IMPROVEMENT OF TUNE MEASUREMENT SYSTEM AT SIAM PHOTON SOURCE

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Abstract

A new tune measurement system was recently developed and implemented at Siam Photon Source (SPS) for both the booster synchrotron and the 1.2 GeV electron storage ring. A new electronic module was installed at the SPS booster for collecting the turn-by-turn signal generated when the beam was excited with white noise and fast kicker. The beam excitation was carefully studied in order to determine the optimum beam response. With this system we observed the variation of the tune during energy ramping. The measurement provides information needed to optimize the working tune and to keep it constant. At the SPS storage ring, the excitation signal was changed from swept frequency signal to frequency modulation (FM) signal to reduce the measurement time. Details of the instrumentation setup and its performance will be presented in this report.

INTRODUCTION

The SPS operates a 1.2 GeV electron storage ring to produce synchrotron radiation in a wide energy range, from infrared to hard X-ray. The SPS booster ramps energy of electrons from 40 MeV to 1 GeV in 660 ms before they are transported to the storage ring. The storage ring then further ramps electron energy up from 1 GeV to 1.2 GeV. The maximum stored beam current is 150 mA. This method of electron beam injection previously took ~ 30 minutes. To cut down the number of steps and reduce the injection time, full energy injection system will be set up. The booster will ramp electron energy from 40 MeV to 1.2 GeV before injecting electrons to the storage ring. Therefore, energy ramping in the storage ring will not be required.

To achieve this, a new ramping pattern needs to be applied. Maximum current of the booster dipole magnets will increase from 1300 A to 1700 A and the current pattern of quadrupole magnets will have to change correspondingly. Since all the booster magnets approaches saturation after reaching the energy of 1 GeV, the current patterns of the quadrupole and dipole magnets are not linearly correlated and cannot be obtained from calculation. Therefore, the betatron tune needs to be measured and kept constant during energy ramping [1-3].

The tune measurement system has been set up at the SPS booster to track the tune shift during commissioning of the new pattern. Libera SPARK module was used to collect the turn-by-turn data from button-type Beam Position Monitors (BPM). At the 1.2 GeV electron storage ring, a new tune measurement system was also developed from the old system that used swept frequency signal to excite the beam. The drawback of this excitation signal was the measurement time which was quite long (10-30 seconds per measurement). The excitation was therefore changed to FM signal for faster measurement.

BOOSTER

Layout of the tune measurement system at the SPS booster is illustrated in Fig.1. The system has two subsystems: the excitation system and the signal detection system, which work together synchronously.

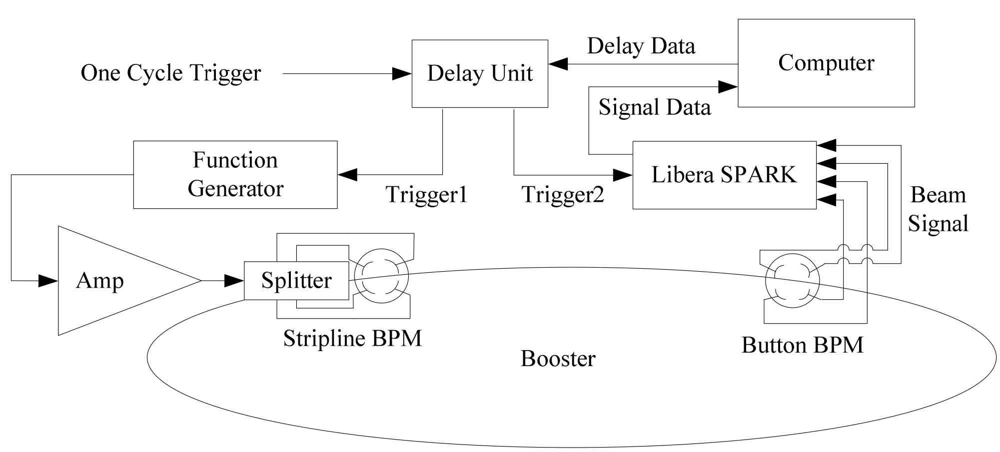

Figure 1: Layout of the tune measurement system at the SPS booster.

