OBSERVATIONS OF FAST MULTI-BUNCH INSTABILITY IN THE SPRING-8 STORAGE RING

T. Nakamura, S. Sasaki, T. Ohshima, M. Ooishi, K. Soutome, M. Takao
JASRI/SPring-8, Mikazuki-cho, Hyogo, JAPAN

Abstract

After the installation of new beam chambers of four 30m long straight sections, we observed the vertical multi-bunch instability of low frequency modes and its strength depend on the length of bunch train and on the vacuum pressure.

We measured the distribution of amplitude of betatron oscillation inside the bunch train and dependence of the amplitude of the betatron motion of a successive second train on the width of a gap between the first train and the change of the properties of the instability on vacuum pressure of the straight sections..

1 INTRODUCTION

In the summer, 2000, beam pipe chambers of four 30m long straight sections in the SPring-8 storage ring were replaced to new chambers for the straight sections to be magnet free. After this, we observed the strong vertical coupled-bunch instability and it limits the filling pattern of the beam. This instability is strong enough and we can not suppress by chromaticity and it became weaker as time goes.

2 MEASUREMENT

Following properties of this instability were observed;

1) At first several weeks after the replacement, we observed strong vertical betatron lower sideband peaks shown in Fig. 1 even with vertical chromaticity 6 where the strength of the beam against multi-bunch instabilities is 2times larger than at chromaticity 0[1]. The highest peak was located at 2-3MHz and lowest betatron sideband was not observed.

At this period, we observed followings;

1) We could suppress this peaks with the vertical chromaticity of $\pm$16 where the strength of the beam against multi-bunch instability is 4 times higher than the strength at zero chromaticity[1]. However, we observed the emerge of similar peaks of horizontal betatron sideband in horizontal beam spectrum when the horizontal chromaticity is 0. Head-tail growth rate was small because of small bunch current, 0.04mA/bunch.

2) The height of the peaks of the instability become higher as the length of bunch train increase.

3) Gaps between bunch trains reduce the height of the peaks of the instability and the gaps of the length more than 100ns suppressed the instability. Thermal motion of ions is the order of 500m/s and 100ns is enough for the ion crowd to diffuse the vertical beam size ~ 10-20micro meters.

4) The height of the peaks of the instability depend on the vacuum pressure.

5) The distribution of the amplitude of the betatron motion in a bunch train shows fast rise-up from noise level and its rise time is less than 1 micro second.

6) The position of the rise of the betatron amplitude moves forward in a bunch train as the stored current increases or as the vacuum pressure increase.

7) The instability became weaker as time goes

Our ring is a light source which require small emittance and long lifetime. At the operation of the multi-bunch filling, we prefer as large number of bunches as we can to obtain longer lifetime which limited partly by Touschek life, excluding the effective beam size increase by the instability. Hence we focused our study on following two questions; 1) How many bucket of gap is effective to suppress the instability, and 2) The dependence of the strength of the instability on time is from the dependence on the vacuum pressure.

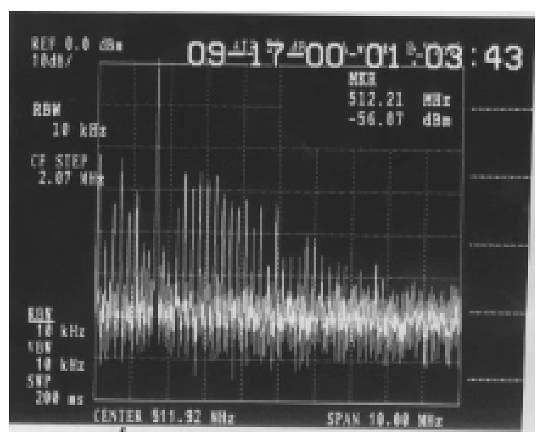

Figure 1: many vertical betatron lower sideband peaks were seen in the signal 2-3 which is shown in Fig. 2. These peaks are at $(m-\Delta\nu_y)f_0$, m=1,2,3,.. and f_0 is the revolution frequency. The frequency span is 10MHz and the highest peak is at RF acceleration frequency, 508.58MHz, and is residual signal which is not canceled completely by 180deg hybrid. This data was taken with 100mA full-fill beam hence harmonics of revolution frequency was not seen. This data was taken at the commissioning of long straight section and the worst situation for this instability.

