SUPPRESSION OF THE TRANSVERSE OSCILLATION IN THE SRRC STORAGE RING BY RF KNOCKOUT METHOD

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Abstract

Transverse oscillations are observed in the SRRC storage ring as the empty filling gap or the chromaticity is not big enough. The source of transverse oscillations are mostly coming from ions. From experimental evidence the beam quality will be improved as transverse oscillation is suppressed. The RF knockout method is employed to cure the transverse oscillations by shaking at the frequency of betatron sideband. The details of the shaking and the improvement on beam quality are discussed as RF knockout method is applied.

I. INTRODUCTION

The SRRC storage ring is dedicated for synchrotron radiation from 1.3GeV electrons. It is routinely operated at 200mA for the users. The vacuum pressure of this routine operation condition is around 2 ntorr. Since the commissioning of storage ring, transverse oscillation of the electron beam has been observed. The behavior of this oscillation is coherent. Figure 1 shows the spontaneous peaks in spectrum analyzer for both transverse planes. It is clear the first harmonics (dipole mode) of the vertical is much stronger than the others and in most cases only this peak shows up. It is also found frequency of the first harmonics for both transverse planes coincide with or is very close to the betatron tune respectively. Synchrotron satellite peaks also show up in the spectrum.

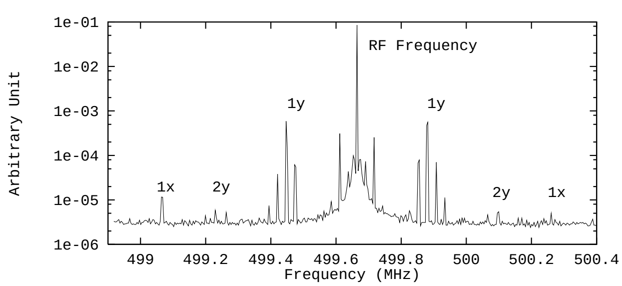

Figure 1. Transverse oscillation spectrum

After a series study the transverse oscillation is found to be cured by leaving a big enough empty gap or by applying strong enough chromaticity. The vacuum pressure is also found to be a critical parameter for this oscillation. The spontaneous peak can be generated by the high vacuum pressure, 10 ntorr locally will produce vertical peak and higher vacuum pressure will in additional excite horizontal peak. During the commissioning of 1.8 tesla wiggler at February this year, a new chamber was installed in the wiggler section and the local pressure is increased up to 100 ntorr with current of 20mA. Drastic transverse oscillation was found in this high vacuum. It is gradually reduced as the vacuum is continuously cleaned by synchrotron radiation. This indicates the transverse oscillation is mostly generated by ions and some of its effect has been studied[1]. At present the beam is stored with a big enough empty gap and strong enough chromaticity is also applied to minimize and to damp the transverse oscillation. While stronger chromaticity means larger nonlinear field on the beam, which will reduce the dynamic aperture and lifetime. If the chromaticity increased from zero to +3, the reduction of lifetime is around three hours. This fact motivates the cleaning study for ions by RF knockout method.

In this paper we approach the study from experimental point of view. The betatron sideband frequency is chosen for the shaking frequency. The effectiveness of the shaking is discussed. Improvements of the beam quality are also shown in lifetime, beam size and in the suppression of transverse oscillation.

II. THE EXPERIMENTAL SETUP

As ions are trapped, the electron beam and the ions interact with each other and two beam instability appears[2,3]. The transverse oscillation is excited by ion kick and the beam performance is then deteriorated[4,5,6,7]. As ion oscillation amplitude is shaken to larger and goes out of trapping, its effect on the beam will be reduced and minimized. This is the sprite of ion shaking.

In this paper, details of the ion cleaning study by RF knockout method are described. The shaking field is applied from Anritsu MG 3601A signal generator to the excitation electrode. Response signal from the electron beam is obtained from stripline and analyzed by HP8568B spectrum analyzer. HP 34401 DVM converts the spectrum analyzer signal to a PC station. IEEE-488 cable is used for the connection between experimental devices. The shaking and the data acquiring process are program controlled in the PC station. Figure 2 shows the setup for this experiment.

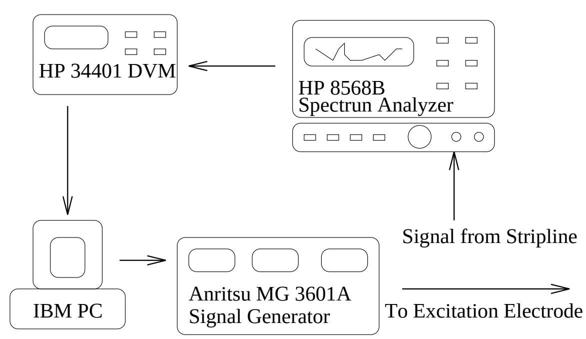

Figure 2. Experimental setup for the shaking and data acquisition system

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III. THE EXPERIMENTAL RESULTS

Theoretically ions can be driven to resonance by shaking its oscillation frequency directly. It is also possible to shake ions by shaking the betatron sideband of the electron beam[8,9] indirectly. The shaking frequency, controlled by PC station, can be swept in a desired range with chosen step. Since vertical dipole mode is the most harmful and obvious one of the instability, this peak was picked up in the spectrum analyzer with zero span to observe the shaking effectiveness as the shaking frequency is swept through.

