THE SYNCHROTRON RADIATION MONITOR UPGRADATION IN NSRRC

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Abstract

Synchrotron radiation monitor in the storage has been operated for a long time. This system is upgrading to booster operation now. The basic system includes optics, digital image acquisition, image analysis, compressed image transportation and visualization tools at workstation. The linearity and dynamic of new is discussed for some beam physics study. This system is also supported to the booster by new camera and addition operation. The hardware configuration and software structure will be summarized in this report.

1 INTRODUCTION

Imaging applications in the accelerator community are most often utilized to measure beam profile and interference fringes. The beam profile may convert form fluorescence, various optical diagnostics (SR, OTR, DR, etc.) [1,2,3]. Usually, the synchrotron light source radiation monitor measures beam profile and beam size of the synchrotron radiation light source in order for performance optimization, routine operation check and various beam physics studies. The monitor should be able to resolve minor transverse beam instability and movement. This tool has been useful for characterizing properties of electron beam analysis since its operation ten years ago. For example, the beam emittance is calculated from the measured beam size. By using digital IEEE1394 camera system [3,4], we are able to eliminate the frame-grabber stage of processing and directly transfer data at maximum rates of 400 MB/sec.

To improve the desired functions of the synchrotron light monitoring system [5], a major upgrade of the data acquisition and analysis system has been implemented recently. The main goals are to increase signal transmission quality, the dynamic range, the linearity of the profile monitor, and better supports for data analysis. The integration of the system with the control system will be described in the following sections. Some results are also described in the system functional demonstration.

2 TO CHOICE IEEE 1394 CAMERA REASONS

Using a fully digital camera has two major advantages over analog CCD camera. First, the A/D conversion is performed closer to the CCD sensor, keeping the amount of electronic noise to a minimum degree. Once the digitized signal is immune to noise, we can implement long haul (10 m ~ 10^3 m) applications in accelerator researching field. Various long hops solution is supported by the IEEE1394A/B interface. The noise immunity and isolation provided by this solution must be welcome in the accelerator environment. Second, unlike analog camera systems, digital systems do not suffer from pixel jitter. Each captured pixel value corresponds to a well-defined pixel on the CCD chip. The IEEE1394 interface is a hot pluggable and self-configuring, high performance serial bus interface that is capable of 400 Mbit/sec data transmission and will be enhanced to 3.2 Gbit/s for next generation products. The interface support asynchronous (guaranteed delivery) and isochronous (guaranteed bandwidth and latency) data transfers. Therefore, data streams between devices are real-time with guaranteed bandwidth and no error correction needed. IEEE1394 complies with the memory mapped model on the IEEE1212.

Low cost scientific IEEE1394 general purposed CCD cameras were chosen for this stage of upgrade. These cameras were QICAM series of QImaging. A progressive scan interline CCD sensor gives a resolution of 1.4 million pixels in 10/12-bit digital output. The QICAM FireWire/IEEE 1394 digital interface offers ease of use and installation with one single wire connection between the camera and computer. There is no frame grabber or additional power supply required. Frame rates of up to 100 fps can be achieved with binning and ROI selection.

3 HARDWARE CONFIGURATION OF SYNCHRTRON RADIATION MONITOR IN THE BOOSTER ANDSTORAGE RING

The synchrotron radiation monitor of booster consists of image forming, image capture, CCD digital camera, and analysis tools. This system is functioning with simple optics. A lens with focal length 500 mm is used to perform 2:1 optics. The band-pass filter is centred at 550 nm with 10 nm band-passes. The camera is working at external trigger mode. A motorized stage can move the CCD camera to accommodate various operating condition range. The system block is shown on Figure 1. The optics has been optimized to minimized measured error resulting from diffraction as well as depth of field effects. Narrowed band pass filters are used to reduce chromatic aberration and to extend dynamic range of the CCD camera. The essentialities of the optics are to optimize the diffraction effect, depth of field and curvature.

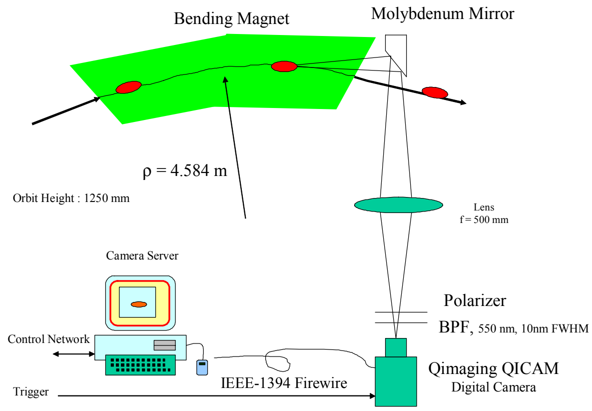

Figure 1: Synchrotron radiation monitor optic layout of the booster synchrotron.

