HIGH BEAM CURRENT OPERATION OF NEWSUBARU RF

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Abstract

The maximum stored beam current reached to the radiation safety limit (500mA) at 1.0GeV in NewSUBARU. The parameter of the RF was one of the keys for the achievement. A change of coupling coefficient (β)of the input coupler from 2.8 to 5.6 pushed up the Robinson's stability limit. A change of a time constant of ALC feedback control reduced the enhancement of the coherent synchrotron oscillation at low synchrotron tune. An adjustment of temperature of the cavity and an adjustment of the Robinson's tuning angle reduced the beam blow-up by HOMs.

1 INTRODUCTION

The synchrotron radiation facility NewSUBARU [1] is an EUV and Soft X-Ray light source at the SPring-8 site. Laboratory of Advanced Science and Technology for Industry (LASTI), at the Himeji Institute of Technology is in charge of its operation, collaborating with SPring-8. The main parameters of NewSUBARU are listed in Table 1.

Table 1: Main Parameters of NewSUBARU in July 2003.

Ring Parameter	
Energy	0.5 ~ 1.5 GeV
Circumference	118.731 m
Betatron Tune ν_X / ν_Y	6.30 / 2.23
Chromaticity ξ_X / ξ_Y	3.2 / 5.8
Momentum Compaction Factor α	0.0014
RF Parameter	
Number of RF Cavity	1
RF Frequency f_{RF}	499.956 MHz
Harmonic Number	198
Shunt Impedance *Rs*	5 MΩ
Q value	28000
Coupling Coefficient of Coupler	5.5
Beam Parameters at 1 GeV	
Maximum Current ;single bunch ;multi bunch	50 mA 500 mA
Acceleration Voltage V_{RF}	120 kV
Radiation Loss Per Revolution U_0	33 keV
Synchrotron Oscillation Frequency	6kHz
Natural Emittance ε_X	38 nm
Natural Energy Spread	0.047%
Linear Coupling	1 %
Damping Time $\tau_H / \tau_\varepsilon$	22 ms / 12 ms

The ring has two operation modes for users. In the 1.5 GeV mode, the beam is accelerated to 1.5 GeV and stored, while in 1.0 GeV top-up mode, the beam current is kept at 250±0.15 mA by an occasional injection with the gaps of undulators closed.

NewSUBARU has one KEK-PF type RF cavity [2], with SiC absorbers. It is powered by a 180kW/500MHz klystron. The shunt impedance of the cavity was much lower than the design value because of an accident at the initial commissioning.

In November of 2001 the permission of a new condition of radiation safety raised the safety limit for the stored beam current from 100mA to 500mA. Some improvements and parameter adjustment followed the permission and we soon achieved a highest beam current of 300 mA in May of 2002, by adjusting chromaticities. However in order to realize a stable operation with higher current than 200mA and to reach to the limit current, 500mA, the adjustments of parameters of the RF cavity was essential. The maximum stored beam current of 500mA was achieved in June 2002.

Here we report our experience of some improvements and some data on the stable operation of the RF cavity with high beam current

2 CHANGE FOR HIGH BEAM CURRENT

2.1 Coupling Coefficient of the Input-Coupler

In March 2002 the stored beam was not stable over 200mA. A fluctuation of power reflected from the cavity rapidly increased with the stored beam current over 200mA (Fig.1), which was lower than the Robinson's stability limit [3]. The synchrotron oscillation frequency became too low by the beam loading. An easy way to stabilize the beam was to increase the RF acceleration voltage (V_{RF}) or cavity power (*Pc*) as shown in Fig. 2. However this was not accepted because the increase of V_{RF} reduced the phase acceptance of RF bucket and made the injection efficiency worse [4]. The change of the coupling coefficient (β) of the input-coupler was the best way to overcome the beam loading.

In May 2002 the β was changed from 3.4 to 5.5. This β = 5.5 was the maximum coupling as far as we use the present coupler. This change pushed up the coherent synchrotron oscillation frequency (*fs*) and made the beam stable at 200mA. The shift of f_S by the beam loading is shown in Fig. 3.

