STABILIZATION OF THE SPECTRAL INTENSITY FLUCTUATIONS WITH THE HIGHER ORDER MODE FREQUENCY TUNERS

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Abstract

A strong excitation of the longitudinal coupled-bunch instabilities, which is suspected to be driven by the TM_{011}-like mode of the DORIS-I cavities, was observed at the higher electron beam current in the storage ring of SRRC. Such instability leaded to heavy fluctuations of the photon beam intensity in the horizontal plane and therefore restricted the maximal useful beam current for the user experiments. This restriction has been released by replacing the damping antennae with the additional tuners. Here, we report our experiences after one-year routine operations of the main RF cavities with the second tuners at SRRC.

1 INTRODUCTION

After the SRRC storage ring was successful commissioning in 1993, a strong longitudinal coupled-bunch oscillation was observed from time to time. It started usually with the beam current of about 180 mA and disappeared when the current decayed. This strong beam-cavity interaction resulted in a blow up of the transverse beam size and leaded to heavy fluctuations of the spectral intensity. This restricted the maximal useful beam current. The TM_{011}-like mode of the DORIS-I cavity was suspected to be the driving source. In the spring shutdown of 1996, the damping antennae were replaced by the additional plunger tuners, i.e., the second tuners, to de-tune the exciting longitudinal cavity mode far away from the synchrotron oscillation sideband. After this re-arrangement, the strong beam-cavity interaction is successfully prevented and now the storage ring is routinely operated with the beam current up to 240 mA with spectral intensity fluctuation less than 0.5%. Here, we report our experience after one-year routine operation of the main RF cavities with the second tuners at SRRC.

2 HIGHER ORDER MODE FREQUENCY TUNER

Two DORIS-I cavities were installed in the storage ring of SRRC as main RF cavities to supply the beam energy loss due to the synchrotron radiation, etc. Each cavity has three main-ports: The first one was mounted with a plunger tuner to compensate for the drift of the fundamental mode frequency due to the fluctuations of the cavity cooling water temperature as well as the beam loading. The second port has been connected to the coaxial coupler for the input of the RF power from the klystron. The third port was originally equipped with a DESY-type damping antenna[1] to reduce the driving impedance of the cavity higher order modes by degradation of those quality factors.

With damping antenna, the ohmic quality factor of the TM_{011}-like mode can be dramatically reduced from 26000 to 2300. However, this might be still not lower enough to avoid excitation of strong longitudinal coupled-bunch oscillation at higher beam current.

As mentioned before, such exciting interaction resulted in a brow up of the transverse beam size, and leaded to heavy fluctuations of the photon beam intensity.

Therefore, the maximal useful stored beam current was restricted. Moreover, the damped cavity higher order modes have a wide resonance band, which enhances the interaction probability.

It is practically difficult to de-tune such resonance only by the adjustment of the cavity cooling water temperature. It has been shown that the TM_{011}-like mode can be de-tuned by the second tuner far away from the synchrotron side-band effectively, and the instability may then be avoided. Without damping antenna, the resonance band of the cavity higher order modes become narrow, and its resonance frequency can be easily manipulated by the variation of the cavity cooling water temperature. A combination of these two approaches enforces the possibility to avoid the instability driven by the cavity TM_{011}-like mode, and the temperature regulation capability of the cooling system can be relaxed. The resonance frequency of the TM_{011}-like mode of the DORIS-I cavity as a function of the second tuner position as well as the cavity cooling water temperature is shown in Fig. 1.

The replacement of the damping antennae by the second tuners was performed in the spring of 1996, following a half-year cold test on the DORIS-I cavity with two plunger tuners for the understanding of its effects on the higher-order modes. In our application, the second tuner works like a manipulator of the cavity higher-order mode (HOM) resonance frequencies. It is therefore named as HOM frequency tuner at SRRC. The first tuner was properly re-positioned such that the resonance frequency of the cavity fundamental mode to be of 499.666 MHz, the accelerating frequency of the SRRC storage ring.

If the electron beam is stored with a uniform filling pattern (and without any empty bucket) in the storage ring, the harmonics of the accelerating frequency (499.666 MHz for SRRC) will be the only spectral lines observable from the beam spectrum, providing that there is not any exciting instability. Obviously, this can be used to identify the existence of the coupled-bunch oscillations.

