# BPM DATA PROCESSING BASED ON EPICS SOFT IOC AT HLS*

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*Abstract*

A data analysis program has been developed and verified successfully for the new beam position monitor (BPM) system of the storage ring at Hefei Light Source (HLS). The new BPM system will be equipped with Libera Brilliance BPM processors in the upgrade project. The embedded system on Libera has completed some basic work, including data acquisition, position calculation, and EPICS IOC data output. A new record type has been developed to accomplish the beam position recalculation by log-ratio method. The new position signal's character was studied in the time and frequency domain. The software performed stably on-line and the preliminary results are presented.

## INTRODUCTION

Hefei Light Source is a second-generation light source operating at energy of 0.8GeV with a stored current up to 300mA. In order to improve the beam quality, an upgrade project is in progress to obtain a beam current with lower emittance and higher intensity. A new BPM system with a higher resolution at the macron level is necessary for measuring the beam position stability. At the same time, the BPM data can be applied in other machine studies, including measurement of tune, phase space and life time, etc.

Libera Brilliance produced by Instrumentation Technologies (IT) is a new generation digital beam position processor instrument, which is widely used in the accelerators around the world, such as Diamond Light Source, SSRF, KEK, etc [1-3]. It is an all-in-one solution, which enables trouble-free commissioning, high precision beam position monitoring, and local and global feedback building.

16 Libera Brilliance will be used on the storage ring BPM system to update the existing processor equipments. The FPGA in Libera Brilliance acquired the primary data and calculated beam position by difference/sum ratio method; an EPICS IOC running on embedded GNU/Linux system provided a run-time database to output the results; a soft IOC on an industrial personal computer (IPC) received data and calculated series of parameters for all Libera instruments, including beam position (log-ratio method), maximal and minimal position, standard deviation, spectrum, tune, digital filter, signal correlation, etc. Client program in the LAN can get the data conveniently with a third-party plug-ins, such as CaLab and MCA, etc.

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## SOFTWARE IN LIBERA BRILLIANCE

The Libera software (Fig. 1) is composed of FPGA embedded software and SBC software based on a standard Linux kernel 2.6. The EPICS IOC, Libera server and other user program can communicate with the FPGA through the CSPI (Control System Programming Interface) layer and GNU/Linux kernel drivers conveniently.

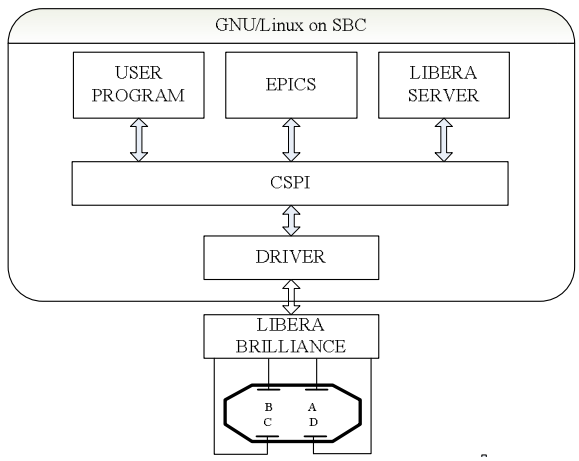


Figure 1: Libera software block diagram.

There are two methods to acquire and save data from Libera FPGA: one is using the Linux shell command directly in Libera server, which is basic and compact but discontinuous in time scale. The other is using an EPICS IOC to supply a real-time database. It can accomplish more works with complex mission.

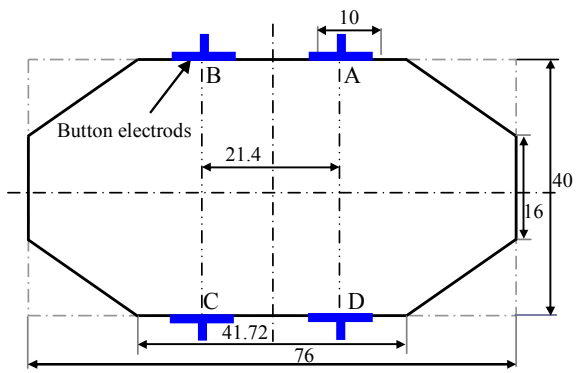


Figure 2: Layout of BPM buttons.