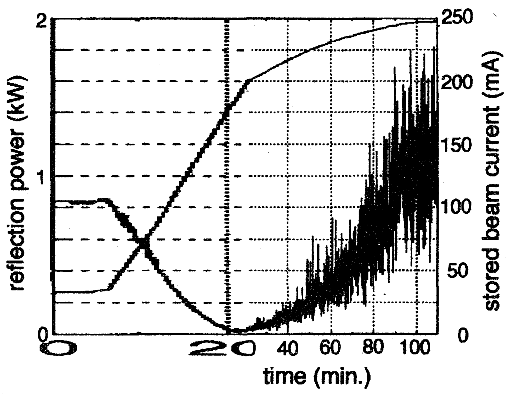

Figure 1: RF power reflected from the RF cavity. Here β=3.4 and V_{RF}=117kV. The reflected power was not stable at over the current with minimum reflection power.

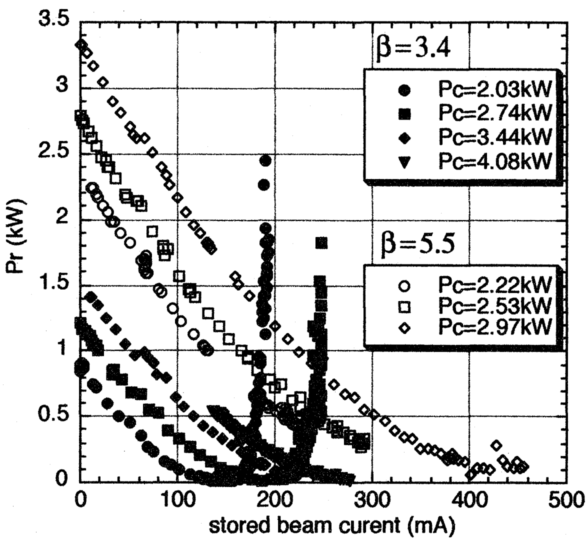

Figure 2: RF power reflected from the RF cavity (*Pr*) with β=3.4 and β=5.5 for various cavity power(*Pc*).

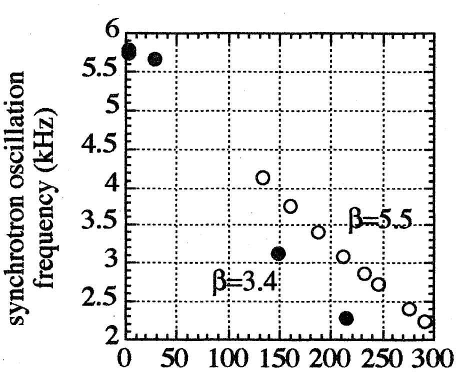

Figure 3: Synchrotron oscillation frequency shift by the beam loading. The open circles with β=3.4 and the shaded circles with β=5.6, both with V_{RF}=107 kV.

2.2 Feedback Parameter

The next problem was the time constant of the low-level feedback control. Because the f_S was still low at the high beam current, the automatic voltage level control (ALC) would enhance the phase modulation end excite the coherent synchrotron oscillation [5].

The time constant of the ALC feedback loop was changed. The frequency response of the loop, at before and at after the change are shown in Fig. 4 [6]. The feedback module of NewSUBARU is the same as that of SPring-8, described by T. Nakamura *et al* [7]. The capacitance C of the Figures was named as C_L in ref.[7]. With the larger C the increase of the synchrotron oscillation amplitude at over 250mA disappeared as shown in Fig.5.

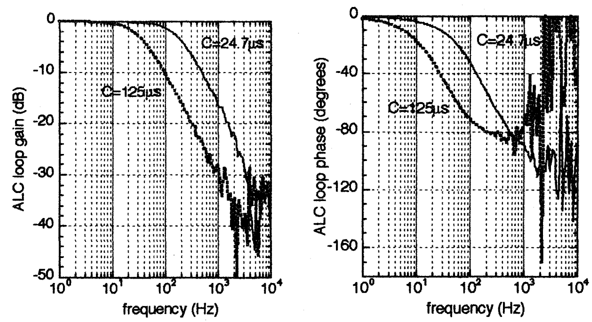

Figure 4: ALC feedback loop gain and phase with different capacitance, fast (C=24.7μF) and slow (C=125μF) case. The C is C_L in ref.[7].

