

DEVELOPMENT OF TRANSVERSE FEEDBACK SYSTEM AND INSTABILITIES SUPPRESS AT HLS

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Abstract

In order to cure and damp coupled bunch instabilities (CBI), a bunch-by-bunch (BxB) measurement and transverse feedback system is under commission at Hefei Light Source (HLS). In this paper we introduce the overview of the measurement and analogy transverse BxB feedback system in emphases. The measurement system is dedicated to observe the beam instability and works as a part of the analogy and digital transverse BxB feedback system. The development of several characterized components and stripline feedback kicker as well as the experiment result of the feedback system in HLS ring is also presented in this paper.

INTRODUCTION

The electron storage ring of National Synchrotron Radiation Laboratory (NSRL), that is Hefei Light source(HLS), a 200MeV injection beam from linac and transport line ramping to 800MeV and operates at 200-300mA in RF is 204.035MHz. The multi-cycle multi-turn injection system is used for current accumulation. A wiggler is available in the HLS. In order to cure and damp CBI, a BxB measurement, analogy and digital transverse feedback system is under commission at HLS.

STRUCTURE OF BXB MEASUREMENT AND FEEDBACK SYSTEM

HLS Bunch-by-Bunch System

The HLS BxB system consists of two projects: the BxB measurement system[1] [2] and the BxB transverse analogy feedback system[2] [3]. Signal detection have implemented by Beam Position Monitor (BPM), which has four-button type pick-ups mounted in a skew 45°[4], and feedback devices is using strip lines.

Using the system, not only measure bunch transverse position oscillation (horizontal and vertical direction), to measure longitudinal phase oscillation, to measure relative bunch charge and to implement transverse wideband feedback, but also obtain single bunch in multi-bunch storage ring and exciting specify bunch. Overviews of the BxB transverse feedback system of HLS been shown in Fig.1. They are composed of pick-up electrodes, front-end electronics circuitry, PXI data acquisition system and wideband exciting devices using stripling length of which is 20 cm.

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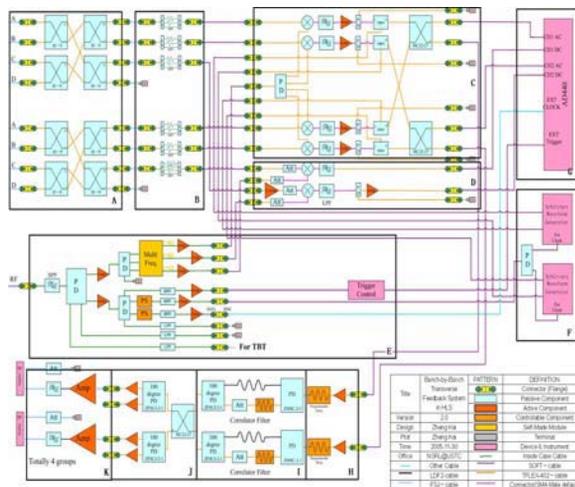


Figure 1: Overview of the BxB analog transverse feedback system of HLS.

In Fig.1, A: for obtaining bunch position oscillation signal from Hybrids at two BPMs; B: notch filter at centre frequency 612MHz ($3 \cdot f_{RF}$); C: vector algorithm to obtain the feedback signal from two BPMs; D: for detecting longitudinal phase oscillation at centre frequency 1.2GHz ($6 \cdot f_{RF}$) by summing BPM signals; E: multiple frequency circuit for centre frequency 612MHz and 1.2GHz; F: vector control circuit for shaping a single bunch or bunch chain; G: PXI digitizer for data acquisition; H: precision programable delay; I: correlator filter to restrain the revolution frequency for saving feedback power; J: vector algorithm for output power rotate 45° ; K: power amplifier.

DEVELOPMENT OF SEVERAL CHARACTERIZED COMPONENTS

Exciting Gate Circuit

In order to research the performance of storage ring, need often exciting beam, for example, measurement damping time etc. Especially, to debug delay time and phase of the BxB feedback system must process in a single bunch. And due to fill mode of HLS storage ring can but only in all bunches at present, so the development of exciting gate circuit for form a single bunch is very importance. On the other hand, due to HLS storage ring absent fast kicker, we need sweep exciting beam by stripling in one gate (10ms) or two gate (5ns) to form a single bunch or exciting single bunch in multi-bunch storage ring. The two gate circuit and the oscillogram of a single bunch formed been shown in Fig.2 and Fig. 3[5].

