STATUS OF THE SYNCHROTRON RADIATION MONITOR AT TLS

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Abstract

Synchrotron radiation monitor of the Taiwan Light Source have been revisit recently. Improvement of optics and modelling was performed to improve accuracy measurement for small beam size. Synchrotron light interferometer is also implemented for complementary measurement. The CCD camera are adopted by newly IEEE-1394 digital CCD camera improve image quality and dynamic range. Intensify gated camera are also adopted for dynamic measurement of the stored beam property observation. Functionality of image analysis too, is also address during this upgrade. Efforts and achievements will be summary in this report.

INTRODUCTION

The synchrotron radiation monitor captures beam profiles and measures the beam size at the synchrotron radiation light source to optimize performance, check routine operations and support various physics experiments using the beam. The monitor should be able to resolve the transverse dimensions and motion of a small beam. The tool has been useful for characterizing the electron beam since the system began normal operations ten years ago [1]. The beam emittance is calculated from the measured beam size. A major upgrade of the data acquisition and analysis system was recently performed to improve the functionality of the synchrotron light monitoring system [2]. The goal was to increase the signal transmission quality, the dynamic range, the linearity of the profile monitor and the quality of analysis. The following section will describe the integration of the system with the control system. Some results are also included in the system functional demonstration.

BOOSTER SYNCHROTRON RADIATION MONITOR

The synchrotron radiation monitor consists of image forming optics, a CCD digital camera to capture images and analytic tools. The optics is required to optimize the diffraction effect, the depth of field and the curvature. A FireWire IEEE-1394 CCD camera [3] with a 12 bit resolution was adopted to improve the functionality of the image capture and the dynamic range scientific CCD cameras. The embedded processor and the built-in ADC of the camera provide exposure time, gain and offset control. The multi-exposure function is also supported in the camera.

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 to support revolving measurement of energy. External triggering of the camera is synchronized to the booster 10 Hz cycle clock. The delay times are adjusted to enable the different beam energy profiles to be captured by the camera. These parameters are controlled via network service, consists of the 10 Hz delay time, camera exposure time. The remote consoles allow all information to be accessed using a client program. Figure 1 presents a system layout. Figure 2 presents an example of the measurement during energy ramping. The vertical beam size is reduced as the energy is increased, because of synchrotron radiation damping. Multiple exposures at low energy are used to measure low-intensity synchrotron radiation light. Multiple exposures also increase the dynamic range for measurement without loss of any linearity, especially in weak light applications.

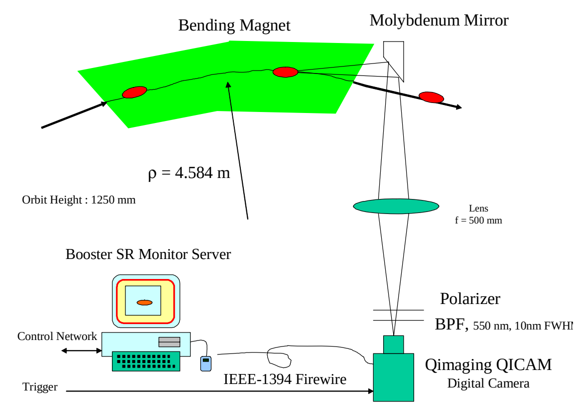


Figure 1. System block diagram of the booster synchrotron radiation monitor.

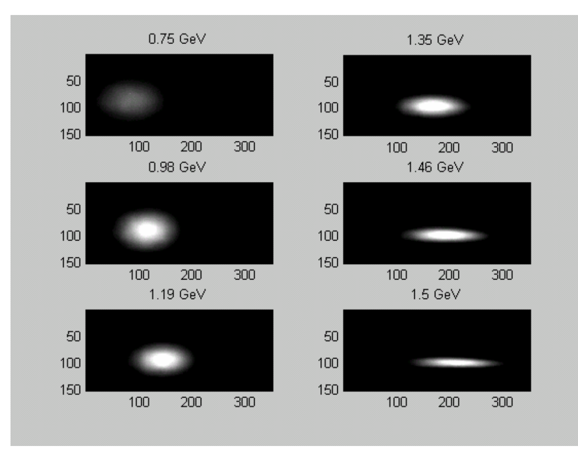


Figure 2. Example of observed beam profiles during ramping with various energies. With 2x2 binning, the pixel size is 9.4 μm x 9.4 μm. Exposure time is 0.5 ms.