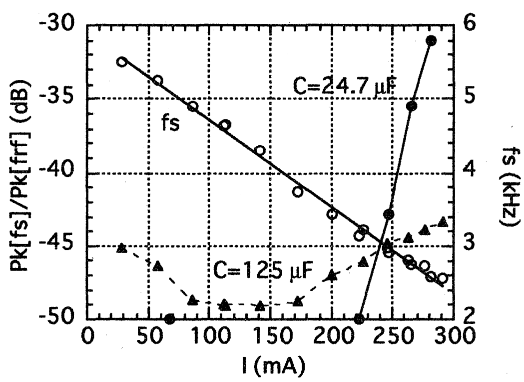

Figure 5: Relative amplitude of the synchrotron oscillation side band to the main RF acceleration frequency. The open circles are f_S. The shaded triangles and the circles were relative amplitude of fs side bands, at before and at after the change. With the small capacitance C the synchrotron oscillation amplitude increased with f_S < 3 kHz. At this time V_{RF}=116kV and β=5.5.

2.3 Cavity Temperature

In fall of 2002 we found a correlation between the stored beam current and the cooling water temperature shown in Fig. 6 (a). In January 2003 the temperature was raised up to 36 degrees. The amplitudes of TM010 mode HOM, frequencies of 790MHz and 795MHz, decreased with the rise of the temperature (Fig. 6 (b)). This change enabled a beam accumulation up to 500mA.

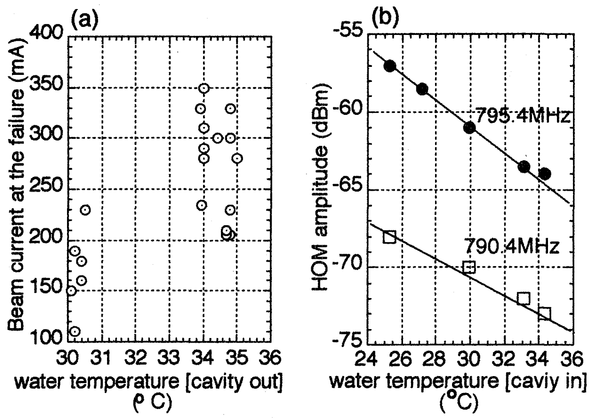

Figure 6: The effect of the water temperature. (a) Stored beam current vs. temperature of cooling water of the cavity. (b) Water temperature vs. HOM frequency.

2.4 Tuning Angle

The next problem was the horizontal instability maybe by HOM of 990 MHz or 790MHz. The HOM made the beam injection unstable at 50~100mA and caused an abrupt beam loss when the RF voltage was raised for the acceleration or during the acceleration. A small jittering of ***Pr*** is observed in Fig.1 at 50~100mA. A change of tuning angle of the cavity, from -5° to -21° eliminated the loss. Fig. 7 shows examples of the beam current during the acceleration from 1.0 GeV to 1.5 GeV. With the new angle parameter, we started the user operation at 1.5GeV at over 300mA.

3 SUMMARY

Some parameter tunings in these two years improved the beam behaviour at high beam current. However there still be a sudden and small beam loss at a high current for about once a month, which we do not have identified the reason.

In this summer we installed another remote controllable tuner, we call it HOM-tuner, and the beam commissioning with it has just started.

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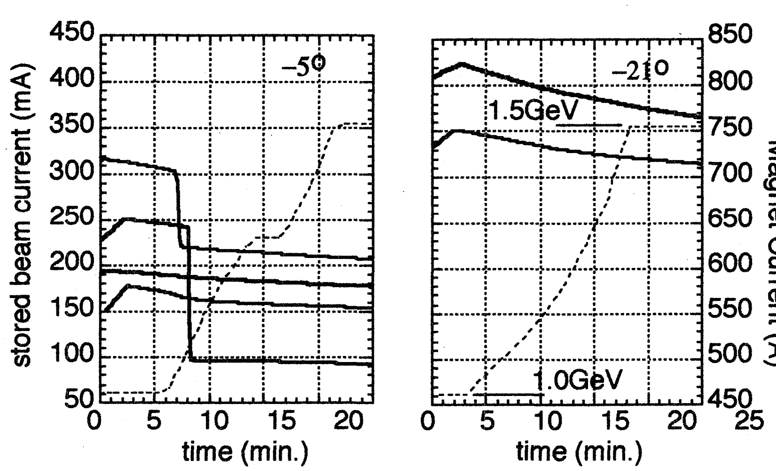

Figure 7: The stored beam current with the tuning angle of -5° (left) and -21° (right). The broken lines are current of bending magnet. The solid lines are examples of stored beam current during the acceleration.