A beam spectrum of a quasi-uniform filling pattern (and no empty bucket) is shown in Fig. 2. In the meantime, the second tuners were adjusted to the so-called optimal

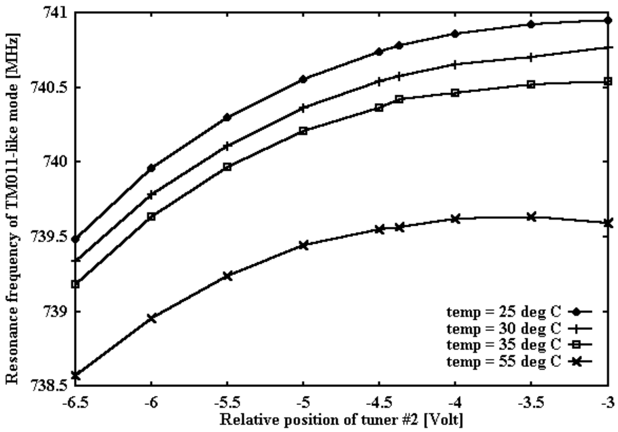

Figure 1: Resonance frequency of the TM_{011}-like mode of the DORIS-I cavity as a function of the second tuner position (measured in unit of volt) as well as the cavity cooling water temperature. The first tuner was properly repositioned such that the resonance frequency of the cavity fundamental mode was kept to be of 499.666 MHz, which was the accelerating frequency of the SRRC storage ring.

positions in both cavities with which the photon intensity fluctuations was minimal and less than 0.5%.

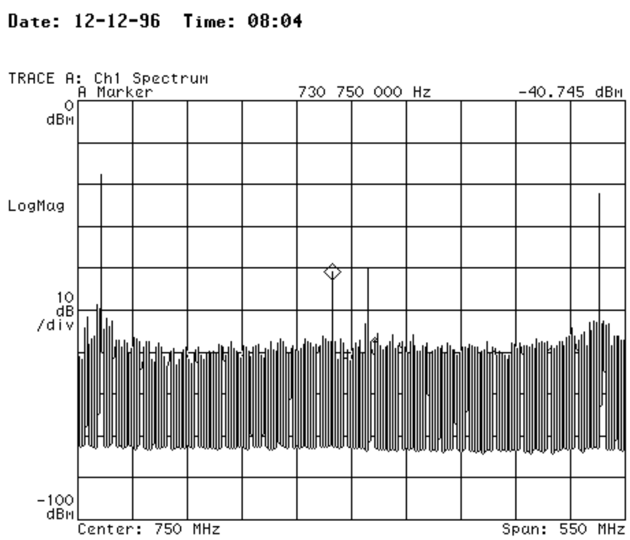

Figure 2: Beam spectrum for a quasi-uniform filling pattern. The second tuner is adjusted to an optimal position such that the spectral intensity fluctuations to be minimal.

The spectral lines had a frequency of 732.01MHz-28.750kHz (n=93) and its alias of 766.98625 MHz + 28.750 kHz (n=107), which were insensitive to the movement of the second tuner. The normalized oscillation amplitude was of about -20 dB or corresponding to 0.2^o phase jitters, which seemed to be driven by the cavity TM110-like mode (767-768MHz).

It has been verified to be insensitive to the tuner movement in our cold test.

3 OBSERVATION

In the operation of the cavity with the second tuner, this strong beam-cavity interaction can even be excited at lower beam current by tuning the resonance frequency of the driving mode closer to the synchrotron side-band.

This provides us a convenient and reproducible way to understand the instability mechanism in the linear and non-linear regime by exciting the beam-cavity interaction with mechanically adjustable coupling strength/exciting level.

As shown in Fig. 3, the oscillation amplitude (in dB) for the synchrotron upper dipole mode of $n = 97$ (742.0035 MHz) is strongly dependent on the second tuner position (the tuner position is measured in Volt, and one volt drop is about 1 cm tuner movement).

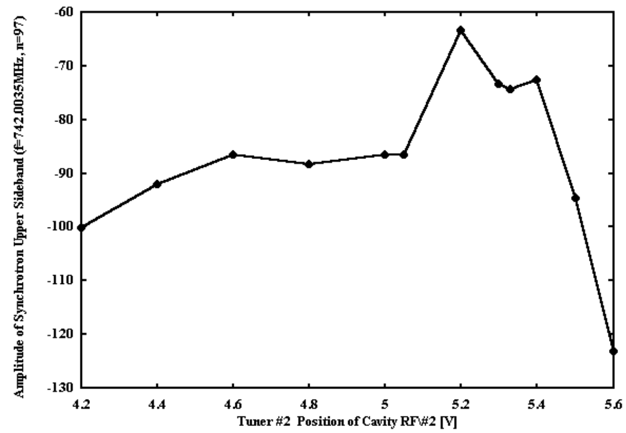

Figure 3: Oscillation amplitude (in dB) of the synchrotron upper dipole mode of $n = 97$ (742.0035 MHz) as a function of the second tuner position of cavity RF #1.

A strong beam-cavity interaction can be identified as the second tuner of the RF#1 cavity to be tuned close to the position of 5.2-5.4 Volt.