Synchrotron radiation monitor hardware structure of the storage ring is almost the same as that of booster. An achromatic lens is used to perform 1:1 optics. The band-pass filter is center at 400 nm with bandwidth of 10 nm. The camera is working at internal trigger mode. A motorized stage can move the neutral intensity filter before the CCD camera to extend the dynamic range. The system block diagram is shown on Figure 2. Intensified CCD camera with beam splitter is also applied to observe turn-by-turn beam profile to support various beam dynamic studies.

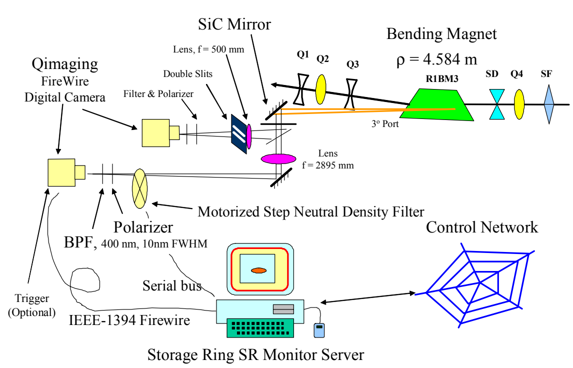

Figure 2: The optic layout of the storage ring synchrotron radiation monitor.

4 SOFTWARE ENVIRNOMENT AND INTEGRATION

The control software is separated into two layers. One is the remote node; the other is local node. The remote node is a normal control console based on LINUX PC that includes of image data access, booster parameter control (database access). This client applications running via LabVIEW server to configure CCD parameters, acquire the image and extract feature parameters from the image. This software of node is located on workstation/Unix and PC/Linux control consoles with commercial software MATLAB and LabVIEW installed. VI pages for routine operation are supported to operate the monitor that is useful for adjusting beam performance.

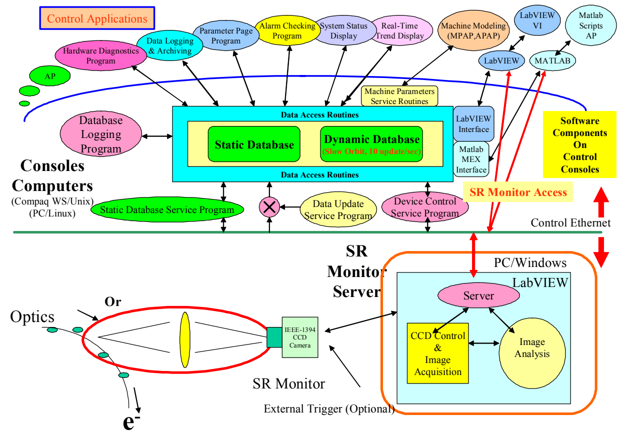

Figure 3: Software environment of the IEEE-1394 imaging system.

The local node is based on windows based-PC running LabVIEW environment, that includes 1394 camera control, network service, image processing and data analysis. This layer is to capture image and to perform pre-processing works. This part of front end PC also handles some camera parameter control including trigger sources, exposure time, times of multiple exposures …etc. Local display page must be supported at the same time in order for local operating and verifying.

This server is configured into multi-threads software environment. These threads based on LabVIEW environment include digital camera driver, Ethernet communication, database control code interface node (CIN), data processing and analysis by Levenberg-Marquardt method CIN, local/ remote computer current status displays. These status include beam size, beam profile display, beam image display, the trigger delay relative to injection timing of booster, and system debugging information.

Image processing and analysis includes extracting the orthogonal profile, beam tilt information of the profile. The pattern reorganization of syntax approach is to identify beam object and reduce beam instability inference. Least square fit are supported to extract beam size and center position. Statistical image analysis tool to analyze spatial moment will be implemented soon to achieve better real-time performance. The display page is broadcasted to whole institute via CATV system and it is web accessible. Functional block diagram of the software environment is shown in Figure 3.

