at 1.0 GeV, 200mA.

BUNCH FILLING AND ION TRAPPING

NewSUBARU vacuum chamber has 16 button-type ion clearing electrodes (ICE) on which the maximum dc voltage of -800kV was applied. This ICE and the RF shaker prevent the ion trapping instability.

The filling pattern of 198 buckets with bunches is also important to prevent the ion trapping. The filling has been optimized for long lifetime considering τ_T and ion trapping. The transition of filling pattern optimized for long lifetime is shown in Table 2. In poor vacuum pressure the ion trap instability appeared strong and partial filling, one 50-bunch train in 198 buckets, was used. As the improvement of vacuum pressure and the stored beam current, the filling with the longer train became the better filling. At the present the two 80-bunch trains are used, with which no effect of ICE is observed. However with uniform filling of 198 buckets we still observe a blow-up of beam size and a small effect of ICE.

Table 2: Filling pattern in user experiments

Date	Filling
Oct. 2001 - Feb. 2002	one 50-bunch train
Feb.2002 – June 2002	two 70-bunch train
June 2002 - now	two 80-bunch train

ACKNOWLEDGEMENT

The authors express their sincere thanks to the staff of SPring-8 accelerator group and the LASTI staff for their collaboration. We also thank Dr. J. Tada, Mr. T. Takagi and other staffs of the radiation safety office of SPring-8 for their help on applying for the new safety condition.

REFERENCES

[1] A. Ando et al., J. Synchrotron Rad. 5, pp.342-344 (1998)

[2] Y. Shoji, et al., “Operational progress of New-SUBARU in these three years,” this conference.

[3] S. Hashimoto, et al., Nucl. Instr. & Meth, A467-468, pp. 145-148 (2001).

[4] Y. Shoji et al., “Upgrading of a vacuum system of the NewSUBARU storage ring: design and effect,” this conference.

[5] Y. Shoji et al., Proc. of 14th Symposium on Accelerator Science and Technology, Tsukuba, pp.533-535 (2003).

[6] S. Hashimoto, et al., “Photo Stimulated desorption Phenomena at the NewSUBARU storage ring,” SRI’03, San Francisco.