Simulation Study of Single Bunch Instabilities in the SPring-8 Storage Ring

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1. Introduction

The single-bunch instabilities driven by broad-band impedance in the SPring-8 storage ring was studied using the simulation code SISR(Single-Bunch Instabilities in Storage Rings)[1] developped in SPring-8.

2. the SPring-8 Storage Ring

The SISR is applied to the study of the instabilities of the SPring-8 storage ring. The parameters of the ring is shown in Table 1.

Table 1. The parameters of the SPring-8 storage ring.

Parameter		Value	Unit
Energy	E_0	8	GeV
Revolution Frequency	T_0	208.77	kHz
Energy Loss per Turn	U_0	9.2	MV
Damping Partition Numbers	J_E / J_β	2 / 1	
Momentum Compaction Factor	α	1.41×10^{-4}	
Betatron Tune (vertical)	ν_0	16.16	
Averaged Betatron Function	β	17.3	m

The broad-band impedance of the ring are estimated with MAFIA[2]. The longitudinal impedance is

$$Z^{\parallel} = -9.68\times10^{-8}\,\omega\, i + 400 + 1.49\times10^{8}\frac{1+i}{\sqrt{\omega}} \quad [\Omega] \qquad (28)$$

and the transverse impedance of small discontinuities is

$$\langle \beta_{BB} Z^{\perp}_{BB} \rangle = 17.3\times\left(-2.13\times10^{5}+5.98\times10^{14}\frac{1}{\omega}\right) \quad [\Omega] \qquad (29)$$

and the transverse impedance of cavities is

$$\langle \beta_{Cav} Z^{\perp}_{Cav} \rangle = 10.0\times 4.2\times10^{19}\,\frac{1+i}{\omega\sqrt{\omega}} \quad [\Omega] \qquad (29)$$

, where β_{BB} is the averaged value of the beta functions at thef small discontinuities and β_{Cav} is the value of the beta function at the cavities. Transverse instabilities are estimated only for y direction which has larger transverse broad-band impedance by smaller aperture of the beam pipe.

3. Simulation Results

3.1 Longitudinal Instabilities

Figure 1 shows the dependence of the bunch length and the energy spread σ_E/E on the bunch current I_b. Because this ring is rather inductive compared to coloreds which have a lot of cavities, the potential-well distortion lengthen the bunch length and the threshold of microwave instabilities can not be seen until the threshold current of the transverse instabilities which is shown later.

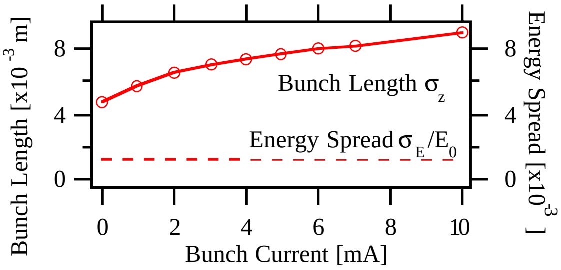

Figure 1. The bunch length and energy spread.

3.2 Transverse Instabilities

Figure 2 shows the bunch current increase vs. time used in the simulation.

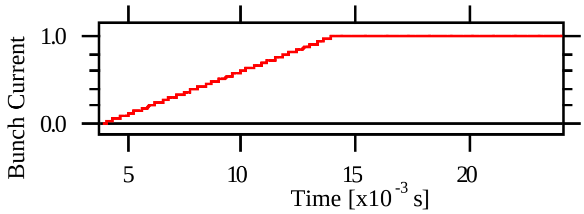

Figure 2. bunch current shape vs. time

Figure 3 and Figure 4 show the amplitude of betatron motion of the bunch vs. time and the spectrum of betatron oscillation for chromaticity ξ=0, respectively. Instabilities occurs at I_b=3mA and I_b=7mA for ξ=0 and I_b=10mA for ξ=4.

From Figure 4, the shift of the frequency of m=0 mode is comparable to the synchrotron frequency, 1.5kHz at I_b =3mA and 2x1.5kHz at I_b=7mA. These instabilities seems to be a mode-coupling instability of m=0 and m=1 at I_b =3mA and that of m=0 and m=2 occurs at I_b=7mA

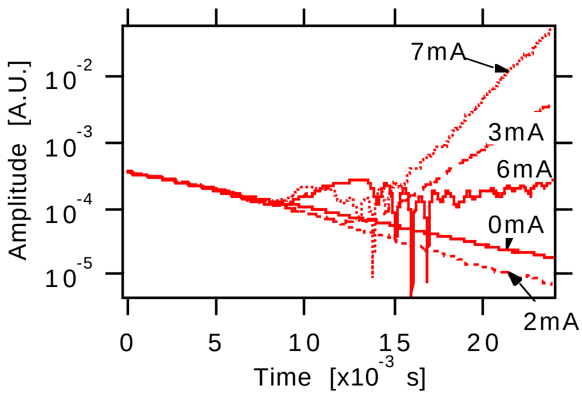

Figure 3. Amplitude of the betatron motion vs. time for ξ= 0.