Since single charged hydrogen molecule ion contributes about 93% in the residual gas and could play an important role in ion effect[1], hydrogen oscillation frequency of around 34MHz at 200mA was applied at the beginning. While no effective improvement was found. The shaking effectiveness is then checked by sweeping from 0.1 to 36MHz with step size of 500 or 700Hz. It is found some of the betatron sideband frequency can suppress the vertical dipole mode. The effective range for the horizontal is from 6 to 20MHz and is not obvious for the rest frequency. The behavior in vertical is much strange. Enhancement of the spontaneous peak has been observed with the application of vertical betatron sideband frequency from 0.1 to 7MHz. As the sweeping frequency goes up, the suppression ability shows up gradually. In the range of 7 to 13MHz the vertical sideband enhances the spontaneous peak first and then suppresses it. For the frequency of 13 to 36MHz, suppression on the spontaneous peaks is obvious.

To check more detail on shaking effectiveness, the beam response signal is input into HP89440A spectrum analyzer instead of HP8568B with a wide enough span to take all of the horizontal and vertical spontaneous peaks. Since the HP89440A has the spectrogram function, it can record the time information of the spectrum during shaking. There is a clear suppression on all of the spontaneous peaks as the effective betatron sideband applied, which indicates the effectiveness of shaking. Since effective frequency is always located at betatron sideband in the horizontal or the vertical in some range, it indicates the effective shaking is shaking beam process indirectly.

The next step is to investigate the detail behavior of the spontaneous peak as effective sideband frequency is applied. The frequency step of the shaking is down to below 50Hz in this case, usually 14Hz frequency step is used. The shaking results for one of the horizontal betatron sideband is shown in figure 3 in which the vertical dipole mode spectrum is suppressed as the frequency of around 11.9MHz is applied. The effective bandwidth for this frequency is around 2KHz.

Suppression ability for the vertical betatron sideband are also shown in figure 4 as the frequency applied around 32.69 and 32.26MHz, which are the fast and slow wave of one high harmonic of the revolution frequency. From what shown in figure 4, the effective bandwidth of around 4KHz is wider than the horizontal. However there is a small range of 1.5KHz within which the vertical dipole mode is not fully suppressed. The feature of the vertical dipole mode not fully suppressed is more obvious for the slow wave. This indicates the shaking ability of fast wave vertical betatron sideband is more effective than the slow one, which can be also found in other literatures[9,10,11]. The effective shaking pattern for the fast and slow wave seems having mirror symmetry w.r.t. one high harmonic of the revolution frequency. Since the effective bandwidth for both transverse betatron sideband is larger than 2KHz, the previous searching of effective frequency from 0.1 to 36MHz with the step of 500 or 700Hz should not lost any information.

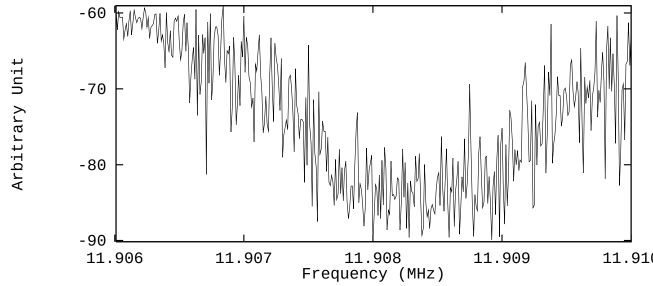

Figure 3. Suppression of vertical dipole mode by horizontal betatron sideband frequency.

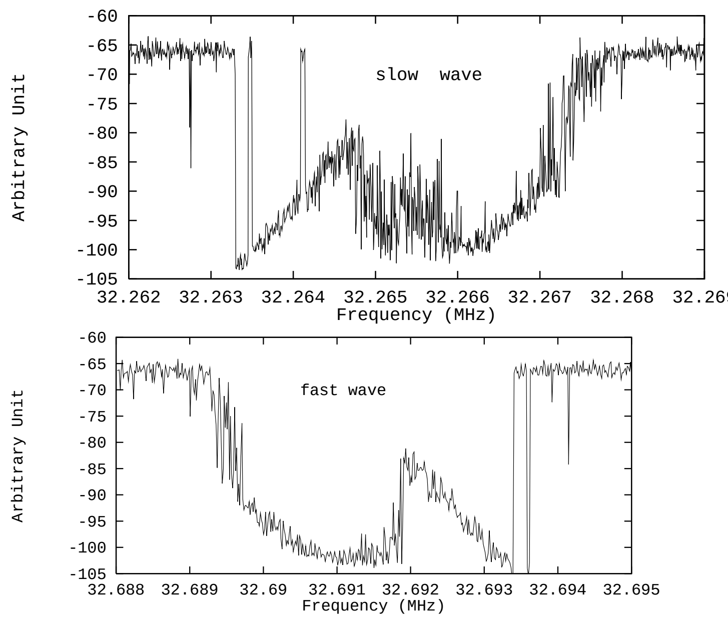

Figure 4. Suppression of vertical dipole mode by vertical betatron sideband frequency