2.1 Setup

Fig.2shows the setup for the measurement of the distribution of the amplitude of the vertical betatron motion in a bunch train. The signals from upper and lower button-type pick-up antennas is fed to 180deg. hybrid junction to cancel their carrier of RF acceleration frequency and extract the component of the amplitude modulation by betatron motion of the beam.
The part of the signal was cut-out by linear gate with the gate signal of which delay and width was controlled by a gate generator. The output signal was send to a spectrum analyzer. These signals were monitored by a oscilloscope. Using this setup, we can measure the position dependence of the amplitude of the betatron motion in a bunch train by changing the amount of delay. Typical data on the spectrum analyzer is shown in Fig. 3

The gate width was set to 30ns in this measurement. Smaller width is better for the detail timing measurement and for high-frequency multi-bunch mode but the sensitivity become smaller because of smaller signal power to the spectrum analyzer. The modes of the instability is rather low and is less than 10 MHz, we think that the gate width of 30ns is enough to observe this instability. To cancel the small fluctuation of the stored current, we normalized the betatron sideband peak height by the peak height of nearest peak of harmonics of revolution frequency.

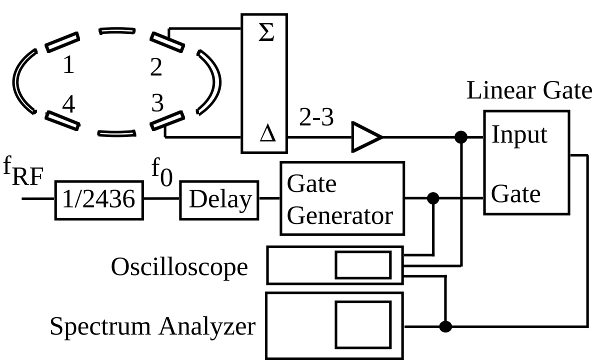

Figure 2: Experimental setup for measurement of position dependence of betatron oscillation amplitude. RF signal is divided to revolution frequency for a gate signal.

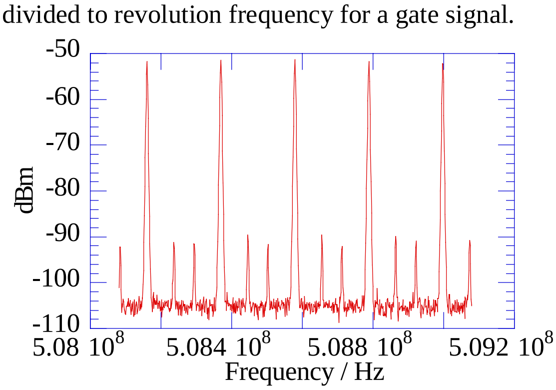

Figure 3: Typical data taken by spectrum analyzer. Higher peaks are harmonics of revolution frequency and lower peaks are vertical betatron sideband. Harmonic signal of revolution frequency should be canceled in 180deg hybrid however we had residual signal.

2.2 Gap width dependence

First, we stored the beam in one third of the ring, 812 RF buckets, by ~70mA. Then, after a gap of width 20ns, 36ns, 75ns and 120ns, the second train of the length 300ns was injected with its peak is the same as the first train. The RF acceleration frequency is 508.58MHz and the bunch spacing is 2ns.

The result is shown in Fig. 1. No betatron sideband is observed in the 2nd train with 120ns gap.

