BUNCH-BY-BUNCH BEAM CURRENT MONITOR FOR HLS *

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Abstract

A new beam current monitor (BCM) has been implemented on Hefei Light Source (HLS) recently. It has been used for bunch-by-bunch beam current measurement, which is useful for filling control and longitudinal feedback, etc. The BCM consists of three parts: the front-end circuit, a high sampling rate oscilloscope for beam current signal acquisition and the data processing system. The signals from the beam position monitor (BPM) of the storage ring are manipulated by the front-end circuit first, then sampled by the AgilentMSO7104 oscilloscope and transported into the control computer for data processing. The sampling rate of the oscilloscope is up to 4GHz and the trigger rate is 4.533MHz. The data processing program is supported by the LabVIEW. The measurement of beam current in multi-bunch operation mode is described. Some important results are summarized.

INTRODUCTION

The HLS machine is a second-generation light source operating at energy of 0.8GeV with a stored current up to 300mA. The storage ring can be filled with the pattern of 45 bunches under the multi-bunch operation mode. In order to get a more stable and higher beam current, the bunch current in each bucket should be monitored and well controlled. There are many tools and methods to measure the beam current in the synchrotron light source. The oscilloscope with a high sampling rate much larger than the bunch cross frequency are widely used to observe the signals of beam current [1, 2]. The signals from the sum signal of pickups of the storage ring are sampled by the AgilentMSO7104 oscilloscope and transported into the control computer for data processing. The operator in the HLS central control room can acquire all the bunch current information in every bucket by remote control. All the data can be stored in the local host computer for off-line analysis.

PRINCPLES OF MEASUREMENTS

Fig. 1 shows the fill-pattern in the HLS storage ring There are 45 pulses in the fill-pattern spaced by 4.9ns. We need a system which can monitor the current in each bucket. The system should be synchronized to the time system at HLS so that it can get the bunch number and the corresponding current value.

We chose the AgilentMSO7104 oscilloscope to observe the signals of beam current. The sampling rate of the oscilloscope is up to 4GHz, which is enough for the measurement.

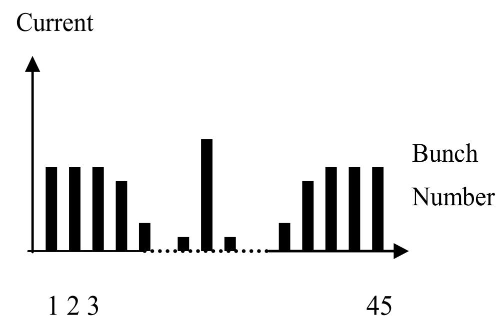

Figure 1: Fill-pattern in the HLS storage ring

However, there is a problem about the point number of the acquisition record. There are two kinds of waveform point numbers related to three waveform point modes for the oscilloscope. The first is the raw acquisition record. The maximum number of points available in this record is maybe up to 8,000,000. The raw acquisition record can only be transferred when the oscilloscope is stopped and retrieved from the analog or digital channels. The second is referred to as the measurement record. It is a 1000 point (maximum) representation of the raw acquisition record actually. This measurement record can be retrieved at any time from any source.

In order to achieve the real-time measurement, we had to choose the second mode. At the same time, the whole fill-pattern is divided to five parts by delay; each part has nine pulses, so that we can get a much higher precision of the current value.

HARDWARE AND SOFTWARE

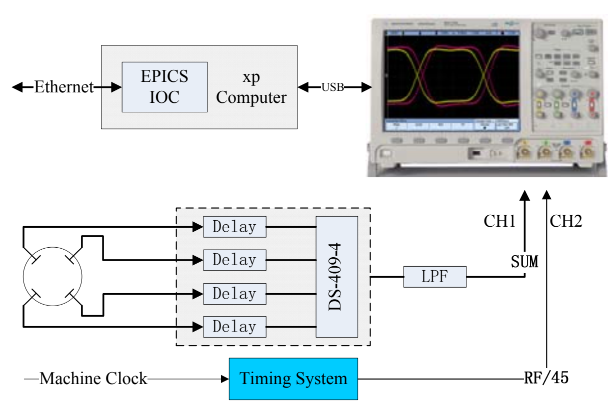

Figure 2: System block schematic

The beam current monitor has three main parts: the front-end circuit, a high sampling rate oscilloscope and the data processing system (Fig.2).

* Supported by the National Science Foundation of China (10675118, 10875117)
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Hardware

The front-end circuit gets the sum signal of four button electrodes from a beam position monitor installed in the store ring; the signal is reshaped with a 380MHz low pass filter to reduce the influence of high frequency and digitized by an Agilent MSO7104 oscilloscope via a special cable [3].