STORAGE RING SYNCHROTRON RADIATION MONITOR

The synchrotron radiation monitor of storage ring uses the same camera interface. The local computer is a Windows based-PC that is running a LabVIEW network server environment; includes camera control with a driver, neutral density control with serial bus, image capture, pre-processing, analysis and display. The client applications running on the control console can control a remote CCD, acquire the image and extract feature parameters from the image. The synchrotron radiation monitor of the booster and storage ring both share the same hardware and software to improve integration and ease of maintenance. Figure 3 shows a functional block diagram of the software environment. Figure 4 shows the basic optics structure in the storage ring.

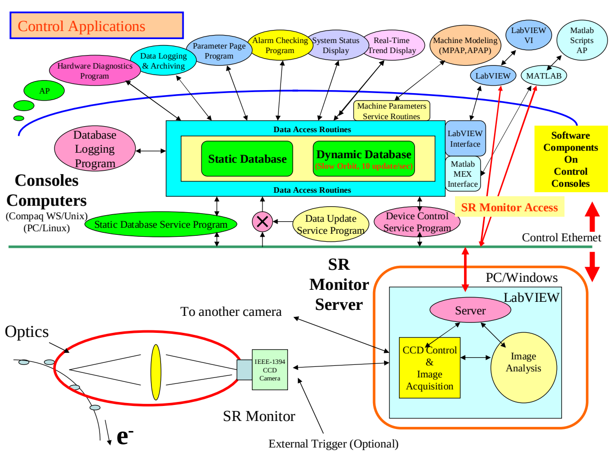


Figure 3. Synchrotron radiation monitor software system.

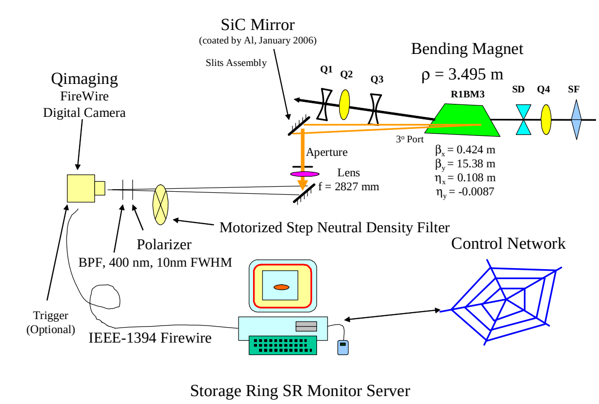
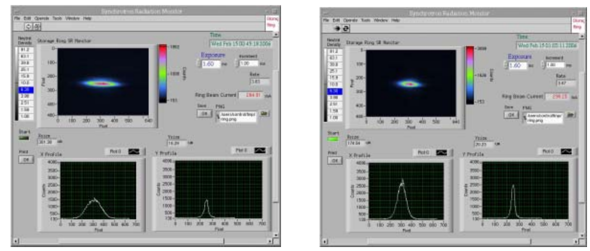


Figure 4. Optics of the synchrotron radiation monitor in the storage ring.

Figure 5 presents the effect of the feedback loop on the measured synchrotron radiation profile. Since the synchrotron radiation monitor is located in the dispersion region, the energy oscillation is more obvious than other location. This effect contributes substantially to the horizontal beam size. After the feedback loop is turned on, the horizontal beam size is drastically reduced.