As the effective frequency was found out, the improvement on the beam is also investigated. The suppression on the transverse oscillation indicates the minimalization of ion effect on the beam. The improvement reveals in the increasing of beam lifetime, the reduction of beam size (emittance) and the stabilization of photon beam etc. The lifetime of the SRRC storage ring is dominated by Touschek effect. As transverse oscillation happens, the beam size dilutes, which results to a bigger lifetime. The lifetime can be larger than 25 hours at the zero chromaticity in this deteriorated performance. At present user run, strong chromaticity was applied to damp transverse oscillation. The beam size is around one thirds of the diluted one, which increases the Touschek scattering process within bunches and reduces the lifetime. As effective betatron sideband was applied to suppress the transverse oscillation, the reduction of the beam size is also found. While there could have an increasing of beam lifetime instead of reduction. The lifetime increasement is around 2 hours, which proves the benefit of this method.

When the shaking is applied as the machine operated at strong chromaticity, i.e the transverse oscillation has been damped, the improvement on lifetime is not obvious. Figure 5 shows the image of the synchrotron light from one of the photon beamline, which can be traced back to get the beam size information at the source point. It is clear the photon beam size is diluted as the transverse oscillation occurs and the improvement is also found if strong chromaticity or effective shaking frequency applied.

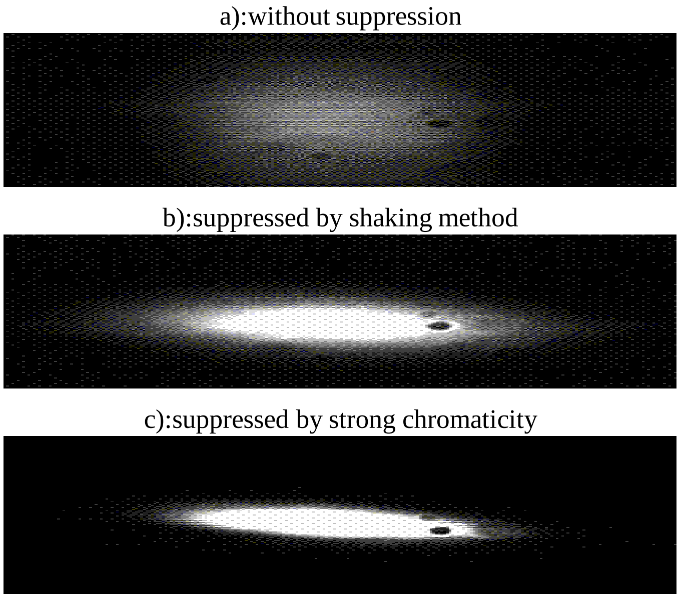

Figure 5. Photon beam size with and without suppression with abscissa the horizontal size and ordinate the vertical size in arbitrary uint

Though the shaking method can suppress transverse instability from ions and increases the lifetime instead of decreasing, it also has difficulty during application, i.e the lock on of resonance frequency. As ions are shaken to larger amplitude its resonance frequency is decreasing[9,10,11,12] which makes the shaking frequency out of lock. In this case the transverse instability comes in again.

IV. CONCLUSION

The transverse oscillation caused by the ions deteriorate the beam performance in many aspects. At least three spontaneous peaks were found among which the vertical dipole mode is the most harmful and obvious one of this instability. The SRRC storage ring is now operated with a big enough empty gap and with a strong chromaticity to damp the oscillation. While a reduction of the lifetime is found as strong chromaticity is applied. The RF knockout method is also possible to clean the trapped ions from electron beam and to suppress the transverse oscillation as effective horizontal or vertical betatron sideband frequency applied. The effective range was searched from 0.1 to 36MHz and it was found has obvious effect from 6 to 20MHz for the horizontal. Vertical effective range is from 13 to 36MHz. The effective bandwidth for the horizontal is around 2KHz and it is wider for the vertical. However there is a 1.5KHz range for the vertical, within which the vertical dipole mode is not fully suppressed. It is also found the vertical fast wave sideband is more effective than the slow one. The beam lifetime could be increased for around 2 hours and the beam size (emittance) is reduced as the proper frequency applied. The pulsation of the beam size is basically canceled and the photon beam of the synchrotron radiation is stabilized. If the shaking frequency is out of lock, the instability could appear again. From the experimental results the RF knockout shaking beam method basically can cure the instability coming from ions. While lock on of the shaking frequency with the ion resonance becomes a critical issue in practical application.

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