The corresponding beam spectrum is shown in Fig. 4 and 5. Obviously, the synchrotron tune spread is broadened, as shown in Fig. 5.

As shown in Fig. 6, the oscillation amplitude was quasi-periodically varied in the time domain, while its growth-rate remains almost the same.

From Fig. 6, the deduced growth rate was of about 0.35 msec, which is close to the theoretical value of 0.4 msec for the TM011-like mode[2].

4 DISCUSSION

In the operation of the SRRC main RF cavities with the second tuners, the strong beam-cavity interaction likely driving by the cavity TM_{011}-like mode was successfully prevented and the photon intensity fluctuations less than 0.5% have been achieved.

Through it may be practically difficult to prevent all of the longitudinal coupled-bunch instabilities only by the operation of the cavity with the second tuner, the maximal

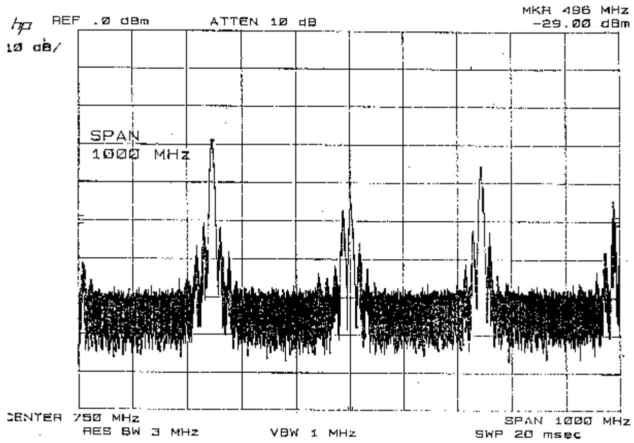

Figure 4: Beam spectrum when the second tuner of the cavity RF#1 was located close to the on-resonance position (tuner #2 position is 5.3 Volt).

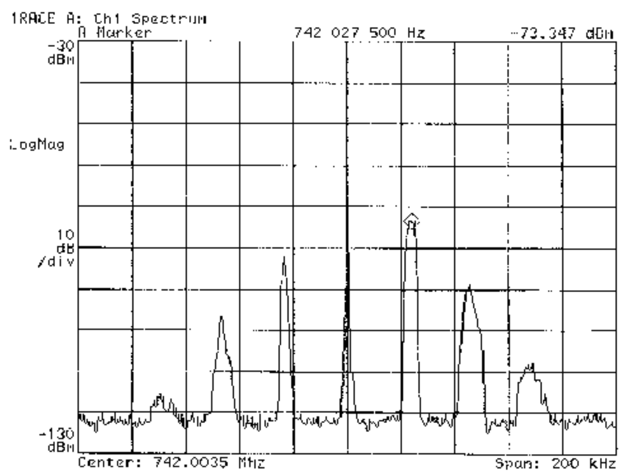

Figure 5: Zoom-in spectrum of Fig. 4.

coupling impedance of the storage ring can be effectively reduced by the optimization of the second tuners position.

Therefore, it will help to decrease the required operating gain of the wide-band high-power driver amplifier for the broad-band longitudinal feedback system. Moreover, such adjustable mechanism provides extra freedom for systematic study of the phenomena of the coupled-bunch instabilities. However, the possible damage of the second tuner due to the cavity HOM heating may be a critical issue and will be numerically studied in more detail in the future.

5 ACKNOWLEDGEMENTS

We benefits the discussions with Dr. E. Weihreter (BESSY II). This work was supported by the National Science Council of Taiwan under contract No. of NSC 86-2613-M-213-003.

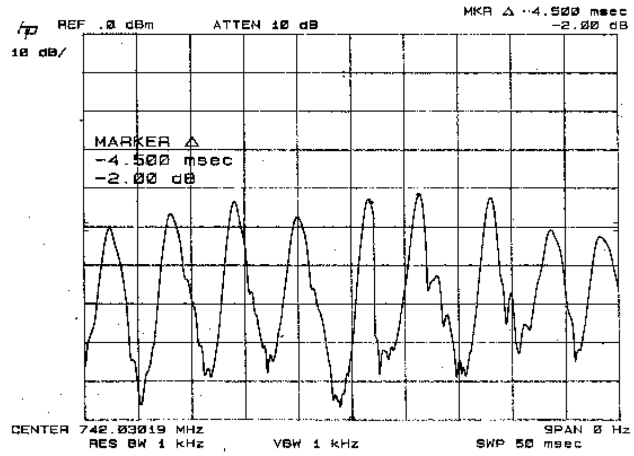

Figure 6: Quasi-periodical variation of the oscillation amplitude of the synchrotron upper dipole mode of $n = 97$ (742.03019 MHz) as a function of time.

6 REFERENCES

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