Tune Measurement of the SPring-8 Booster Synchrotron

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Abstract

The time variation of betatron and synchrotron tunes from beam injection to extraction has measured at the SPring-8 booster synchrotron. It has observed that the betatron tune has deviation from the design value at the lamping period of beam energy from 1 GeV to 8 GeV and has a fluctuation with frequency of 60 Hz at the flat-bottom period.

1 Introduction

The SPring-8 booster synchrotron is designed to accelerate an electron beam from 1 GeV to 8 GeV with a repetition rate of 1 Hz [1]. A current pattern of magnet power supplies is controlled corresponding with the beam energy. The effective acceleration voltage is changed from 2 MV to 18.6 MV by a phase difference pattern of RF power between two klystrons.

At the booster synchrotron, betatron tune at the energy lamping had not been measured. In order to realize the fine tuning of the current pattern and the phase pattern, it is necessary to measure the tune at an arbitrarily timing. We have designed a new system of tune measurement by using with a real-time spectrum-analyzer (SONY Tektronix 3056).

2 Measurement System

Figure 1 shows the block diagram of tune measurement system. The system consists of a signal pick-up and a beam shaker. Four stripline electrodes with a 30-cm length for signal pick-up are installed in a vacuum chamber where the betatron function β_x and β_y are 10 m, respectively. The induced voltage from the electrodes is calculated with power divider and 180° hybrid. The direction of measuring betatron oscillation is selected by switching the picked-up signal from two electrodes. The phase differences of the signals from four electrodes have been adjusted zero in advance by the phase shifters. The calculated signal is amplified and is observed by the real-time spectrum-analyzer.

For the beam shaker to excite a betatron oscillation, RF knock-out system for single-bunch beam operation is used [2]. Four stripline electrodes with a 1-m length generate an electromagnetic field to kick the electron beam. RF power from the 200-watt amplifier is divided four and is fed to the electrodes. The kick direction of the electron beam is switched corresponding to observed tune direction.

Betatron tunes are calculated as follows:

$$\nu_x = m \pm \Delta f_{\nu x} / f_{rev} \quad (1)$$

$$\nu_y = n \pm \Delta f_{\nu y} / f_{rev} \quad (2)$$

where f_{rev} is a revolution frequency of the synchrotron; $\Delta f_{\nu x}$ and $\Delta f_{\nu y}$ are differences between revolution harmonics and its side-band of tune frequency; m and n are an positive integer. Low level signal of beam shaker is a sinusoidal wave with designed frequency of $\Delta f_{\nu x}$ or $\Delta f_{\nu y}$, and a frequency modulation of some tens of kHz is applied.

3 Result

Figure 2(a) and 2(b) show the frequency spectrum of synchrotron and betatron tune displayed on the real-time spectrum-analyzer. These data were measured at single-bunch beam operation. The pulse length of the beam from linac is 1 nsec and average beam current in the synchrotron is 0.6 mA. Harmonics of revolution frequency (262x756.8 kHz), betatron frequency and synchrotron frequency are observed from beam injection to extraction.

The synchrotron frequency and the vertical betetron tune have been adjusted roughly to the design value before this measurement. The horizontal betetron tune is not in constant at the lamping period of beam energy. The fluctuation of the betatron tune has observed at the flat-bottom period with frequency components of 60 Hz. It is appears that the fluctuation is caused by current-ripple of power supplies of magnet.

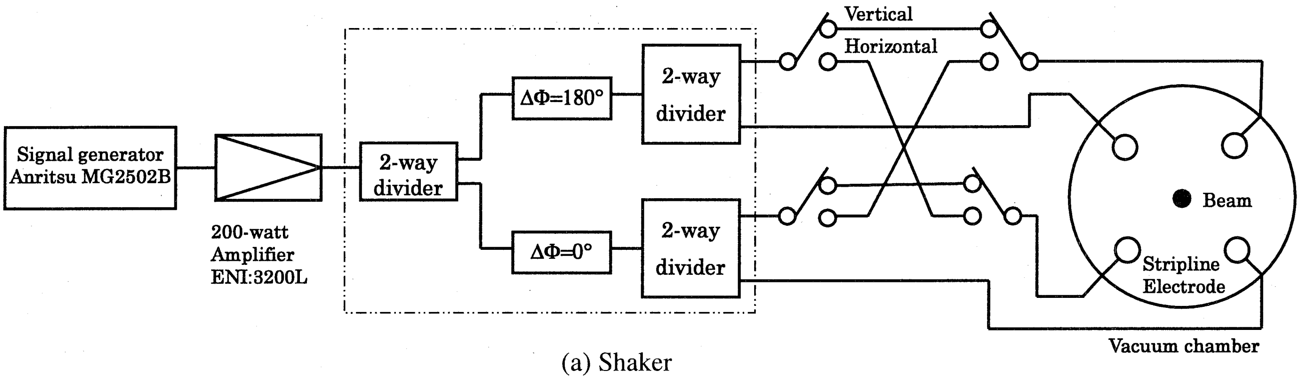
4 Conclusion

We have successfully measured the time variation of the tune from beam injection to extraction. By using this tune measurement, it has become possible that the fine tuning of the parameters of each equipment in the synchrotron. In future, we intend to adjust the current pattern of quadrupole magnets to keep the betatron tune at design value.

