Observation of the Single-Bunch Instabilities in the SPring-8 Storage Ring

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1 Introduction

Measurement of the bunch-current dependent phenomena on the beam was performed in the SPring-8 storage ring. We measured the bunch-current dependence of bunch length, synchronous phase in the RF acceleration field and the frequency response of the betatron motion of the bunch. During this measurement, we observed the vertical oscillation of the beam without external force above certain bunch current. We measured the dependence of this threshold current on chromaticity of the ring and positive chromaticity can cure it and we could store more than 10mA/bunch which is twice of the target bunch current. The analysis of the results based on the simulation study is reported in. [1].

The machine parameters of the SPring-8 storage ring is summarised in Table 1. The beam pipe elements are in the reference[1].

Table 1 : Parameters of the SPring-8 storage ring

Energy	E_0	8	GeV
Circumference	C	1436	m
RF Frequency	f_{RF}	508.58	MHz
Harmonics	h	2436	
Momentum Compaction Factor	α	1.46×10^{-4}	
Radiation Loss/Turn	U_{rad}	8.91	MV
Nominal Acceleration Voltage	V_c	12	MV
Synchrotron Frequency	f_s	~1.5	kHz
Natural energy spread	σ_δ	1.086×10^{-3}	

(calculated from the magnetic field measurement of the dipole magnets.)

2 Bunch Length

The bunch length was measured by a streak camera, Hamamatsu C6860 with a synchro-scan unit, using visible synchrotron radiation from a bending magnet.. The full scale of time range used in this measurement is 100ps to 200ps and timing resolution is 2ps to 4ps, respectively. The timing signal for the synchro-scan unit is the 1/7 frequency divided signal of the 508.58MHz reference signal for the RF acceleration system. The phase of the cavity voltage is controlled by a phase-lock loop to keep the relative phase to this reference signal.

The bunch current dependence of the bunch length is in Fig 1 and the shape of the bunch is shown in Fig 2. At low bunch current, the natural energy spread can be obtained from the bunch length using the relation $\sigma_\tau = (\alpha/\omega_s)\,\sigma_\delta$ where σ_τ is rms bunch length, σ_δ is the rms relative energy spread and ω_s is the synchrotron angular frequency. The obtained value of σ_δ is consistent with the energy spread measurement using chromatic synchrotron side-bands[2].

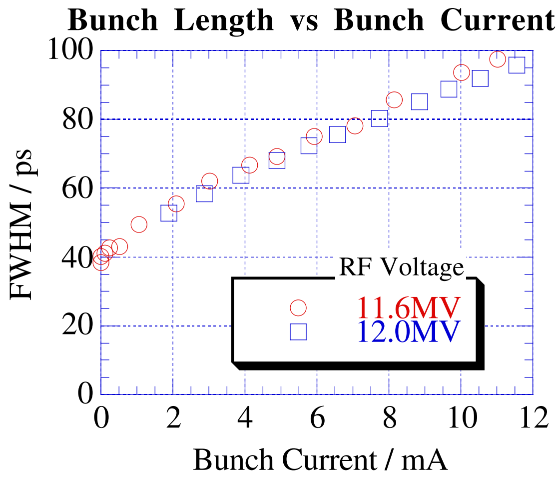


Fig.1 Bunch length vs. bunch current at two values of the RF acceleration voltages.

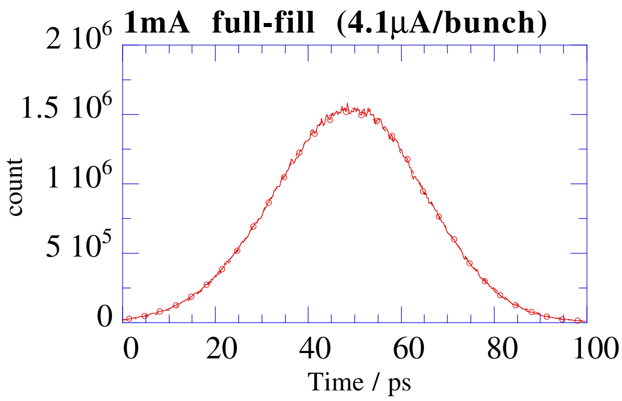


Fig.2 bunch shape at low current. The solid line is a fitted curve using Gaussian shape with rms. = 16.3ps. The RF voltage is 11.6MV and the synchrotron frequency is 1520Hz. The calculated value from the natural energy spread is 16.6ps.

