SYNCHROTRON RADIATION MONITOR IN THE BOOSTER OF NSRRC

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Abstract

The synchrotron radiation monitor is applied in the storage ring of NSRRC for a long time. The new technique and instrument are necessary in the booster from before operation experience, to measure transverse beam profile with various operation and ramping energy. To provide many dynamic booster parameters, this diagnostic tool must be synchronously and automatically operated. The beam profile measurement system composed optics, image acquisition, and analysis. This system is based on a new generation digital camera that is supported to high dynamic range and fast transient image acquisition. Design, implementation, and performance will be report in this conference.

INTRODUCTION

Synchrotron radiation monitor measures beam profile and beam size of the synchrotron radiation light source for performance optimization, routine operation check and various beam physics study. The monitor should be able to resolve small transverse beam dimension and motion. This tool is 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.

To improve the functionality of the synchrotron light monitoring system, a major upgrade of the data acquisition and analysis have been done recently. The goal is to increase signal transmission quality, the dynamic range, the linearity of the profile monitor, and better analysis supports. The integration of the system with the control system will be described in the following sections. Some results are also included in the system functional demonstration.

HARDWARE CONFIGURATION

The synchrotron radiation monitor of booster consists of image forming, image capture, CCD digital camera and analysis tools. This system is equipping with simple optics. A lens with focal length 500 mm is used to perform 2:1 optics. The band-pass filter is center at 550 nm with 10 nm band pass. 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 due to diffraction as well as depth of field effects. Narrow band pass filter are used to reduce chromatic aberration and to extend dynamic range of the CCD camera. The essential of the optics is necessary to optimize the diffraction effect, depth of field and curvature. FireWire IEEE-1394 CCD camera with 12 bits resolution was chosen to improve the functionality of the image capture and to increase dynamic range (USB2 and Ethernet based scientific CCD camera also emerging market at this moment). The camera embedded ADC on board provides exposure time control and multi-exposures.

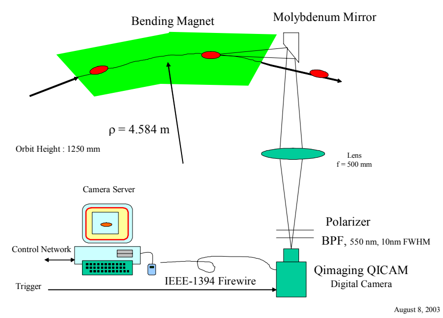

Figure 1: The optic image system of the booster synchrotron radiation monitor.

SOFTWARE ENVIRNOMENT

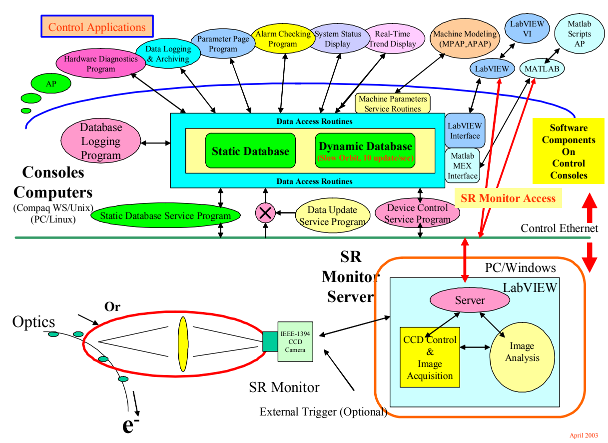

Figure 2: The software system block diagram of the synchrotron radiation monitor.

The control software is separate to two layers. One is remote node; other is local node. The remote node is normal control console based on LINUX PC that include of image data access, booster parameter control (database access). This client applications running on via LabVIEW server to configure CCD parameters, acquire the image and extract feature parameters from the image. This application layer is located at workstation/Unix and PC/Linux control console, supporting commercial software Matlab and LabVIEW. VI pages for routine operation are supported to operate the monitor that is useful to adjust booster performance.

The local node is based on windows based-PC running LabVIEW environment, that include of 1394 camera control, network service, image processing and analysis. This layer is to capture image and to perform pre-processing. This role of front PC also handles some camera parameter control including trigger sources, exposure time, time of multiple exposures …etc. Local display must be supported in the same time.

The local PC is an image server to receive control command from client via TCP/IP protocol. This server is configured to multi-threads software environment. These threads based on LabVIEW include digital camera driver, Ethernet communication, database control code interface node (CIN), data processing by Levenberg-Marquardt method CIN and status display for local/ remote computer. These status include beam size, beam profile display, beam image display, the trigger delay relative to injection timing of booster, and system debug information.

Image analysis includes extracting the orthogonal profile, beam tilt 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 also broadcast to the CATV system and access via web. For demand user, Matlab scripts are also supported; the users can configure their measurement by themselves and gain the benefit of powerful image analysis toolbox of the package. Functional block diagram of the software environment is shown in figure 2.

IMAGE ACQUISITION AND DATA ANALYSIS

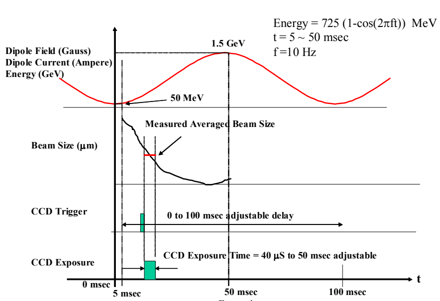

Figure 3: Concept of the measurement sequence during energy ramping of the booster synchrotron.

