OBSERVATION OF THE LONGITUDINAL BEAM OSCILLATION AT ATF-DR

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Abstract

The longitudinal beam oscillation was observed by using a streak camera at the high intensity multi-bunch operation of the ATF-DR. Two mode measurements were used for observing the behaviour with bunch by bunch measurement basis. The measurement results showed the possibility of the HOM of the RF cavity exciting the instability. This paper describes the measurement technique and discusses about the cure method of the oscillation.

INTRODUCTION

The longitudinal beam oscillation was observed at the high intensity multi-bunch operation of the Accelerator Test Facility Damping Ring (ATF-DR) in KEK. The multi-bunch operation at the ATF-DR was started since 2000. However, the beam storage was not so stable because of the beam loss at the injection. The injection loss was improved by adopting the RF gun, since Autumn 2002. The single train consists of twenty bunches with 2.8ns spacing, which can be changeable from one to twenty. The ATF-DR was designed for a maximum of five trains operation. The three trains of the multi-bunch beam can be stored stably. Four trains and five trains are not yet stored because of the effect of the pulse tail of the injection kicker. [1] The stored current already reached 60mA at the three trains multi-bunch, which is limited by the radiation safety regulation of the maximum power of the stored beam until Summer 2003. The limitation was refined from Autumn 2003. Minimizing the longitudinal beam oscillation is a significant issue for the ATF-DR at the high intensity multi-bunch operation.

The ceramic chamber of the injection kicker was suspected as the source of the oscillation, which had a narrow beam aperture, 14 mm diameter, and the shape formed a cavity like a dip. The temperature of the ceramic was heated up according to the stored current. [2] A conductor was inserted at the inside of the ceramic chamber to avoid exciting the electric field. However, there was no clear difference even after inserting the conductor. The simulation predicts that the cavity or the chamber which has a cavity like shape excite the oscillation. The estimated Q-value is not so high. [3]

MEASUREMENT

The hardware of the SR monitor including the streak camera is described in reference [4]. The streak camera(Hamamatsu 5650) is a two-dimensional streak camera which can observe the bunch length and the time trend.

Observation with a fast single scan mode of the streak camera

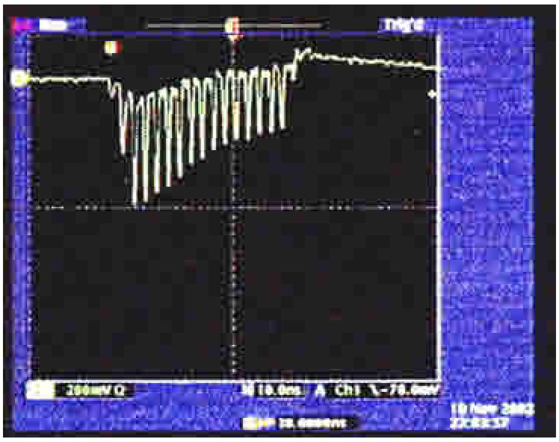

Fig. 1 bunch shape of the stored beam by a wall current monitor

Fig.1 shows the bunch current by a wall current monitor. Seventeen bunches were stored at this time. The total charge was 3.7x 10^10 electrons and the bunch charge was about 2.5x10^9 electrons. The streak camera image and the profile are shown in Fig. 2. Each image shows the same bunch with 8 ms interval. Fig. 2 (A) is the 1st bunch and (B) is the 4th bunch. The streak timing was synchronized with the revolution. If the beam circulates stably, the streak image should be shown at the same position. The 4th bunch was clearly unstable compare to the 1st bunch. The statistical data of the oscillation amplitude, 1σ of the amplitude distribution, of each bunch is plotted in Fig. 3. The amplitude of the oscillation of the succeeding bunches were clearly increased. The amplitude was also increased according to the beam intensity. The amplitude at the case of the 5x10^9 corresponded to 1.5x10^-4 of the energy spread. The oscillation seemed to come from the beam-induced instability from these results. The longitudinal oscillation makes the energy spread. Fig. 4 shows the energy spread, which is measured by the profile monitor at the extraction line. The scatter area assumed come from the longitudinal oscillation. The measurement agreed with the streak camera measurement.

The fast scan mode of the streak camera can observe the single bunch behaviour of the multi-bunch, however the sweep interval is limited up to ~1ms. The frequency component of the oscillation could not be observed in this mode.