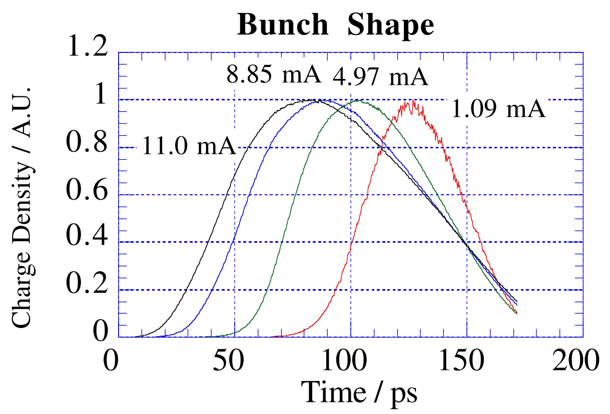


Fig.3 Bunch shape and forward shift of bunch position. As the bunch current increases, the bunch has longer tail and the timing of bunch become earlier to compensate the parasitic energy loss of the bunch. The parasitic loss is the energy radiated to wake fields at impedance.

3 Synchronous Phase

The bunch-current dependence of the synchronous phase of the centre of mass of the bunch in RF acceleration field was measured also by the streak camera and the results are shown also in Figure 2.

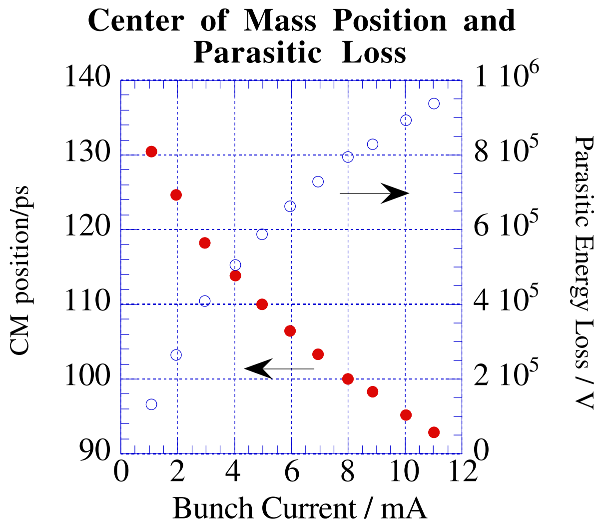


Fig. 4 Centre of Mass position of the bunch and calculated parasitic energy loss vs. bunch current.

The synchronous phase, $\phi_s = \omega_{RF} \times$ (CM position in time), is related to the energy loss of the bunch during one revolution, U, with the relation $\sin\phi s = U / eV_c$ where V_c is the acceleration voltage. The energy loss U is the sum of the radiation loss U_{rad} which is constant and the parasitic loss U_{para} which is dissipated to the wake field and has dependence on bunch-current.

5 Transverse Instabilities at Negative Chromaticity

When the chromaticity of the ring is -4.3, we observed vertical betatron oscillation without adding external shaking , at the bunch current above 0.5mA/bunch. This oscillation is detected by a button pick-up electrode attached to the beam pipe and the signal from it was monitored by the spectrum analyser. When this oscillation arose, the eminent peak near the vertical betatron frequency was observed at the display of the analyser. The single-pass beam position monitor system with button pick-up electrode also detected this oscillation.

4 Transverse Instabilities at Non-Negative Chromaticity

At nearly zero vertical chromaticity, ξ_y = 0.24, We observed vertical betatron oscillation without shaking of the beam at the bunch current above 3.5~4 mA/bunch which is one order larger current than at negative chromaticity -4.3. With vertical chromaticity above 4, we could not observe any oscillation of the beam up to 12 mA/bunch where we had to stop injection because of the increase of the vacuum pressure. The current value of the nominal vertical chromaticity is set to this.

