An Observation of the Head-tail Stabilization by Difference Resonance

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Abstract

An anomalous phenomenon which was observed in SRRC, an 1.3 GeV third generation light source, will be discussed in this paper. When the transverse tunes are sitting at difference resonance, all sextupole magnets can be turn off without serious beam loss. It happened even at the beam current was higher than 120 mA. The detail observations and studies will be discussed.

1. INTRODUCTION

The head-tail instability[1] is a well known effect of the circular accelerators. In general, the natural chromaticities of circular accelerators is negative. Due to the negative chromaticity, the head-tail mode (transverse dipole mode m=1, longitudinal monopole mode l=0) will be unstable. To cure this type of instabilities, we have to tune the chromaticities to the positive values by introducing the sextupole magnets in the dispersive regions. The sextupole magnets, as a nonlinear device, will shrink down the dynamic aperture. That will in turn reduce the beam lifetime and may also restrict the injection efficiency. Therefore, people has been thinking to use other method to stabilize the head-tail instability, e.g., using Landau damping by octupole field. In the case of small beam current, several electron storage rings have been observed that the beam can survive at a slightly negative chromaticity. It was understood that the stabilization mechanisms were provided by the Landau damping effect due to ions and for high energy machine the radiation damping also helps. We observed in the storage ring of Taiwan Light Source(TLS) that for the same size of negative chromaticity when setting at the transverse tune difference resonance the survivable beam current is about a fact of 5 higher than that of the normal operation tune setting.

2. THE MULTI-BUNCH MODE OBSERVATIONS

When the 1.3 GeV storage ring of the TLS operated in multibunch mode, the filled bucket number is about 100 and a gap of 100 empty buckets is used for ion cleaning. For multibunch mode operation, when the beam current go beyond 150 mA, it became unstable. It was observed that there are two methods which will be able to quite down the beam. The first one is by setting transverse tunes at the difference resonance. Later, it was found that increase the chromaticities from the slightly positive to a larger positive values will be able to quite down the beam. The first method, we paid by increasing the vertical emittance. The second method, it was the beam life time that we loss, due to the smaller dynamic aperture. The second method is being used in the recent routine operation. While we were studying the second method, it was found that a beam current of more than 120 mA could still survive even when we set all of the current of the sextupole magnets to zero. The horizontal natural chromaticity is about -15.3 and the vertical natural chromaticity is about -7.1. The beam spectrum as shown in the Figure 1, we can see the large tune spread due to the large chromaticity values. Beside that, the spectrum is quite clean. The amount of the survival current will dependent on how do we decrease the current setting of the SF and SD families. It will also dependent how well the tunes sitting on the resonance. The smaller the SF and the SD currents the more stringent the second criteria will be.

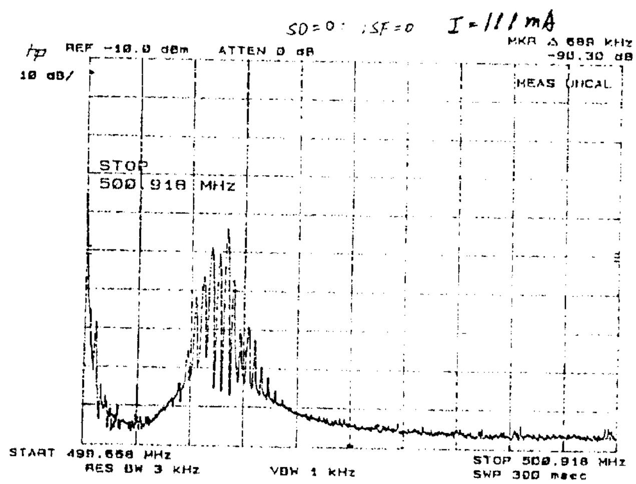

Fig. 1 The beam spectrum at the zero SF and SD current.

3. THE EXPERIMENTS

Because the head-tail effect is due to the broad band impedance, therefore, it is a single bunch effect. We want exclude the other effects, e.g. couple bunch instabilities and ion effects, while we are doing the experiments. It is why that lately most of the systematic observation was done in the single bunch mode.