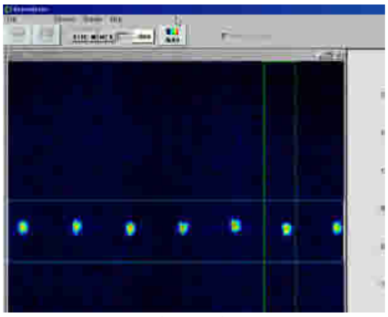

Fig. 2(A) The profile of the 1st bunch of the 17 bunches

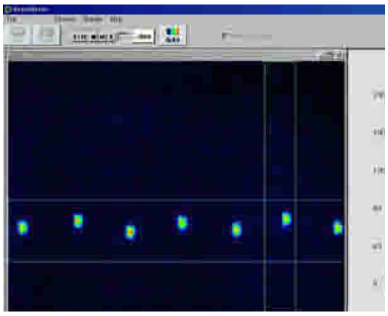

Fig. 2(B) The profile of the 4th bunch of the 17 bunches

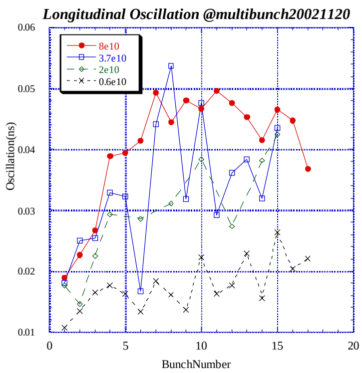

Fig. 3 The amplitude of the longitudinal oscillation at each bunch

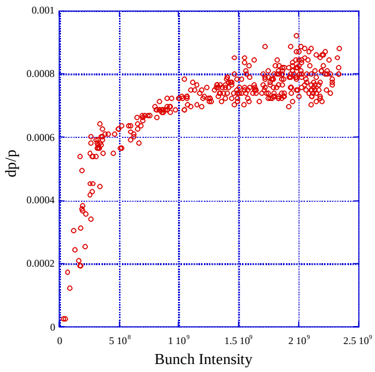

Fig. 4 The energy spread: measured at the extraction line beam profile monitor

Observation with a synchro-scan mode of the streak camera

The streak camera can change the sweep mode by changing the sweep unit. The synchro-scan mode is swept by the divided RF frequency, 89.25MHz, which is 1/8 of the 714MHz RF accelerating frequency. The beam profile is the projection of all of the bunches with this mode. Some of the examples are shown in Fig. 5. The two lines are mirror images of the same beam profile with the inversed form.

Frequency

The frequency of the longitudinal oscillation was the synchrotron frequency. The synchrotron frequency was written by the following equation,

$$f_s = \frac{1}{2\pi}\left(\omega_{rev}{}^2 \frac{h\eta_c eV_0 \cos\varphi_s}{2\pi\beta c\, p_0} \right)^{1/2}.$$

The synchrotron frequency changes with the square root of the accelerating voltage. Figs 5 A) and B) show the oscillations. The frequencies were changed according to the accelerating voltage. The measurements agreed with the calculation.

Damping phenomena

The streak camera could observe the damping phenomena of the oscillation. Figs 6(A) and (B) show the bunch profile in each time from the injection. The big dipole oscillation was damped with the time, however the small oscillation existed even after 400ms from injection.

Temperature of the cavity

The amplitude of the oscillation was changed with the season. We suspected the temperature of the RF cavity. If the dumping of the higher order mode (HOM) was not enough, there is a possibility of the oscillation, which is induced by the HOM of the RF cavity. The dumped cavity was designed for dumping the HOM in the cavity, however the data measured the dumping of the frequency up to a few GHz. There is a possibility that the HOM exists at more than a few GHz. [5]

We carried out the experiment at different temperatures of the cavity. The present system could not change the temperature of the cooling water of the cavity, arbitrarily. So we reduced the water flow of the cooling water and controlled the temperature by changing the RF power. The sweep frequency was changed in this measurement to observe the oscillation of each bunch. Figs 7(A) and (B) show the oscillation at the case of 24.3°C and 29.1°C, respectively. Each line shows the single-bunch profile of the multi-bunch. We could clearly observe the difference of the amplitude of the oscillation. The sweep frequency was changed from 89.25MHz to 95.2MHz in this measurement in order to observe individual bunch oscillation. The different amplitude was observed at each bunch and the phase was the same in Fig. 7(B). The bunch number was not yet identified.