Since the booster synchrotron is a 10 Hz machine, the injected beam is accelerated from 50 MeV to 1.5 GeV within 50 ms. The exposure time should be as short as possible. The measurement timing is shown in figure 3. One profile measurement is possible at specific energy by adjusting the delay time of dipole power-supply. Slipping the delay time, the profile at different energy can be acquired. An example of the measurement is shown in figure 3. The vertical beam size are reduced when energy increase due to strong damping. Multiple exposures will be used for low energy measurement without scarified linearity and dynamics range.

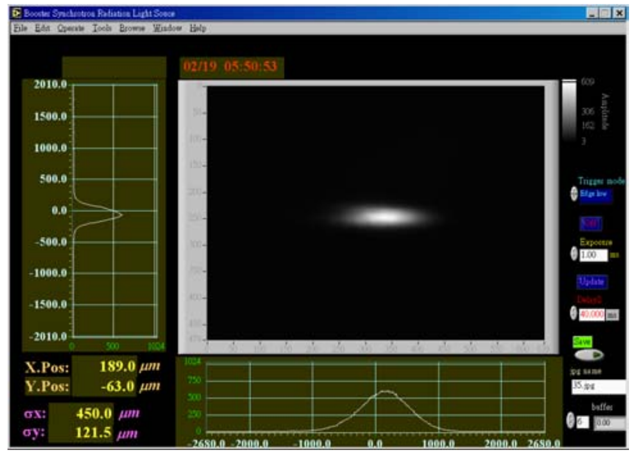

Figure 4: Display page for the booster synchrotron radiation monitor in local node.

The extern trigger circuit of camera is synchronized to 10 Hz trigger. By adjust 10Hz delay times; the difference beam energy profile is captured from camera. This image and profile is shown in the figure 4. This is local control user interface. This tools can adjust 10 Hz delay time, camera exposure time, beam size analysis and networking service. These informations are sent to remote console.

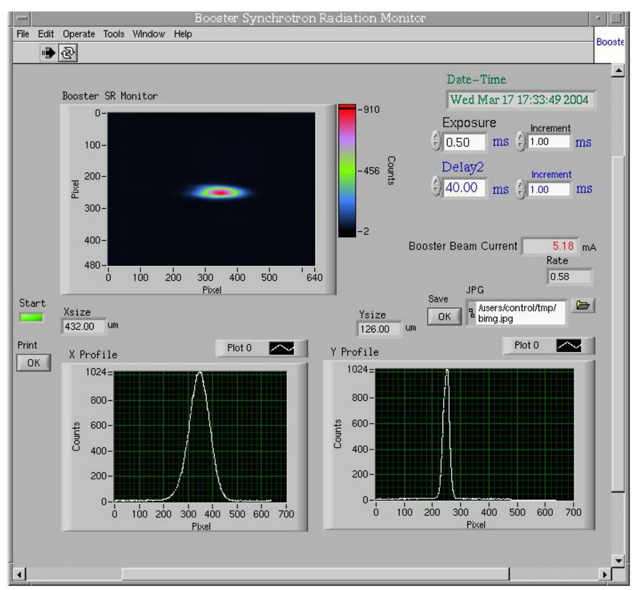

Figure 5: Graphic user interface on remote control console.

The remote console is support that image access, profile access, exposure time of camera control, 10Hz delay time control and booster beam current display. This graphic user interface is shown in the figure 5.

The profile image versus beam energy is shown on figure 6. The 10 Hz delay time is converted to beam energy by equation 1.

$$Energy = 725(1-\cos(2\pi ft))MeV \qquad (1)$$

where t = 5 ~ 50 msec delay time, f = 10Hz.

In the low energy, the beam intensity is weak. So, high dynamic range CCD camera is necessary in this application.

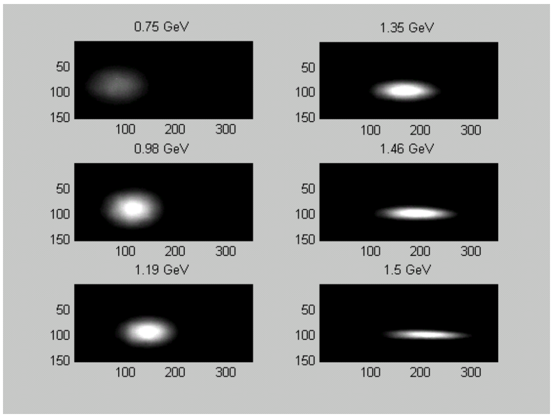

Figure 6: An example of observed beam profile during the ramping with several various energies. One unit in the scale corresponding to 9.4 µm. Exposure time is 0.5 ms.

REFERENCES

[1] C.H. Kuo, et al., “Transverse Profile Measurement System ay SRRC”, Proceeding of the EPAC’94, 1646 (1994).

[2] Åke Andersson, Juri Tagger, “Beam Profile Measurements at MAX”, NIM A364 (1995) 4-12.