The data sampled with ADCs are processed in four identical channels. Each channel consists of a digital down converter (DDC) followed by parallel processing in the FPGA software, including additional filtering,

decimation and position calculation by difference/sum ratio method. Position calculation formula is:

$$\begin{cases} X = K_{\Delta/\Sigma,x}\dfrac{(V_A+V_D)-(V_B+V_C)}{V_A+V_B+V_C+V_D} - X_{offset} \\ Y = K_{\Delta/\Sigma,y}\dfrac{(V_A+V_B)-(V_C+V_D)}{V_A+V_B+V_C+V_D} - X_{offset} \end{cases} \quad (1)$$

Fig. 2 showed the layout of BPM buttons for HLS [4]. The octagon is a symmetric vacuum chamber cross section. A, B, C and D represent the four button electrodes.

The real-time database of EPICS IOC acquired useful data ($V_A$, $V_B$, $V_C$, $V_D$, X, Y, Q, SUM, etc) from hardware so that other client programs in the LAN could get it easily to finish further studies. There are several main data paths in use:

ADC raw data: this data is directly acquired from ADCs at ADC sampling frequency (about 117MHz) on trigger. The 1024 samples long buffer is enough to acquire few cycles' data and helpful for machine physics studies in accelerator.

Turn-by-Turn (TBT) and First turn (FT) data: TBT data at revolution frequency (4.533MHz at HLS) is filled continuously into circular buffer on the SBC. Data can be acquired on demand or on trigger. It is useful to study the beam position and related parameters in a large time scale. Acquisition of first turn must be done on trigger.

Fast Acquisition (FA) data: It is continuous data at approximately 10 kHz for fast feedback calculation and for interlock calculation.

Slow Acquisition (SA) data: It is a data stream derived from FA data at rate about 10 Hz. It is defined by software filtering and decimation to obtain high resolution data.

## SOFTWARE DEVELOPMENT IN THE IPC

In order to release on-line data, necessary calculations for all Libera instruments are done in a soft IOC which is running in an IPC.

The so-called soft IOC is an EPICS IOC record whose value is only from command operation or other records but not hardware. The soft IOC can run on any computer in the LAN with good portability.

The log-ratio method, with a higher sensitivity and greater linear range, was used to recalculate the beam position with the button signal data in the buffer. The recalculation formula is:

$$\begin{cases} X = K_{\log,x}\log\left(\dfrac{V_A+V_D}{V_B+V_C}\right) - X_{offset} \\ Y = K_{\log,y}\log\left(\dfrac{V_A+V_B}{V_C+V_D}\right) - X_{offset} \end{cases} \quad (2)$$

Where, $K_{\log,x}$=10.04mm and $K_{\log,y}$ =8.18mm are calculated using Matlab for the BPM buttons of HLS.

### *New Record Type*

The record types in EPICS base package can not perform advanced array operations. A new record type was developed to analysis data in the time and frequency domain for further studies (Fig.3). This record type is based on the synApps calc module of APS [5]. In order to achieve above goals, the needed migration algorithms include FFT, convolution and deconvolution, correlation and digital band pass filter. The updated record type with good versatility and scalability can be used by standard EPICS IOC programs.

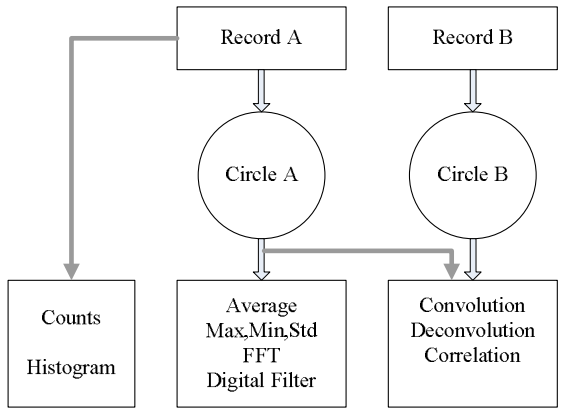


Figure 3: New record type block diagram.

### *Database*

Two database files were created with VDCT (visual database configuration tool).

Data1.db defined some environment variables and made several basic calculations for data in different mode, such as ADCCW, TBT, PM, SA. Each position record had six input records, including signals from 4 buttons, gain coefficient and position offset.

Data2.db finished studies in the time and frequency domain. The amount of data is very large from Libera via Channel Access protocol. Delay and shift operations were used to reshape each button signal to an appropriate sub array. The sub arrays were stored in the two circle buffers for further processing. A serial of calculations were done in respective record to study the time and frequency domain features.

Several macros were used in the database template files to increase the versatility. With specific configuration file, all data in selected Libera instruments can be analyzed with corresponding macro when loading database in the soft IOC.