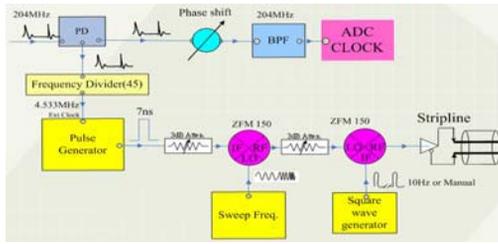


Figure 2: Circuit with two high speed switching gate.

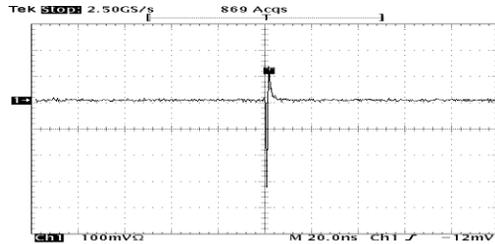


Figure 3: Single bunch oscillogram obtained by use of two fast gates.

Phase Space Characterized using Single BPM

Generally, describing the phase space need by two BPMs. However when know the TWISS parameter of location of a BPM, to compute the track of x direction of bunch will obtain x', the plane image described in x and x' as coordinate respectively that is phase space. The formula (1) and (2) show those. Fig.4 is a phase space trace acquired by a BPM[1]:

$$x(s) = a\sqrt{\beta(s)} \cos\left(\int \frac{ds}{\beta(s)} + \phi_0\right) \quad (1)$$

$$x'(s) = \frac{1}{\beta(s)} \left[-\alpha x(s) + a\sqrt{\beta(s)} \cos\left(\int \frac{ds}{\beta(s)} + \phi_0 + \frac{\pi}{2}\right) \right] \quad (2)$$

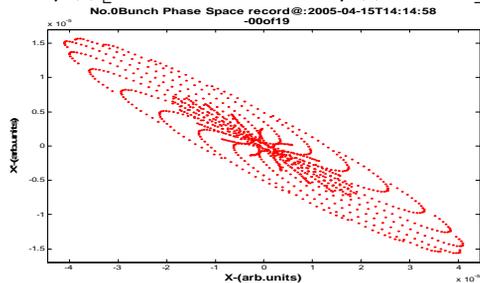


Figure 4: Phase space trace acquired by a BPM.

Fiber Notch Filter

To restrain the revolution frequency in the feedback signal, an analogy or digital notch filter is select in most feedback system. As the circumference of HLS is only 66 meters, we produce a notch filter by cable, which can provide 1.5dB insertion loss and at least 30dB filter depth. Because of the inevitable imbalance attenuator of different cable, there will be a special point with the best filter effect in the amplitude response in the frequency domain. We would like to offer a filter with higher operation frequency, more stable amplitude response and wider working span in frequency domain.

So we collaborate with YYlab to develop the fiber notch filter [6]. Finally, we get very satisfying experiment result,

which is shown in Fig. 5. Appearance of fiber filter shown in Fig. 6.

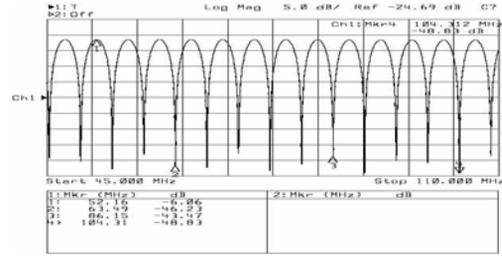


Figure 5: Amplitude response of fiber filter.



Figure 6: Appearance of fiber filter.

STRIPLINE FEEDBACK KICKER

The kicker is an important part in the transverse feedback system, because it will give a net electromagnetic force.

Length of Stripline

Due to the circumference of HLS storage ring is 66 meters, only can provide a 30 cm straight segment for designing a 20 cm stripline. So we reference the design of SPring8 short stripline[7].

$$E \times T \times \frac{1}{\tau} \times \Delta = C \times F_k \times L \times \sqrt{\beta} = C \times \sqrt{P} \times L \times \sqrt{\beta} \quad (3)$$

Left hand side: required amount of kick

Right hand side: provide possible amount of kick.