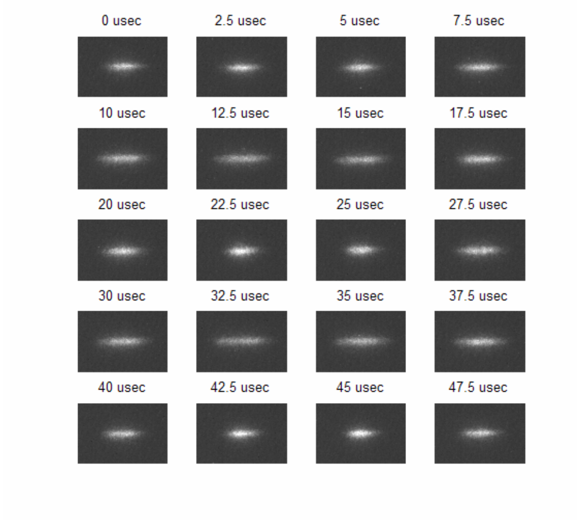


(a) Loop open (b) Loop closed

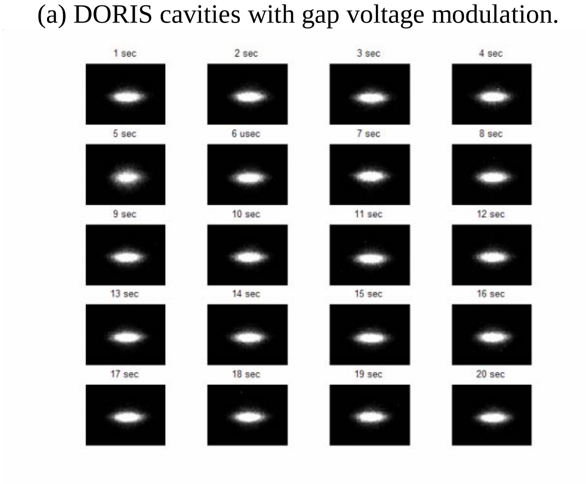
Figure 5. Transverse beam profile with and without longitudinal feedback. Source of the synchrotron radiation is in the dispersion region. The horizontal beam size is effectively reduced by the longitudinal feedback loop.

USE OF GATED CAMERA FOR MEASURING A SINGLE TURN BEAM PROFILE

An intensified gated CCD camera was used to make low-light observations to study profile variations under various operating conditions. The synchrotron radiation monitor is located in the dispersion region; energy oscillations contribute to the horizontal beam size. If the RF system is longitudinally stable, then the energy oscillation is small and the variation of the horizontal beam size is negligible. Unstable energy oscillation in the high-order mode of the Doris conventional cavities is severe. RF gap voltage modulation was used to relieve the high order mode (HOM) effect of these cavities and to stabilize the stored beam before the SRF upgrade. The modulation frequency and depth are twice the synchrotron frequency ($2f_s \approx 50$ kHz) and 5% of the total 800 kV RF gap voltage, respectively. The exposure time of the camera was set to 400 ns, which is same as the revolution time of the stored beam, to observe a single turn beam profile. The trigger signal input to the CCD camera, is synchronized with the RF gap voltage modulation source. The images of different delays after triggering were presented in Figure 6 (a). The horizontal beam size is small when the RF gap voltage is minimal. The maximal beam size is in the maximal RF gap voltage. The image change period is the same as the modulation period. A stable horizontal beam size is obtained by using a low-speed imaging system that is presented to effective image integration. The beam profile is fluctuated without this gap voltage modulation, indicating that the longitudinal instabilities significantly degrade the beam stability. The two Doris cavities were replaced by one CESR superconducting RF cavity to increase the beam stability and to double the maximum stored beam current. The total gap voltage is increased to 1.6 MV. The measured single-turn beam profile is much more stable than before, as presented in Fig. 6 (b). The variation of the horizontal beam size due to longitudinal coupled bunch oscillation is much less than that of the Doris cavities because the SRF cavity is almost HOM-free.



(a) DORIS cavities with gap voltage modulation.



(b) After SRF upgrade.

Figure 6. Single turn profile. (a) Observed beam profile at difference phase of RF gap voltage modulation cycle for conventional RF cavities with gap voltage modulation. Period of modulation signal is about 20 μs (2 fs ≈ 50 kHz). (b) Single turn profile observation after SRF system upgrade over an observation period of 20 s. The time on the top of each profile image is the time elapsed from the beginning of image acquisition.

Turn by turn beam position measurement is just after the injection kicker fired, the stored beam is perturbed by the leakage of four kickers local bump. Horizontal and vertical betatron oscillation is excited in the injection. It can see from the centroid position change by the turn-by-turn beam profile measurement. Clean beataron oscillation shows in Fig. 7.

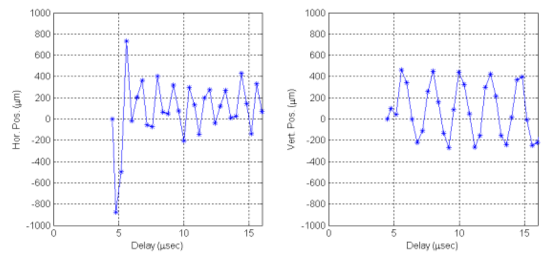


Figure 7. Variation of beam profile centroid just after injection kicker fired. Stored beam performed betatron oscillation in horizontal (left side) and vertical plan (right side).

SUMMARY

The synchrotron radiation monitor of the TLS was updated to improve functionality and performance. A high-linearity IEEE-1394 CCD camera replaced the original camera. Various application programs are being developed to support the new imaging system and will also provide a user-friendly interface for various applications. The upgraded synchrotron light monitor is convenient to use. High linearity will help in making beam physics measurements..

REFERENCES

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[3] Website : http://www.qimaging.com.