Tune and Bunch Length Measurements of SRRC Booster During Ramping

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Abstract

Betatron tune of the SRRC (Synchrotron Radiation Research Center, Taiwan) booster was measured along the acceleration cycle. Results showed that for the most frequently used operation setting file, the fractional tunes were ν_x = .166 and ν_y = .437 at injection, 50 MeV; and drifted to ν_x = .146 and ν_y = .286 at ectraction, 1.3 GeV, respectively. These results were compared with what was observed in 50 MeV, DC mode operation. Bunch length variation during ramping was measured at fixed peak rf voltage, 200 keV. Corresponding beam energy spread was then calculated from the measured bunch length and compared with the theoretical expectation.

I. Tune Measurement

1. Experimental layout

The diagnostics instrumentation for betatron tune measurement during ramping is shown in figure 1. Electron beam was excited by a pulsed magnetic field. This pulsed magnetic field was provided by the extraction kicker with 300 ns flat top pulse. A specially made coil was installed onto the extraction kicker to produce magnetic field in both horizontal and vertical directions. This excitation pulse was properly triggered along ramping cycle for the experiment. Beam response after the kick was picked up by the stripline and mixed with the booster rf operating frequency, 499.654 MHz, so that a beating signal can be extracted. A 5 MHz low pass filter was used to enhance the signal to noise ratio of the revolution frequency, 4.167 MHz. Signal was then fed into the Tektronix TDS 540 oscilloscope in which fast Fourier transform (FFT) was performed. The frequency resolution was 10 kHz and the uncertainty of the fractional tune reading was about 2%. During the experiment, suitable kicker strength has to be adjusted as the beam energy varied. At low energy, a strong pulsed field might kick out the beam. As the beam energy became higher, a stronger field was needed to disturb the beam and a pronounced enough signal could be obtained. During the experiment, the tunes were found to be independent of the applied pulsed field strength available in this experiment.

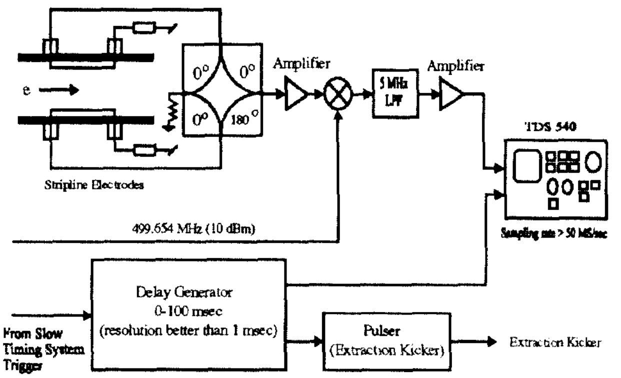

Fig.. 1 Betatron tune measurement instrumentation system

2. Results and discussions

Figure 2 gives the betatron tune variation during ramping for both ν_x and ν_y. In the figure, it shows that betatron tunes drifted from ν_x = .166 ν_y = .437 (1 ms after injection) to ν_x = .146 ν_y = .286 (before extraction). The variation range is $\Delta\nu_x$ = .020 and $\Delta\nu_y$ = .151, respectively. These values are somewhat different from the designed tunes of ν_x = 4.40 and ν_y = 2.43 [1] due to the dynamic tracking between magnet families in a resonant ramping cycle.

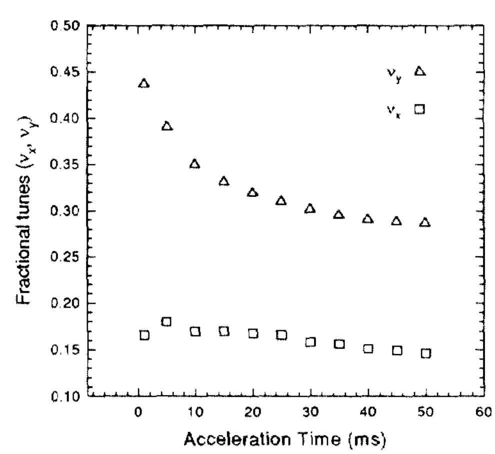

Fig. 2 Betatron tune of the accelerated beam

Figure 3 shows the drifted tune in the tune diagram during ramping cycle. Notice that the accelerated beam survived while crossing three third order resonance lines along ramping cycle with this particular operation setting file. Electron beam was injected at 50 MeV and then was ramped up to 1.3 GeV for extraction. Data was presented in the step of 5 ms. It indicates that these third order resonance were not serious enough to shake up the beam and to make it lost. This result is consistent with what was observed in 50 MeV, DC mode operation. [2]