5 OPERATION RESULTS

Since the booster synchrotron is a 10 Hz machine, the injected beam is accelerated from 50 MeV to 1.5 GeV within 50 ms. Exposure time should be as short as possible for energy revolving measurement. External trigger of the camera is synchronized to 10 Hz trigger source. By adjusting 10Hz delay times, the different beam energy profile is captured from camera. Available tools can adjust 10 Hz delay time, camera exposure time, beam size analysis and networking service. All information is also sent to remote console.

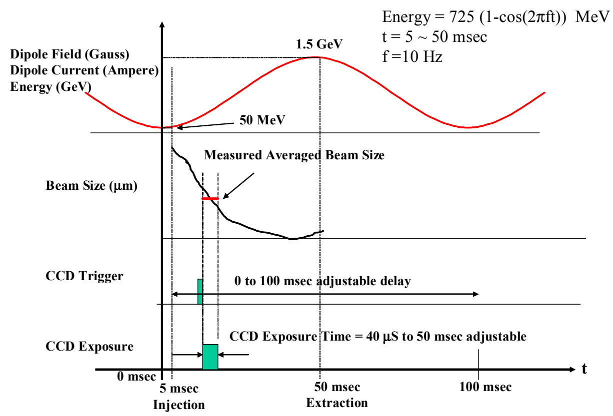

Figure 4: Concept of the measurement sequence during energy ramping of the booster synchrotron.

The relationship of measurement timing is shown in Figure 4: An example of the measurement is also shown in Figure 5. The vertical beam size is reduced when energy increased, and it is due to synchrotron radiation damping. Multiple exposures will be used at low energy side due to low power radiation for measurement without scarified linearity and dynamics range.

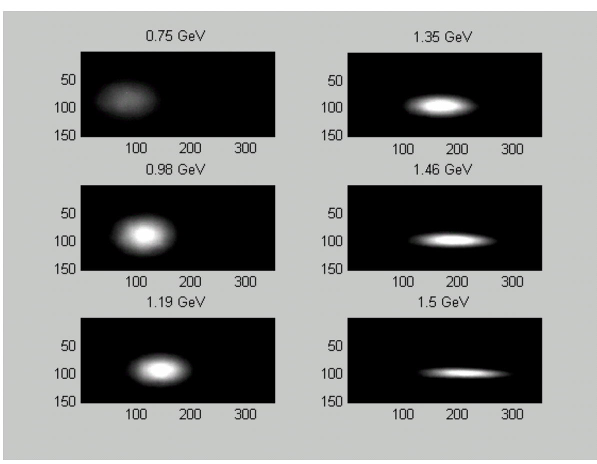

Figure 5: An example of observed beam profiles during ramping with various energies. One unit of the scale is corresponding to 9.4 μm. The exposure time is 0.5 ms.

Intensified Retiga was used for low light application. Here is an example to observe turn-by-turn beam profile of the storage ring after setting RF gap voltage modulation magnitude to double of the synchrotron frequency (2fs ≈ 50 kHz), that helps to relief the effect from high order mode (HOM) of the cavity and to stabilize the stored beam. Modulation depth is about 5% of the total 800 kV RF gap voltage. For turn-by-turn observation, the exposure time of camera was set to 400 ns, which is the revolution time of stored beam. Trigger input to CCD camera is synchronized with the RF gap voltage modulation source. Different delay times after trigger were observed and shown as in Figure 6. The horizontal beam size is at minimum when the RF gap voltage is minimal, and maximal beam size occurs at maximal gap voltage setting; also the profile period value is the relative to modulation frequency. Stable horizontal beam size is obtained by low speed imaging system that enables the integration procedure performed effectively.

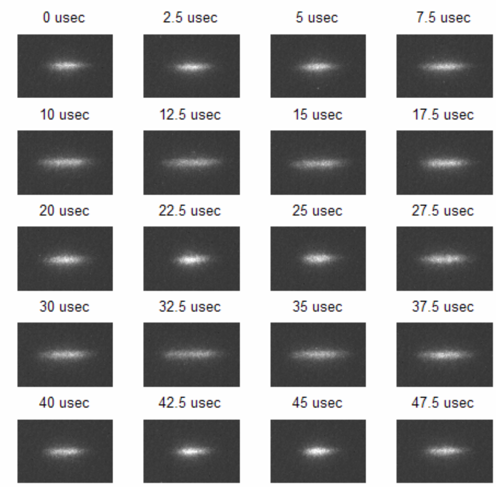

Figure 6: Observed RF gap voltage modulation effect corresponding to the beam profile. Period of the modulation signal is about 20 μsec.

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