PERFORMANCE OF THE TRANSVERSE COUPLED-BUNCH FEEDBACK SYSTEM IN THE BEPCII STORAGE RING

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Abstract

In order to cure the transverse coupled bunch instabilities due to higher order modes of RF cavities and resistive wall impedance in the BEPCII storage ring, an analog bunch-by-bunch feedback system was designed and used. The main components are two sets of beam oscillation detectors, betatron phase adjuster, notch filter and stripline kicker. This paper will describe system parameters, specifications of key components and experiment results.

INTRODUCTION

BEPCII is an upgrade project of the Beijing Positron Electron Collider (BEPC), in which a new inner ring has been installed inside the old one. BEPCII will provide colliding beams with 910mA at the centre-of-mass energy 1.89GeV in colliding mode. There are 93 bunches in every rings, the bunch spacing is 2ns. In the last commissioning stage, over 500mA beam has been successfully stored in both rings, the colliding luminosity has been reached to 1×10^{32} cm^{-2}s^{-1}. When the current reaches to 200mA, strong transverse instabilities occurred in both BEPCII electron and positron rings which limited the maximum storable currents. In order to cure these instabilities, two sets of transverse bunch-by-bunch feedback systems for both rings have been developed and put into operation. The transverse feedback systems suppress the instabilities and make the beams stable to collide.

Table 1: Feedback related parameters of BEPCII rings

Parameters	value	unit
Energy	1.89	GeV
Circumference	240	m
Bunch current	9.8	mA
Number of bunches	93	
Revolution frequency	1.2621	MHz
RF frequency	499.8	MHz
Radiation damping times	25	ms
Tunes	6.46/7.42	
Most fast rising time of instabilities (ECI)	0.5	ms
Kicker shunt impedance (at 125MHz)	4000	Ω

The system is an analog bunch-by-bunch system in time domain with frequency domain bandwidth of 125MHz. The first operation of the BEPCII rings has suggested that this feedback system can provide 40dB damping of beam oscillation in full bandwidth. Table 1 gives us some feedback related parameters. In this paper, we will describe the design and operation results of this system.

TRANSVERSE FEEDBACK SYSTEM

The idea of transverse feedback system is based on the feedback systems developed in NSLS [1], ALS [2], PLS [3] and KEKB [4]. The BEPCII transverse feedback system consists of pickup electrodes, signal processing electronics, power amplifiers, and a stripline kicker. Figure 1 shows an overview of the transverse feedback system. Two x (or y) signals from pickups located about 90 degrees apart in betatron phase are added together with appropriate coefficients to produce a 90-degree betatron phase shift between the pickup signal and the kicker for arbitrary kicker location and betatron tune. The beam oscillation signal is detected at the third harmonic of the RF (1.5GHz) in order to take advantage of the good sensitivity of the button pickups at this frequency; the signals then are demodulated to the baseband with heterodyne receivers. The DC offset at the pickups is removed by two ways, one is that a fraction of sum signal is added to or subtracted from the beam moment signal, and another is to use a two-tap notch filter. The one-turn delay is provided by coaxial cable. In each ring there is one stripline kicker and four 75-watt power amplifiers for both directions to apply the correction kick signal to the beam.

Front-end electronics

The signals from pickup is firstly divided into three branches by a power combiner and summed up again by another power combiner. Three cables have different length and the difference is the wavelength of the 1.5GHz detection frequency. Two combiner and three cables make up of a very effective FIR filter, the magnitude-frequency characteristic is shown as figure 2. The centre frequency is 1.5GHz and bandwidth is 480MHz. Then the filtered signal passed a hybrid network, the true x and y signal and the sum signal will be produced. The local DC rejection circuit in fixed-voltage mode [4] is used. Some fraction of sum signal is added to or subtracted from the beam moment signal. The magnitude of sum signal is changed by a manual attenuator (here is double balanced mixer) to make the magnitude of the original beam moment signal changing to zero. This circuit can provide 20dB rejection of orbit offset [5]. Subsequently, the signals are down-converted to baseband using heterodyne mode detection.