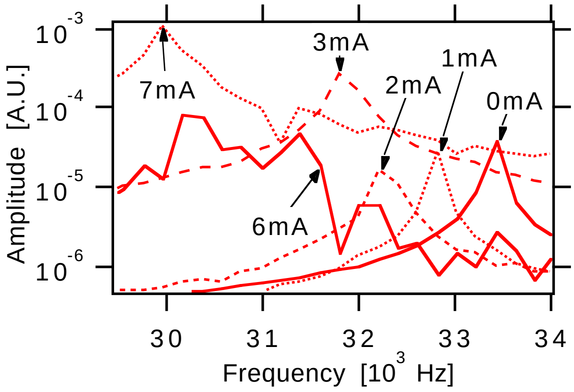

Figure 4. Spectrum of the betatron motion of the bunch for ξ= 0.

In Figure 5, which is for ξ=4, No instabilities occurs near I_b=3mA, but the m=2 mode growths up at I_b=10mA. The difference between ξ=0 and ξ=4 seems to be from the effect of the head-tail damping, which can be seen at the beginning of the bunch current increase at time ~ 5ms in Figure 5 and it is much faster than radiation damping seen at I_b=0mA.

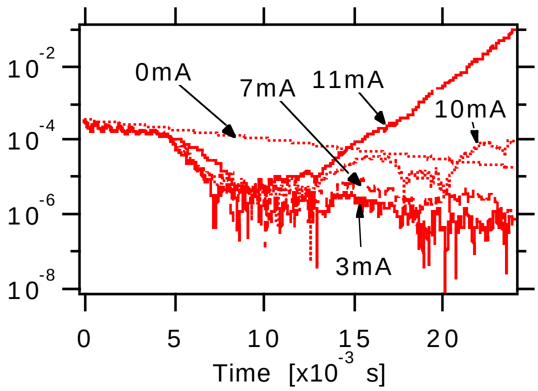

Figure 5. Amplitude of the betatron motion vs. time for ξ= 4.

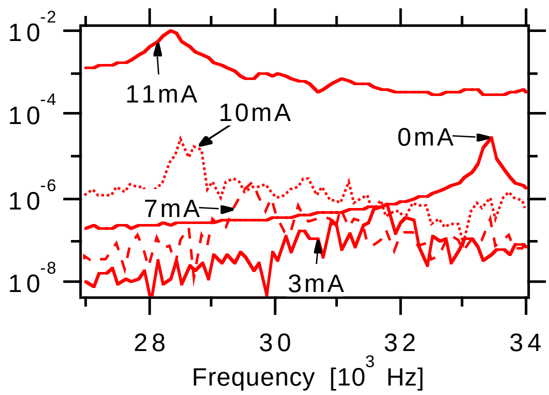

Figure 6. Spectrum of the betatron motion of the bunch for ξ= 4.

Figure 7 and Figure 8 show the case of chromaticity ξ=-2. The m=0 mode grows rapidly and obvious threshold current is not seen. This is the typical characteristics of the head-tail instabilities.

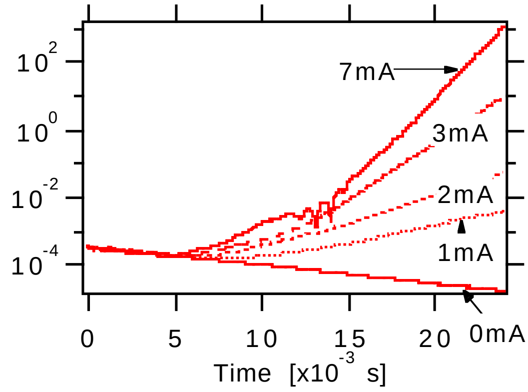

Figure 7.Amplitude of the betatron motion of the bunch for ξ=-2.

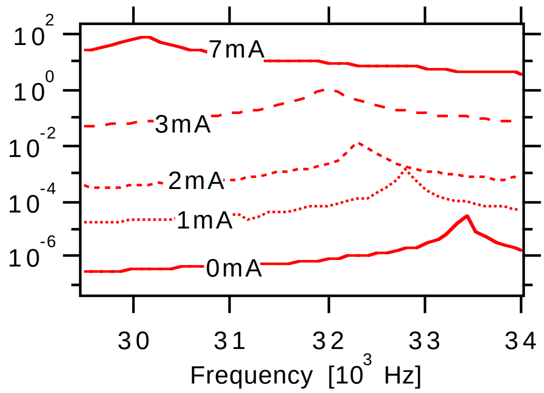

Figure 8. Spectrum of the betatron motion of the bunch for ξ= -2.

4. Conclusion

The simulation code for single-bunch instabilities was developed and applied to the SPring-8 storage ring. Bunch lengthening caused by potential well distortion effect is seen but no longitudinal microwave instabilities occures until the threshold current of the transverse instabilities. The threshold current of the transverse mode-coupling instabilities of m=0 and m=1 is a few mA and the strength of this coupling is so small and can cure with the positive chromaticity. However the mode-coupling instabilities of m=0 and m=2 is strong and can not be cure by increase of the chromaticity.

5. References

[1] T. Nakamura, “Broad-Band Impedance of the SPring-8 Storage Ring,” The Fifth European Particle Accelerator Conference, Sitges(Barcelona), June 1996, p1099. and also a related paper is in SPring-8 Annual Report 1995.

[2] T. Nakamura, “The Simulation Study of the Single-Bunch Instabilities in the SPring-8 Storage Ring,” The Fifth European Particle Accelerator Conference, Sitges(Barcelona), June 1996, p1102 and also a related paper is in SPring-8 Annual Report 1995.