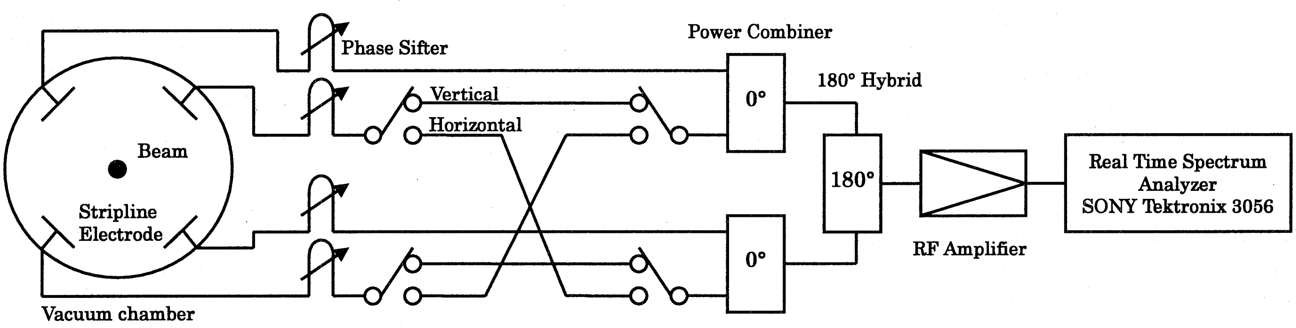
References

[1] H. Suzuki et al. (1995) Rev. Sci. Instrum. 66 (2), 1964-1967

[2] H. Suzuki et al.11th Symp. on Acc. Sci. Tech. (1997) 80-82



(a) Shaker



(b) Signal pick-up

Fig.1 Block diagram of tune measurement system