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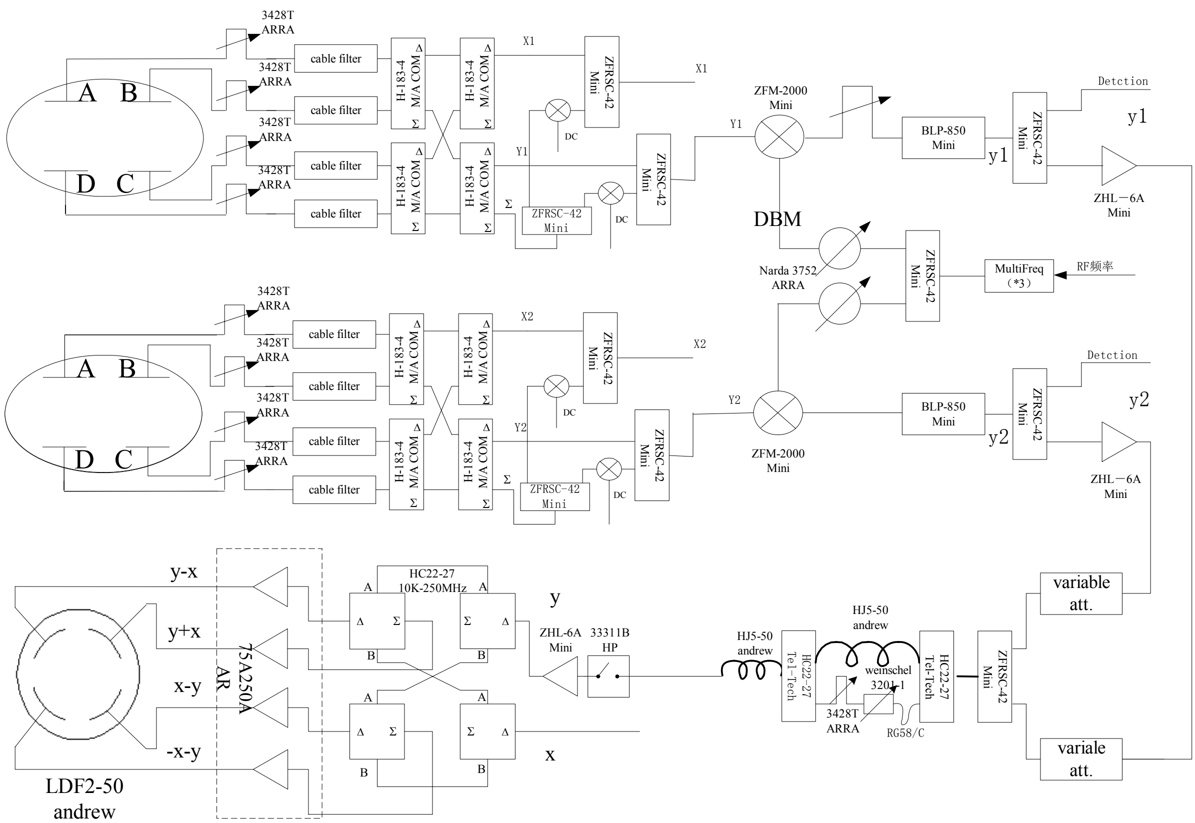

Figure 1: An overview of transverse feedback system of BEPCII.

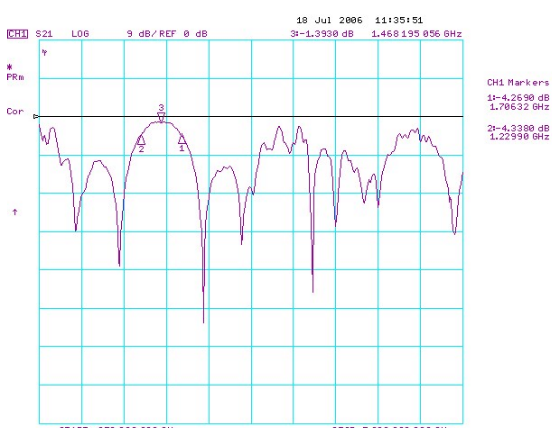

Figure 2: Magnitude-frequency characteristic of three cable filter.

Signal processing system

The two beam pickup signals are attenuated by mechanic attenuators and vector summed. By setting different attenuations of the two beam signals, the phase between the pickup and kicker can be changed in the range of 360 degrees. In order to reject the DC offset signal, a two-tap coax-cable notch filter is used to reject the revolution frequency component. As shown in figure 3, the notch depth reaches up to -41dB. After a long cable for one-turn delay, the output signal from the notch filter is sent to a hybrid network to make a correct signal for the stripline kicker.

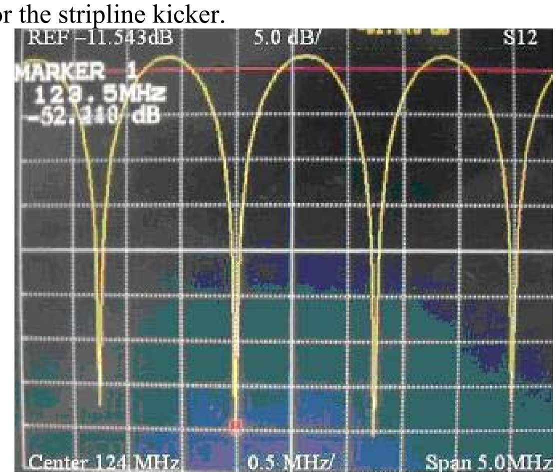

Figure 3: The performance of the notch filter.

Power amplifier and kicker

Four 75-watt AR amplifiers are used for each ring. Each ring has only one kicker with four-stripline for both transverse directions because of the tight space in the rings. The stripline is 600mm (λ/4 of 125MHz) long. All striplines are careful assembled to match 50Ω impedance. 4kΩ shunt impedance is obtained at the frequency of 125MHz. The kicker electromagnetic design has been carried out mainly by means of the Hewlett&Packard

high frequency structure, the test and operation results are good.