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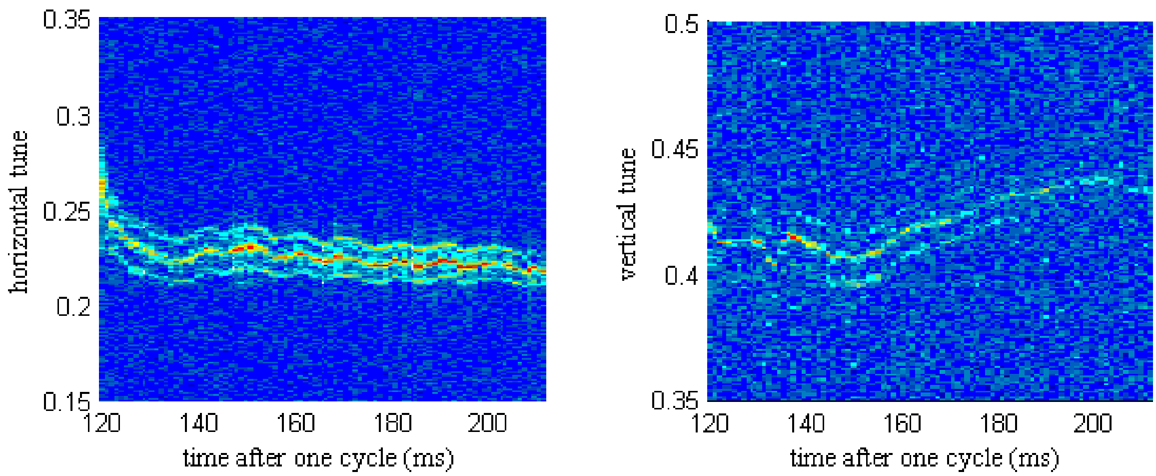

Figure 2: FFT of the signal from BPM showing horizontal tune (left) and vertical tune (right) at the injection point in the booster. Electrons were injected into the booster at 119.5 ms after one cycle trigger.

The tune excitation system consists of a function generator (Agilent 33250A), a 150W rf power amplifier (ENI A150) and a stripline which was used as a kicker. The function generator was used to generate white noise signal with 0 to 3.4 MHz bandwidth. The signal was amplified before being sent to the stripline. In order to excite the whole ramping, the signal amplitude should be increased with the electron energy [1]. However, additional instruments will be required. A workaround for this requirement is to use excitation signal with constant amplitude for one measurement, and excite it before collecting the data. The tune can be measured in approximately 10 ms for one measurement. The next measurements at higher energies are performed with the use of delay unit since it is possible to do only one measurement per one cycle of acceleration. Betatron tune of the whole ramping process is finally constructed from each of these measurements.

The signal detection system consists of a four-button BPM and a Libera SPARK module. The button BPM was used to detect the beam signal and send it to Libera SPARK for data collection. MATLAB routine was used to analyse the data by finding the bunch-by-bunch data and performing Fast Fourier Transform (FFT). Figure 2 shows averaged FFT signal of all bunches when electrons were injected into the booster. The horizontal and vertical tunes can be clearly seen with the resolution of 10^{-3}, which is sufficient for operation. However, the vertical tune cannot be seen after around 500 ms after injection. This is probably because the power of the excitation signal is not high enough, or it may be because the BPM probe was located where the vertical betatron tune is low. Therefore, fast kicker pulse is also used with white noise to measure the tune at higher energy. Using this measurement, the horizontal and vertical tunes can be adjusted to find a new, optimized operating point that provides higher beam current. This was successfully done without any beam loss during energy ramping.

STORAGE RING

The tune measurement system at the SPS storage ring has undergone a minor modification. Layout of the system is illustrated in Fig.3. It should be noted that this system is not a turn-by-turn measurement setup. Real-time spectrum analyser is used to find the tune. The old measurement system used swept frequency signal to excite the stored beam through a stripline. Each measurement took 10-30 seconds, resulted in a long machine study time where the tune measurements are usually involved. FM signal (as shown in Fig. 4) is therefore used instead of the swept frequency signal to improve the measurement speed.