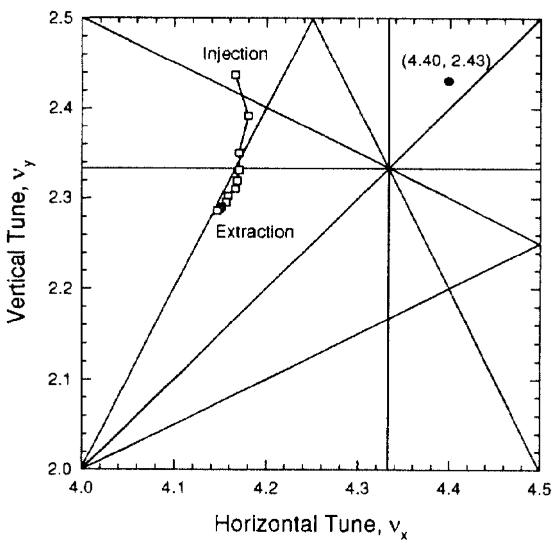

Fig. 3 Tune diagram indicating booster tune shift during acceleration

II. Bunch Length Measurement

Bunch length is one of the major beam parameter to be determined. Measured bunch length provides more direct information on the beam energy spread than that from the beam size measurement. [3] With the measured momentum compaction factor and calibrated peak rf voltage, the measured bunch length was converted directly to the beam energy spread.

1. Experimental layout

Functional block diagram for this experiment is shown in figure 4. Electron bunch signal picked up from the stripline was fed into the Tektronix 11801A digital sampling oscilloscope with 20 GHz bandwidth SD-24 sampling head. Since the sampling rate of this scope is quite limited (200 kHz), proper triggering of the diagnostic system is crucial for this experiment. To measure bunch length during acceleration, a 10 Hz reference signal from slow timing system was used to start a 2 ms gate from a delay generator. By properly adjusting the delay time, bunch length measured at a particular point during acceleration can be obtained. During the 2 ms gate period, beam revolution signal (4.167 MHz) was used to externally trigger the sampling oscilloscope. This revolution signal was picked up from the accelerated beam by a fast current transformer (FCT) installed in the booster ring.

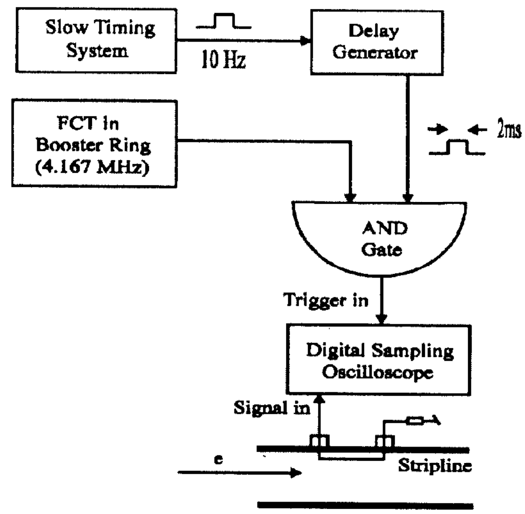

Fig. 4 Functional block diagram of the beam diagnostic system for bunch length measurement

Measurement was made in single bunch mode operation with average beam current of about 0.1 mA. The booster rf cavity gap voltage was operated at a fixed value of 200 kV to simplify the bunch length to energy spread conversion. Since the measured bunch length is rf voltage dependent, a quick check on the bunch length and rf voltage used at injection energy is performed by making used of the following relation, $\ln\sigma_t$ = constant - 0.25 $\ln(eV_{rf}^2 - U_0^2)$, where σ_t , V_{rf} , U_0 represent bunch length, peak rf voltage, emitted radiation energy; respectively. This relation was confirmed experimentally at injection energy with various peak rf voltage and their corresponding measured bunch length.