An auto save module was used to save and restore some important parameters such as the gain coefficient and position offset. The parameters were loaded from stored files when the IOC started. A new file will be created if there is no stored file. And the new values will be written into the stored files when the parameters are changed. It is useful for parameter testing in machine study.

### *Display*

EDM (EPICS display manager) is used to create and edit display content for instrument debugging under GNU/Linux. The EDM panels are used to set parameters during running and show important machine status and results. All features are integrated into a single interface




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and each module can be opened as an independent subroutine.

## DATA ANALYSIS

The data processing program introduced above has been tested on-line in the HLS BPM system successfully. The soft IOC in the Libera Brilliance released original BPM data under different mode and the soft IOC in the IPC collected turn-by-turn and slow acquisition data to study interested parameters.

The interested results can be showed on-line in the EDM panel conveniently. Fig. 4 showed the raw waveform of vertical position, the spectrum and the statistics results. 1024 circles data was stored and updated in the buffer for analysis. The statistics range for histogram can be changed easily.

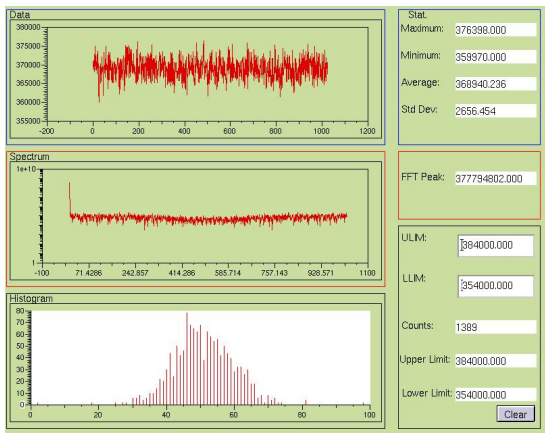


Figure 4: Waveform, spectrum and statistics results.

At the same time, the important data can be saved into text files with LabVIEW or Matlab program for off-line analysis in the future.

The tune can be calculated easily by spectrum analysis with turn-by-turn data during the injection or excited with an external source during operation.

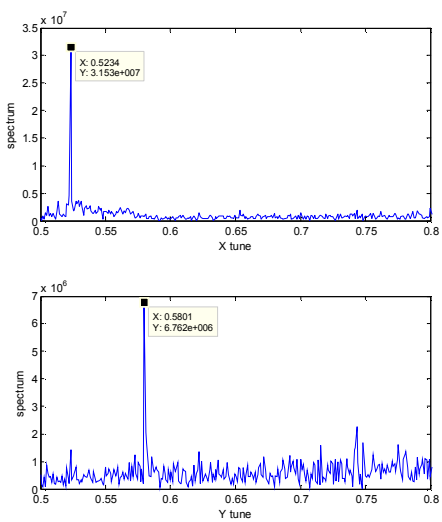


Figure 5: Fractional tune measurement of injection.

Fig. 5 showed the spectrum of data at a certain point in time during injection and the fractional part of tune was obtained. Horizontal value is 0.5234 and vertical value is 0.5801.

Fig. 6 showed the change of tune in the resonance diagram. In order to maintain the beam stability, the change should be as small as possible to avoid crossing some dangerous resonant lines. In this picture, the tune change is 0.0117 in horizontal direction and 0.0049 in vertical direction.

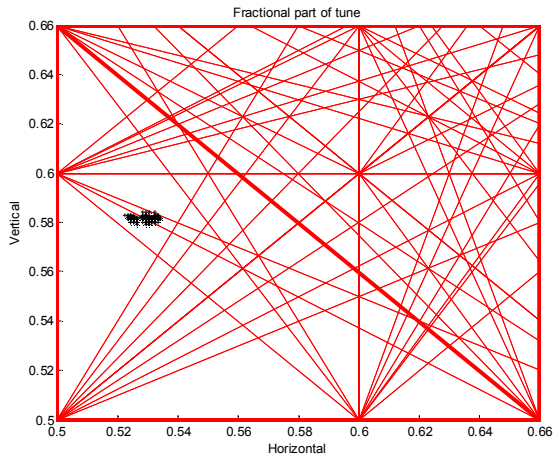


Figure 6: Change of tune during injection.

## SUMMARY

The Libera Brilliance and the corresponding data processing EPICS soft IOC has been running stably for a long time. The results showed a good performance and high precision on the storage ring. The turn-by-turn beam position measurement accuracy can be up to micrometers and the tune measurement accuracy is up to $10^{-4}$. More studies and analysis will be done with this system in the future.

## ACKNOWLEDGMENTS

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