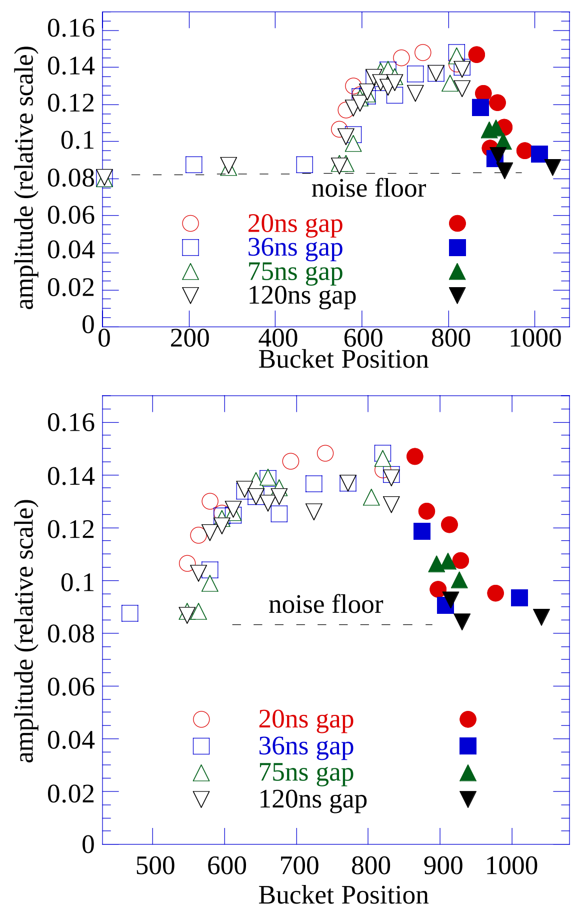

Figure 4. Betatron amplitude distribution in two bunch train with different gap width between them. Marks filled inside is the data for the 2nd train. Upper graphs shows The motion of whole bunches and lower graph shows expanded area where betatron amplitude was observed.

2.3 Vacuum Pressure Dependence

All bibliographical and web references should be numbered and listed at the end of the paper in a section called “References.” When referring to a reference in the text, place the corresponding reference number in square brackets [2].

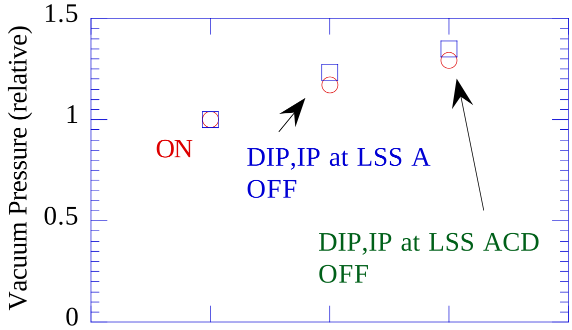

Figure 5: Vacuum pressure at measurement shown in Fig. 4.
Circle: averaged vacuum pressure at normal sections normalized to 4.4×10^{-8} Pa. Square: averaged vacuum pressure at long straight sections normalized to 9.6×10^{-8} Pa.

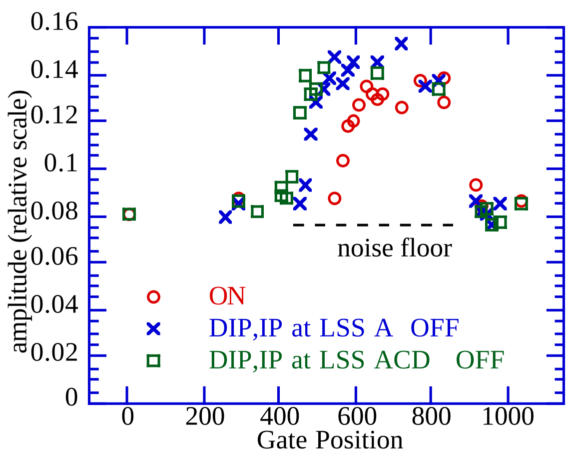

Figure 6: amplitude of betatron motion for different vacuum pressure. The 2nd train was stored after 120ns gap.

Circle: all vacuum pump were on., Cross: distributed ion pump and ion pumps at a long straight section A ware off. Square: adding Cross, ion pump at two long straight sections C, D were off.

3 CONCLUSION

After the installation of new chambers, we observed vertical coupled-bunch instability and it limits the filling pattern of the stored beam. The strength of this instability depends on the length of the bunch train and vacuum pressure. It can be suppressed by dividing long bunch train to shorter bunch trains with more than 100ns gap between them. The strength of the instability was reduced after several month from the installation of the new chambers.

4 REFERENCE

[1] “Chromaticity for Energy Spread Measurement and for Cure of Transverse Multi-Bunch Instability in the SPring-8 Storage Ring,” T. Nakamura, TPPH131, This conference.