The oscilloscope is strong enough to let you debug your mixed-signal designs using up to four analog signals and 16 tightly correlated digital signals simultaneously. Two of the four analog channels have been chosen for waveform sampling and external trigger. The sampling rate of the oscilloscope is up to 4GHz and the bandwidth is 1GHz. The trigger frequency got from the ring clock system for synchronization to define the bunch number is 4.533MHz.

When the beam current is high, the output level of the front-end sum signal will be affected by the transverse instability and longitudinal instability. In order to improve measurements resolution, the data will be sampled in equivalent time mode (256 turns) and averaged, taking advantage of the processing capabilities of the oscilloscope [4].

Each bunch sampled by the oscilloscope induces a bipolar pulse signal, whose intensity is proportional to its current value (Fig.3). Further processing of the observed signal is related to the bunch current.

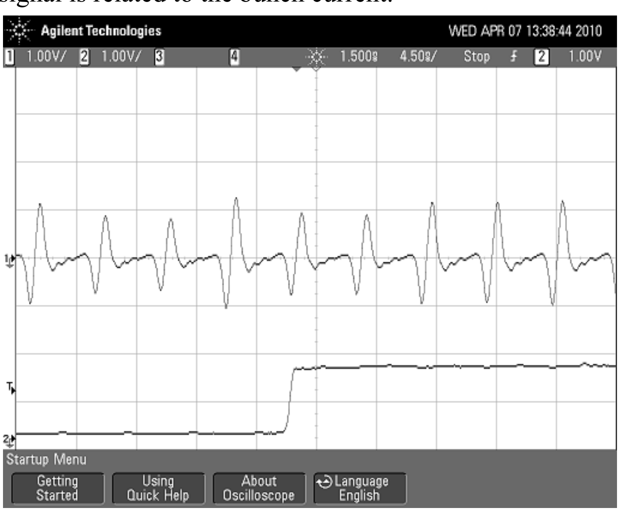

Figure 3: Part of raw BPM signal waveform

The oscilloscope is connected to the control computer in the store ring via an USB interface and it can be remote controlled in the central control room by LAN. The raw data of the waveform points displayed on the digital oscilloscope will be stored in the database of the local host for off-line analyzing.

Software

A LabVIEW application running on the Windows XPpro platform is used to extract the bunch current through peak amplitude measurements of each pulse and set up the working parameters of the oscilloscope, such as sampling rate, acquisition mode, vertical and horizontal scale, channel selection, trigger source and electric level, etc.

The waveform data of 45 bunches is divided to 45 same parts by the application. Each part including one bunch is used to analyze the peak value, which is proportional to the real beam current.

The peak value of each bunch extracted from the data of the waveform point by the LabVIEW application is called the relative beam current, which should be transformed to the absolute beam current by demarcated with the value of interrelated parameters.

There are two methods usually used to demarcate the relative beam current. The first method called the linear mode is based on the linear relation between the bunch current and the output signal intensity. The second method called the normalization based on the mathematical principle can get the absolute beam current by calculating the proportion of each bunch current in the all bunches and demarcating with the DC Current Transformer (DCCT). The latter is chosen because of the instability of the bunch length.

Individual bunch value is computed from:

$$I_i = \frac{A_i}{\sum_{k=0}^{44} A_k} I_{dcct}, i = 0,1,2,3......44 \qquad (1)$$

A_i is the peak value of each bunch, and I_{dcct} is the current value of the DCCT read from the database of the EPCIS host via LAN.

The ultimate current values of 45 bunches are transported in to the EPICS host for on-line reading via a channel of the ActiveX control box.

Another application working on the other computers in the LAN is used to display the real-time bunch current value (Fig.4). The data is read from the database of the EPICS system and synchronous to the data written before. The operator can observe the change of each bunch and adjust the state of the machine during the injection and operation in the control centre room.