Improving the water cooling system

From these results, we are now preparing the new cooling water system for the RF cavity, which can control the temperature from 15°C to 35°C. If the HOM of the RF cavity produce the oscillation, the dependence will be observed by the function of the cavity temperature. The more precise data will be taken by using the system

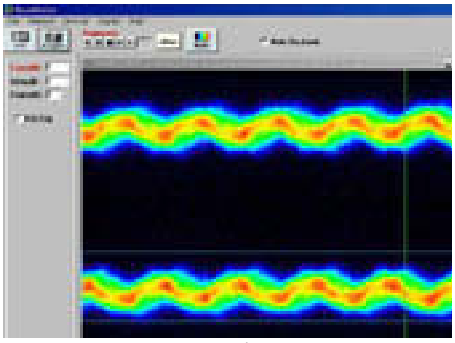

Fig. 5 A) Vc=300kV, f=10.4kHz

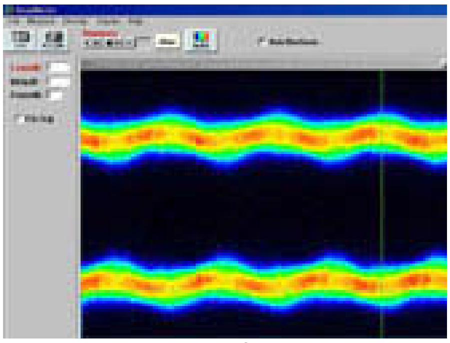

Fig. 5 B) Vc=150kV, f=7.14kHz

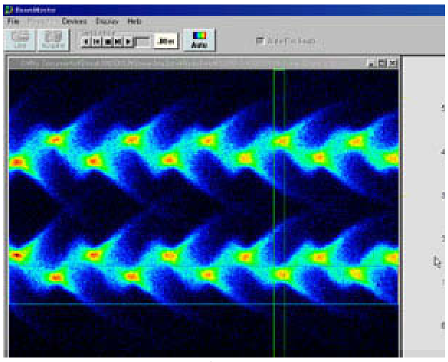

Fig. 6 A) 0.04ms after the injection

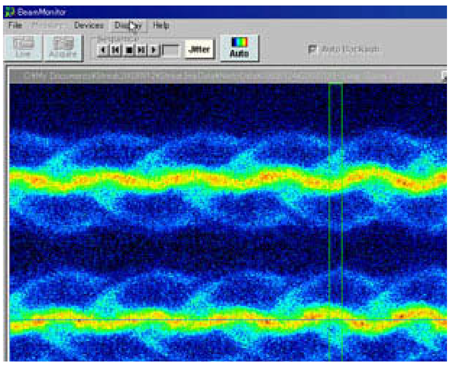

Fig. 6 B) 2ms after the injection

SUMMARY

The longitudinal beam oscillation was observed by using a streak camera. The measurement result showed the possibility of the HOM of the RF cavity exciting the instability. The detail of the oscillation source will be studied at the various temperatures by using the new cooling water system. The cure method of the oscillation will be found in these measurements.

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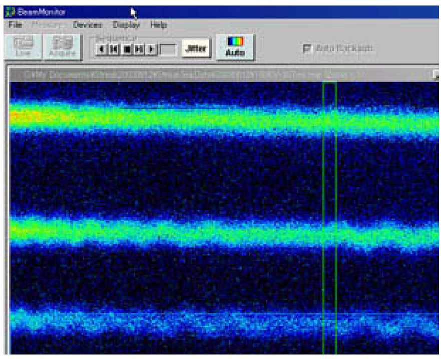

Fig. 7 A) 180kV, 24.3°C

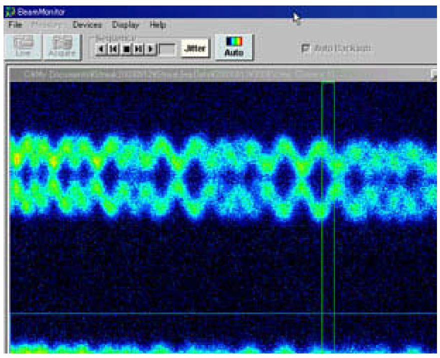

Fig. 7 B) 300kV, 29.1°C