The bunch-current dependence of the frequency response of the vertical betatron motion of the beam to external shaking was measured and is shown in Fig 6. The tune monitor system of the ring is used for this measurement and the set-up is shown in Fig 5.

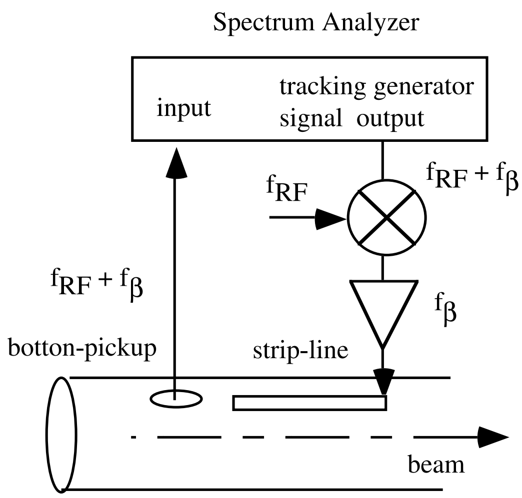
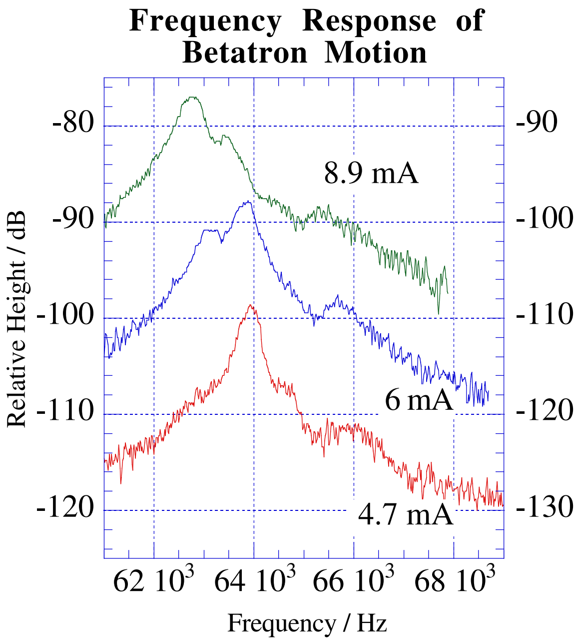


Fig. 5 Set-up for the measurement of the frequency response of the vertical betatron motion of the beam.



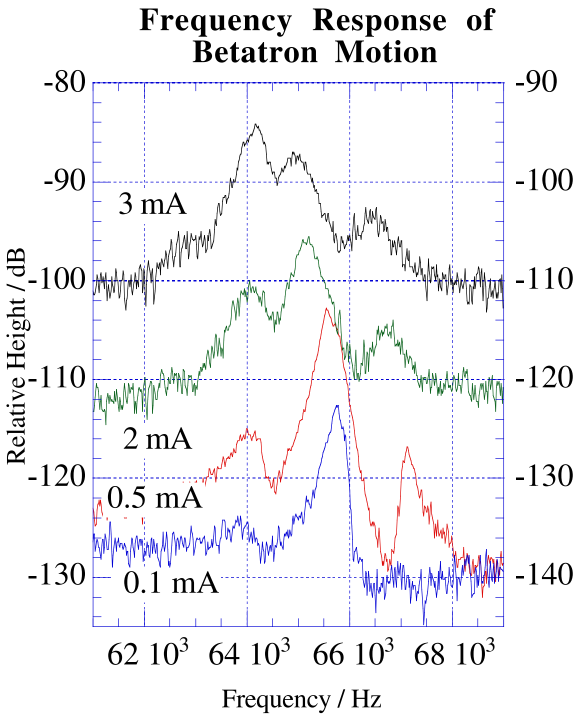


Fig. 6 Frequency response of vertical betatron motion vs. bunch current.

References

[1] T. Nakamura et al., "Single-Bunch Instabilities in the SPring-8 Storage Ring:: Comparison with Simulation based on Estimated Impedance", this proceedings.