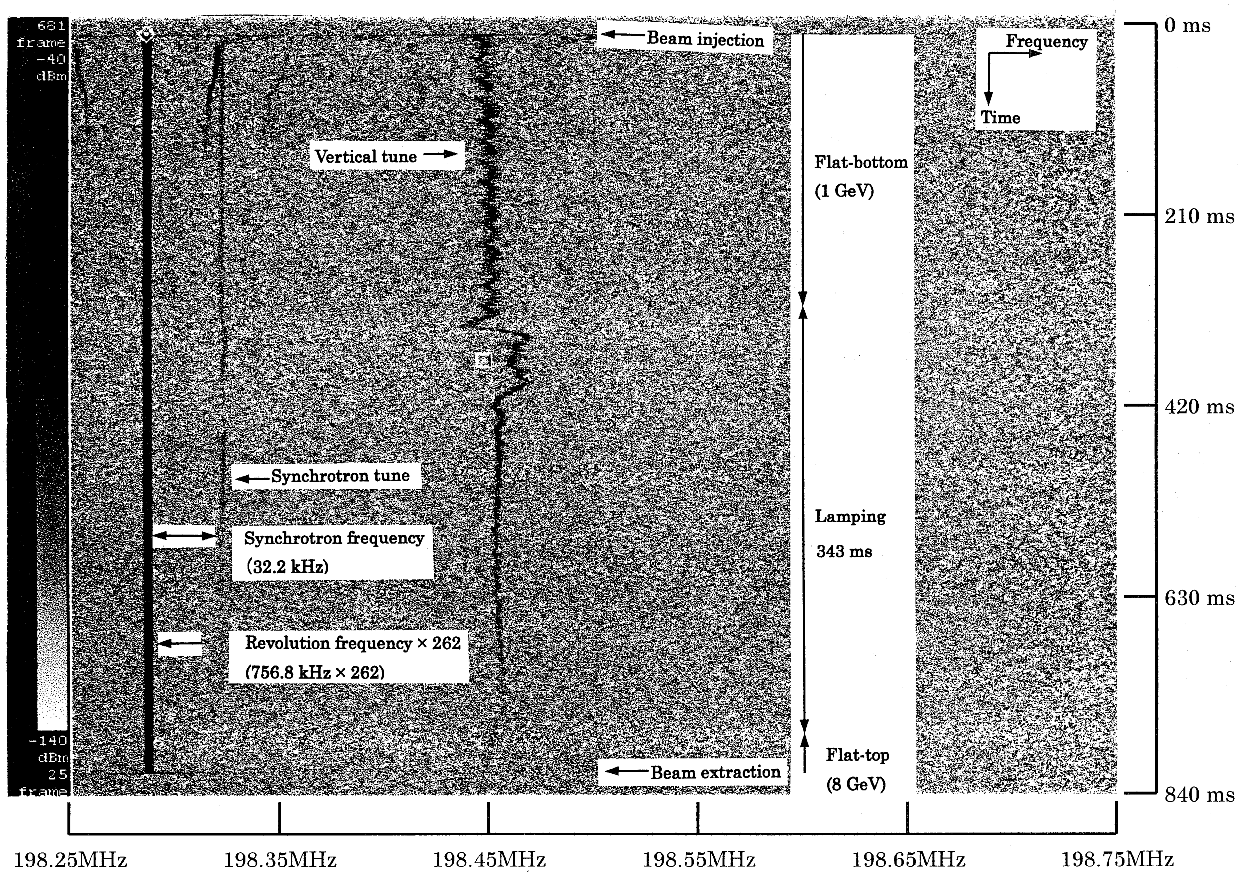


Fig. 2(a) Frequency spectrum of synchrotron tune and vertical betatron tune

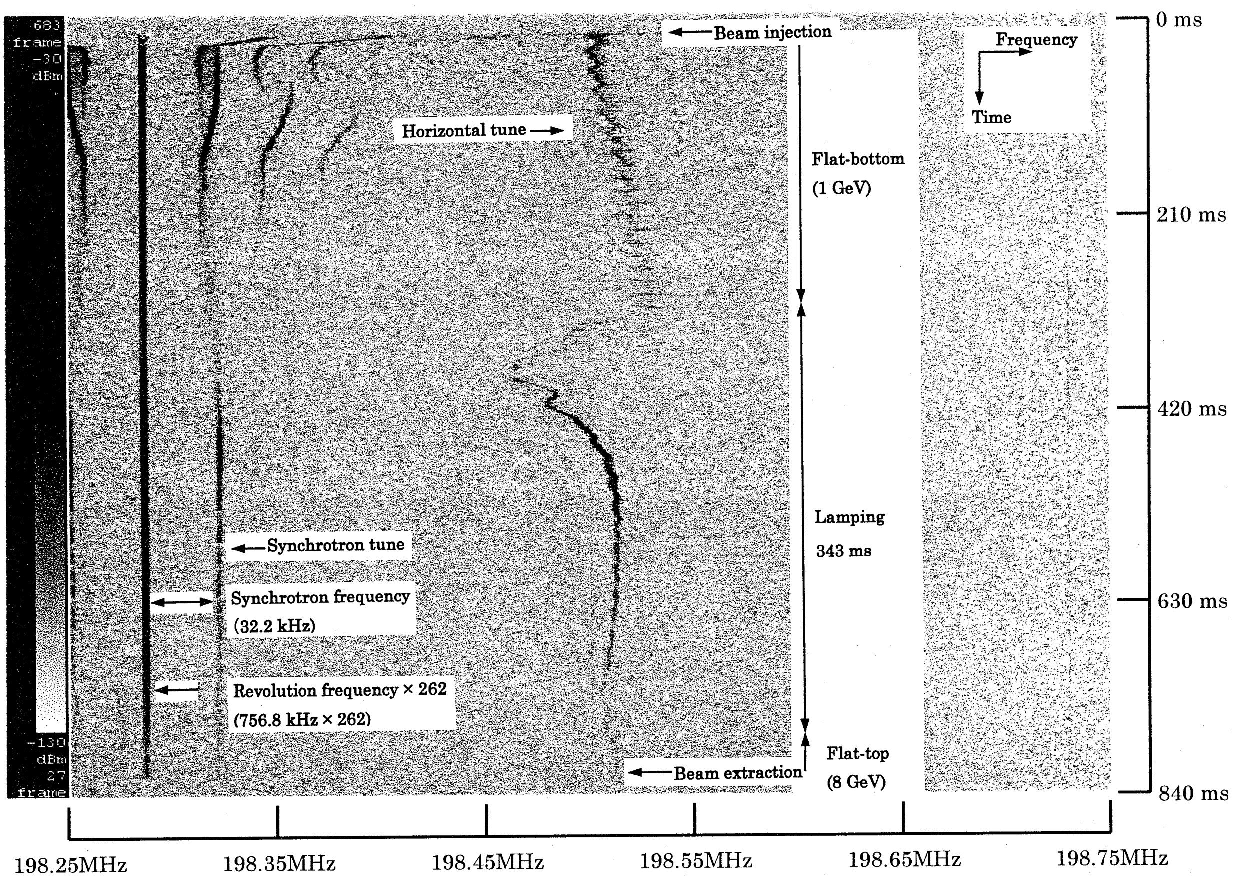


Fig. 2(b) Frequency spectrum of synchrotron tune and horizontalal betatron tune