What was observed in the multibunch mode about the head-tail stabilization was observed in the single bunch mode as we expected. The survival current is still very strongly dependent on the process which we decreased the SF and the SD strength. It was understood that because when we changed the SF strength , we will change both the chromaticity x and the chromaticity y. In order to produce a reproducible result, we created two combination knobs. Each one of them will change both the strength of SD and SF in a certain ratio such that one of the two knobs will only change the chromaticity x and the other one will only change the chromaticity y. Combining the chromaticity x knob and the chromaticity y knob, we furthermore created another type of knobs, the chromaticities knob, which will change both the chromaticity x and the chromaticity y in an assigned ratio. Figure 2 and figure 3 are two sets of the typical results done by the chromaticities knob. In this case, we set the ratio of the chromaticity x and the chromaticity y is 2:1. Figure 2 is the results for normal operation tune settings, i.e. tune x = 7.18 and tune y = 4.13. Figure 3 is the results for the difference resonance, i.e. tune x = 7.136 and tune y = 4.136. We see that while decreasing the chromaticities the survival current stepping down That means that for a certain value of chromaticities the beam became unstable and loss a chunk of beam current and stable for a while. Because we kept decreasing the chromaticities eventually the beam will became unstable again and loss another chunk of beam current. The same process reoccurred. The beam life time (around 400 mins. to 1000 mins.) while the beam is stable, is much longer than the experimental time (less than 10 mins.) therefore the beam loss due to the finite beam life time is not a concern. It is obvious that for the same chromaticities the survival current in the normal tune settings is much less than that of the difference resonance tune settings. Please note that in order to show the stepping type beam current change, we used different horizontal scale in figure 2.

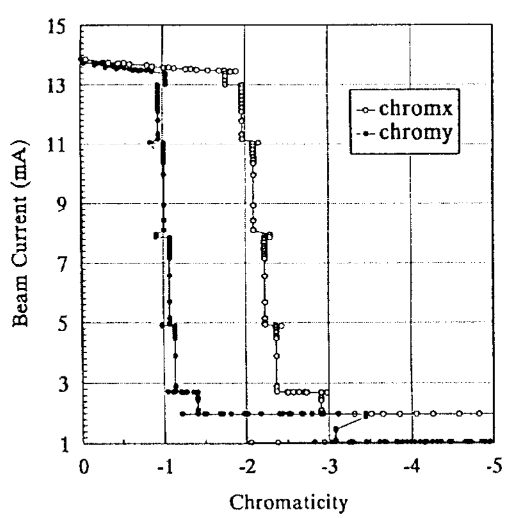

Fig. 2 The chromaticities knob vs. survival beam current for the case of the normal tune setting.

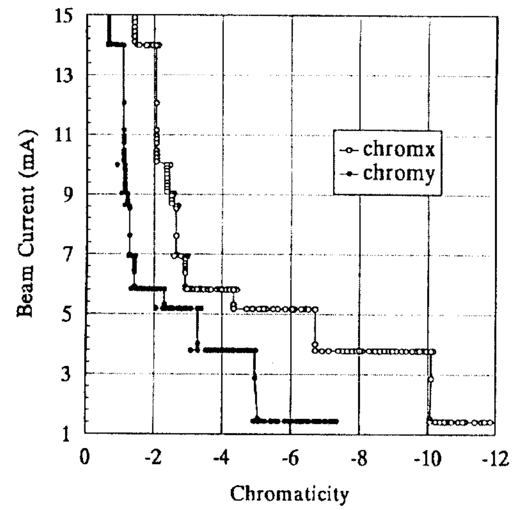

Fig. 3 The chromaticities knob vs. survival beam current for the case of the difference resonance tune setting.

We did the same experiment for the chromaticities knob with the ratio of the chromaticity x and the chromaticity y being 1:0.168. For each ratio value, we did both case of the normal tune settings and the difference resonance tune settings and we did twice for each run. The results are shown in figure 4. The data of the normal tune settings is concentrated in the lower left corner. For the four upper right curves are for the difference resonance tune settings. The two solid line curves of the four are the case of the ratio of the chromaticity x and the chromaticity y being 2:1. The two dot line curves are the case of the ratio of the chromaticity x and the chromaticity y being 1:0.168.

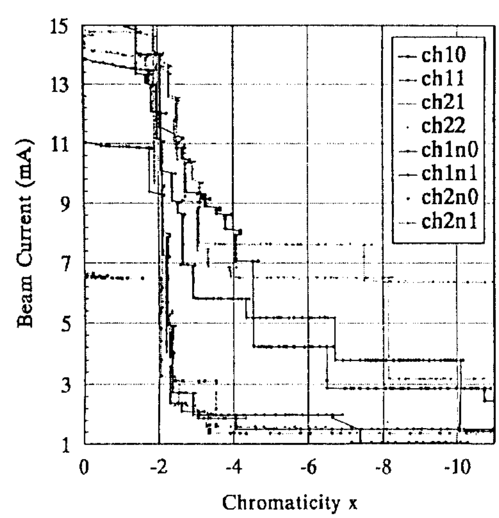

Fig. 4 The chromaticity x vs. survival beam current (please see the text for the conditions for different curves)

4. DISCUSSIONS

The theory of this phenomenon is not clear yet. More experiments trying to clarify some ambiguous points are under going on.

5. ACKNOWLEDGMENT

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6. REFERENCE

[1] C. Pellegrini, *Il Nuovo Cimento* **64A**, No. 2, 447 (1969) and M. Sends, SLAC Report TN-69-8 (1969).