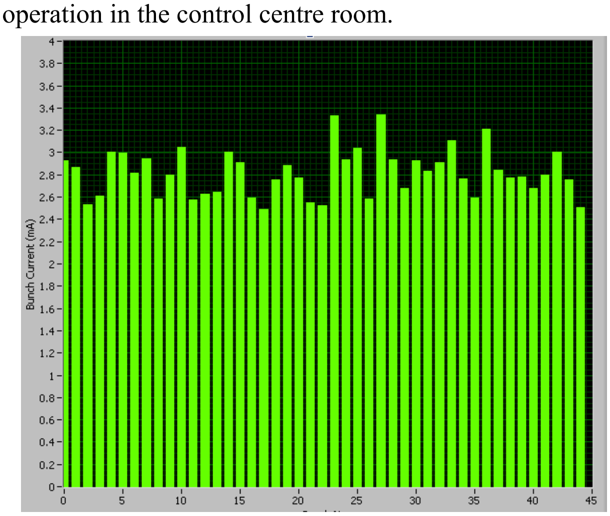

Figure 4: Bunch Current Monitor display

OFF-LINE ANALYZING

There are several off-line results analyzed from the data saved in the database by the operator. The data is useful for investigating the change tendency of the beam current in a long time.

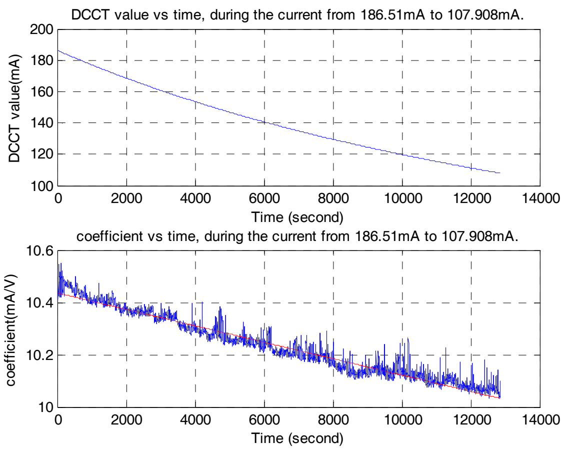

Figure 5: DCCT current and coefficient value vs. time

The top half of Fig.5 shows the decrease of the DCCT current value refreshed at the rate of 0.5Hz during about 1.3×10^4s. The range of the beam current value is about 107mA to 186mA. And the bottom half shows the calibration coefficient (I_i/A_i). The coefficient is not a constant so that we had to choose the normalization method to get the absolute bunch current.

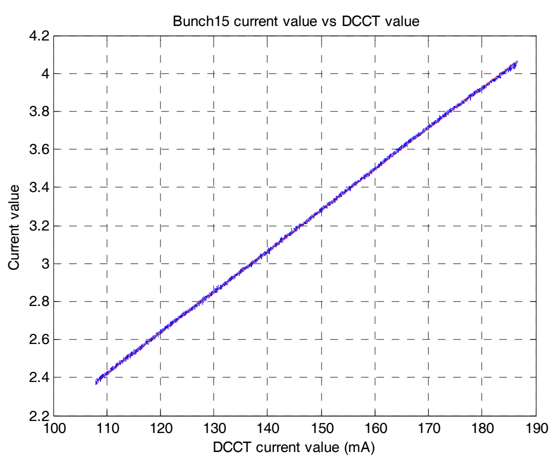

Figure 6: Bunch 15 current value vs. DCCT

The fitting line in Fig.6 shows the relation of the current of bunch 15 and the DCCT current. The fine linearity of the two parameters shows the high time resolution and peak precision of the system. And Fig.7 displays the error distribution of bunch 15 current during the corresponding time which shows the high accuracy of the measurement.

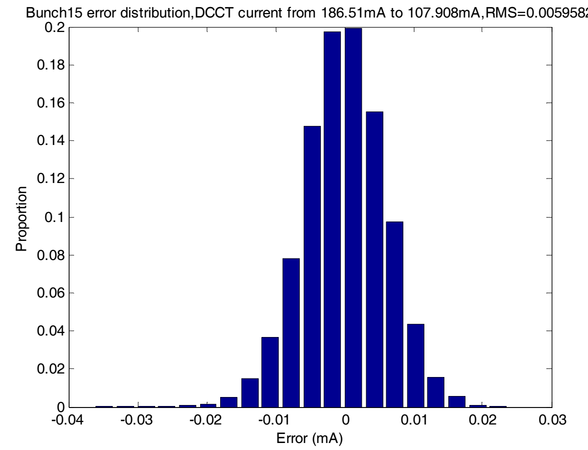

Figure 7: Error distribution of bunch 15 current

SUMMARY

BCM, a bunch-by-bunch beam current measurement system based on a high sampling rate oscilloscope has been developed at HLS and worked successfully. The bunch current value in each bucket can be monitored in the central control room. The visualization of details of the fill-pattern provided useful information for daily operation. In the future, the system will be integrated with a FPGA module to achieve more advanced features. Filling pattern will be well controlled to help to implement the top-up injection and longitudinal feedback, etc.

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