The main reason to have this check at injection energy is that the signal broadening effect from the diagnostics system is relatively less significant at this energy judging from the measured results. For each measured bunch length at a particular time, the sampling period may cover a number of acceleration cycle. It was noticed that the measured bunch length was fluctuating within +/- 3% throughout the accelerated beam energy range, from 50 MeV to 1.3 GeV. About 50 meters of RG214 coaxial cable was used in connecting stripline and oscilloscope. Signal broadening effect has been taken into consideration before the bunch length information was analyzed. Impulse response of the 50 meters RG214 cable was obtained by computing the inverse Fourier transform of the frequency domain data with a HP8753C network analyzer and was determined to be around 183 ps.

2. Results and discussion

Figure 5 shows the measured bunch length variation along acceleration cycle. Corresponding beam energy spread together with theoretical expectation is shown in figure 6. Notice that the damping process is not completed at every moment in the acceleration cycle due to the non-equilibrium situation under 10 Hz operation. This observation is similar to the results obtained from beam size measurement. [3]

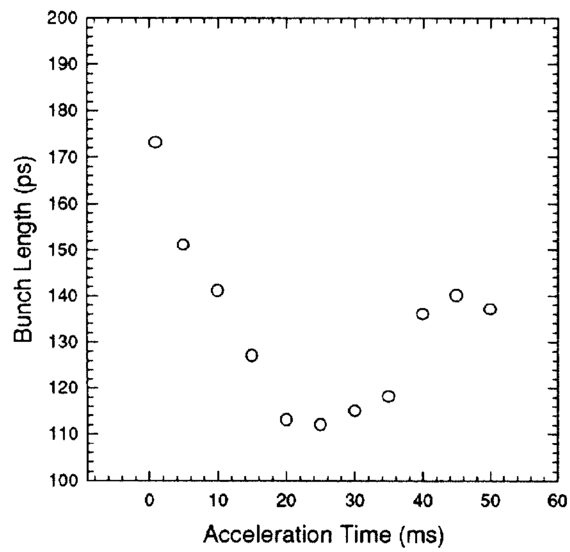

Fig. 5 Bunch length during acceleration

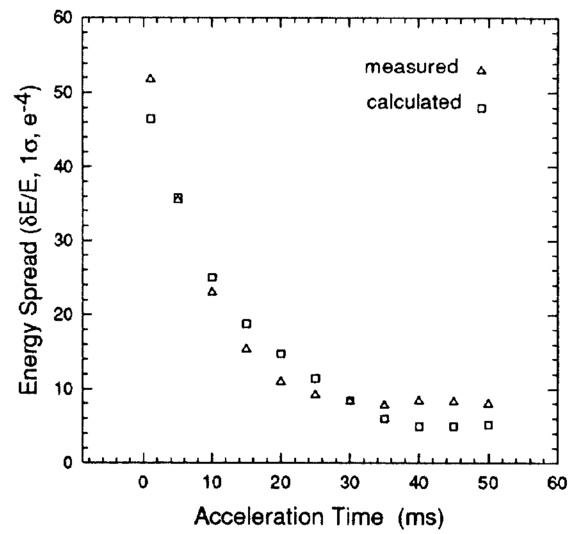

Fig.6 Energy spread during acceleration

III. REFERENCE

[1] J. Modeer, "1.3 GeV Electron Synchrotron", Proceedings of the 1993 PAC, APS, p.2034.

[2] K. K. Lin, K. T. Hsu, T. S. Ueng, Proceedings of the 1993 PAC, APS, p.2031.

[3] K. K. Lin, K. T. Hsu, T. S. Ueng, Y. C. Liu, SRRC/IJ/IM/92-07, September, 1992.