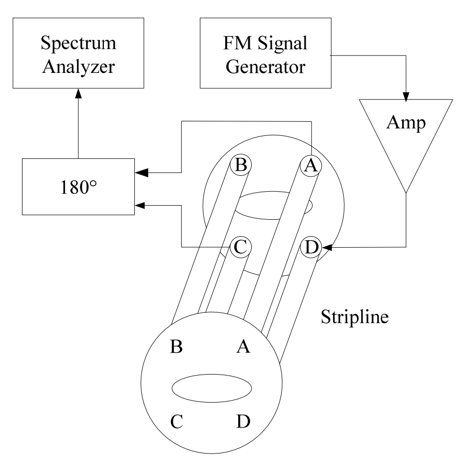

Figure 3: Layout of the tune measurement system at the SPS storage ring.

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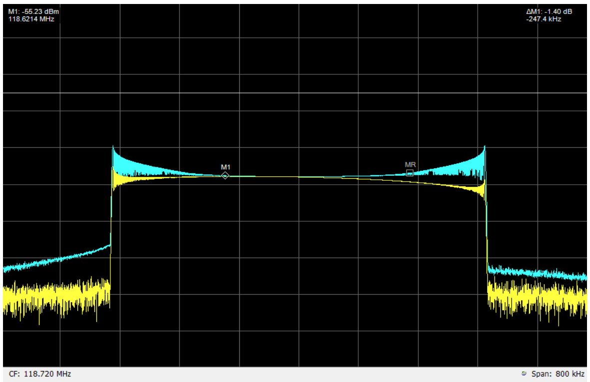

Figure 4: FM signal on spectroscope in real-time mode (yellow) and max hold mode (blue). The center frequency is 118.79 MHz with 500 kHz span.

The FM signal with 118.79 MHz center frequency is created by a signal generator (ROHDE&SCHWARZ SMC100A). The frequency deviation is around 500-800 kHz. The signal is sent to a 300W rf power amplifier (ENI A300) and then to one line (D) of the stripline. Two other lines in diagonal (A and C) were used for data collection of the beam signal. The signal from A and C were combined together with 180° phase difference using a hybrid coupler. The summed signal was then sent to the real-time spectrum analyser (TEKTRONIX RSA5103A). This setup is capable of measuring the betatron tunes with 10^{-3} resolution.

The result of tune measurement using FM signal is presented in Fig. 5. The horizontal and vertical tunes could be measured in real time and the resolution is good enough for operation and machine study.

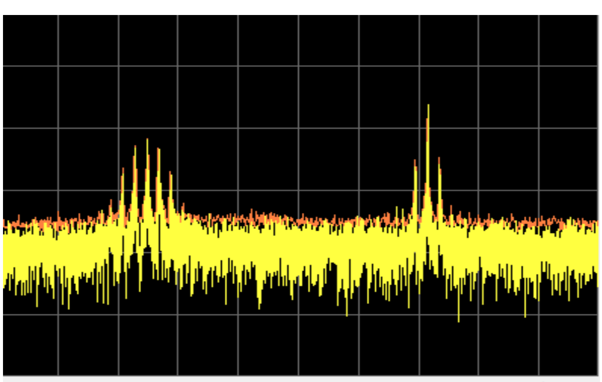

Figure 5: Result of tune measurement using FM signal. Peaks on the left are for vertical tune while peaks on the right are for horizontal tune.

SUMMARY

New system for tune measurement at the booster and storage ring were developed and implemented at Siam Photon Source. The new electronic module installed at the SPS booster will provide betatron tune information during machine commissioning for 1.2 GeV full energy injection. At the SPS storage ring, the use of FM excitation signal can reduce the measurement time from 10-30 seconds per measurement in the old system to real-time in the new system which saves time considerably during machine study.

In the future, some instruments of the system in the booster will be changed or modified to further improve the performance of tune measurement. Some examples are increasing the power of excitation and ramping it with the beam energy, or improving data acquisition system by increasing buffer size of the memory to expand the amount of collected data per one measurement. In the storage ring, the tune can be measured only in machine study time, not when machine is operated for users. This is because the excitation created perturbation to the stored beam. Real-time tune measurement during machine operation is also of interest for future work. However, more work on beam dynamics need to be done in order to reduce the beam distortion induced by the excitation.

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