Performance of the transverse feedback system

In the last commissioning stage of BEPCII, 500mA beam current has been reached in positron and electron rings, respectively. In any ring, when the beam current is over 200mA, the transverse instabilities occurred and the beam blows up. It can be seen that the sidebands disappears when the feedback is on; the beam profile is stable and then the beam current can be increased again. At last, we can realize 500mA×500mA colliding beams, the luminosity reached the aim we expected.

Fig.4 shows the beam sidebands with the transverse feedback turning off and on. It was measured by a spectrum analyzer when the positron ring operated on the colliding mode at 243mA with 93 bunches. The background frequency lines are revolution frequency harmonics and the dark-coloured lines are instability sidebands. We can see that the magnitude of instability sidebands is attenuated more than 30dB when the feedback is on. Fig.5 shows the beam profiles with the transverse feedback turning off and on.

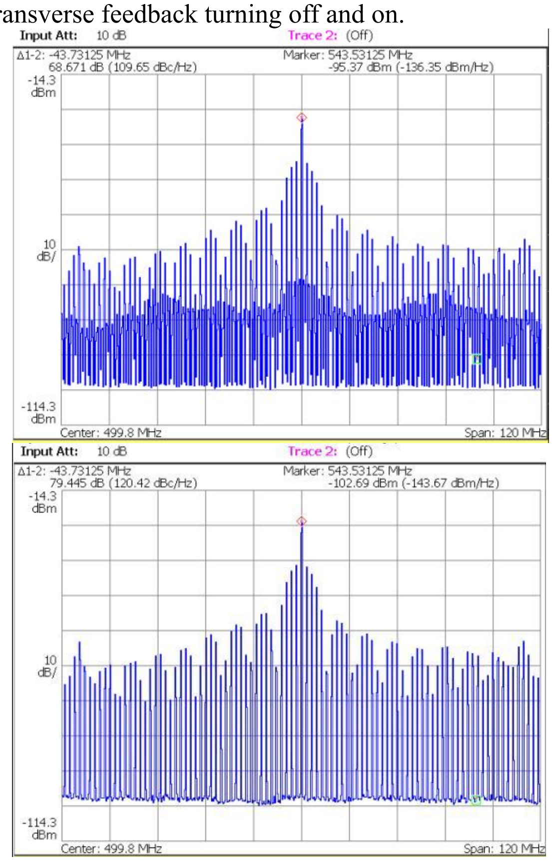

Figure 4: The sidebands of beam with the transverse feedback turning off (upper) and turning on (lower).

SUMMARY

The transverse feedback systems of BEPCII have been installed and played an important role during the commissioning of BEPCII double rings. It can suppress the strong multibunch instabilities at the higher beam current of over 500mA. In the next stage, we need careful tuning the system and make sure of suppressing the transverse instabilities at more higher current. In addition, remote control and damping time measurement will be completed.

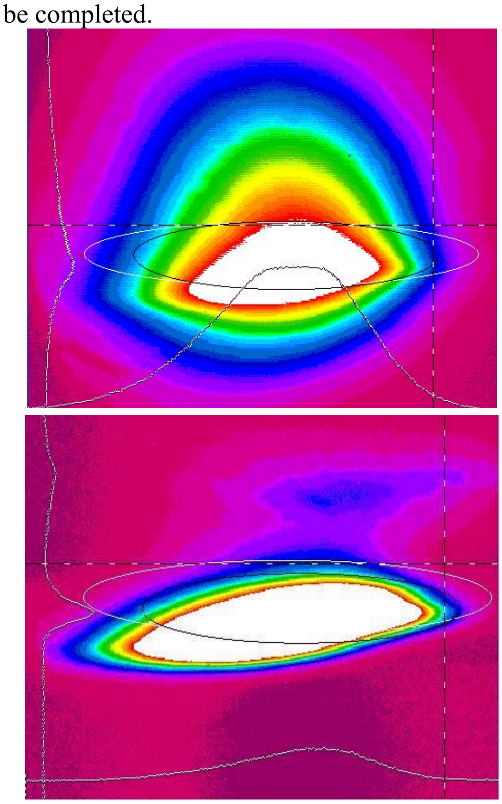

Figure 5: The beam profiles with the transverse feedback turning off (upper) and turning on (lower).

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REFERENCES

[1] J.Galayda, “Performance of a Correlator Filter in Betatron Tune Measurement and Damping on the NSLS Booster”, IEEE Transaction on Nuclear Science, Vol. NS-32, No.5, October 1985, p2132-2134.

[2] W.Barry, J.Byrd, J.Corlett et al., “Design of the ALS transverse coupled-bunch feedback system”, PAC1993, Washington D.C., p2109-2111.

[3] J.Y.Huang, M.K.Park, D.T.Kim et al., “Transverse beam feedback system for PLS storage ring”, Nuclear Instruments and Methods in Physics Research, A467-468 (2001), p103-105.

[4] Makoto.Tobiyama, Eiji.Kikutani, “Bunch-by-bunch feedback systems for KEKB Rings”, PAC2001, Chicago, U.S.A., p1246-1248.

[5] W.Barry, J.Corlett, M.Fahmie, “Status of the PEP II transverse feedback systems”, PAC1998, p2344-2346.