E: Energy; T: kick rate (that as Revolution period)

τ: Damping time by feedback; P: Power of amplifier

β: Beta function at kicker; L: kicker length

Structure of Stripline

The kicker has four-stripline type pick-ups mounted in a skew 45°. Each electrode and vacuum pipe forms a transmission line with 50-Ohm characteristic impedance. Its characteristic parameters are shown in Tab. 1[8]

Tab.1 Characteristic Parameter of Stripline

Bandwidth	100MHz
Length	20 cm
Opening angle	60°
Thickness	2 mm
Radius of stripline	33 mm
Radius of pipe	44 mm

The kicker is manufactured by stainless steel, the inner surface of pipe and the surface of stripline are coated by copper. The appearance of kicker is shown as fig.7.

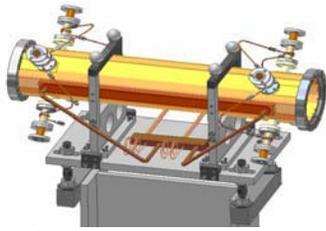


Figure 7: Appearance of kicker cavity.

The effectiveness of the kicker is defined by shunt impedance. As for the stripline, the shunt impedance can be calculated by below formula, shunt impedance obtained by calculate see Fig8:

$$R_{K\perp} = 2Z_c \left(g_{\perp} \frac{l}{a} \cdot \frac{\sin kl}{kl} \right)^2 \quad (4)$$

Coverage factor g_{\perp} : $g_{\perp} = \frac{4}{\pi} \sin\left(\frac{\theta}{2}\right)$

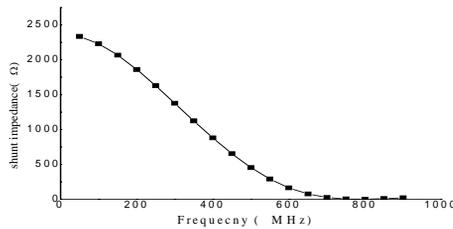


Figure 8: Shunt impedance.

Performance of Stripline

We measure the S11 parameter of the stripline, as shown in fig.9. In the bandwidth of 100MHz, the reflection coefficient is 3.15%, in another word; the reflection power will be no more than 1%.

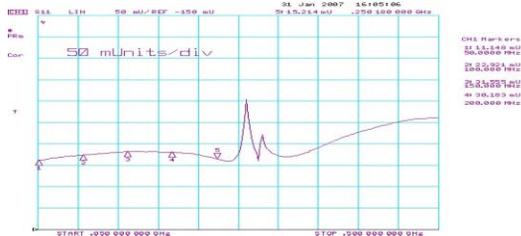


Figure 9: The S11 parameter of the stripline.

We also measured the time domain reflection about the kicker; we can find the stripline is most matched with pipe except some connection point.

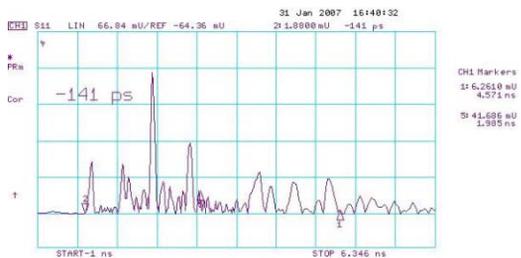
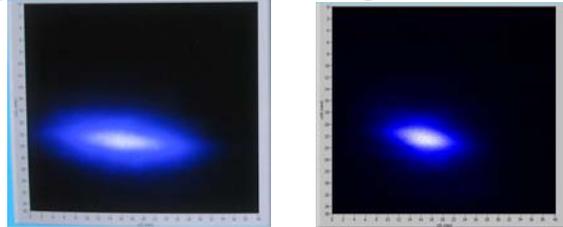


Figure 10 The time domain reflection about the stripline.

EXPERIMENT RESULT OF ANALOG TRANSVERSE FEEDBACK SYSTEM

In the experiment, the beam profile can be observed to test the effect of the feedback system, the Fig.11 show the effect, after turning on the system, the beam profile will get small clearly during 800MeV operation.



(a) Feedback off (b) Feedback on

Figure 11: Feedback effect in operation (800MeV).

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