USER INTERFACES DEVELOPMENT OF IMAGING DIAGNOSTIC DEVICES FOR THE TAIWAN PHOTON SOURCE

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Abstract

Taiwan Photon Source (TPS) is a 3 GeV synchrotron light source which is being construction at campus of National Synchrotron Radiation Research Center (NSRRC) in Taiwan. Many diagnostic devices are used for the implementation and will be deployed to assist commissioning and operating the TPS. The imaging diagnostics devices, includes screen monitor (SM), streak camera (SC), and intensified CCD (ICCD) are used and its user interfaces are plan to develop. Control of these applications is centered around EPICS IOC. The windows OS based system, such as SC and ICCD, are controlled respectively through the Matlab (combined with LabCA module) and LabVIEW (combined with DSC module) tools and share the data as EPICS PVs. The main user interfaces and data analysis are constructed by Matlab GUIDE toolbox. The progress of the plans will be summarized in this report.

INTRODUCTION

Taiwan Photo Source (TPS), a 3 GeV third generation synchrotron light facility, featuring ultra-high photon brightness with extremely low emittance which is being installation at National Synchrotron Radiation Research Center (NSRRC) campus. For optimize machine operation and diagnostics applications, the two-dimensional beam-related images were recorded by screen monitor, streak camera, and intensified CCD, which are widely used in synchrotron light source facility. Due to the most of machine parameters in future TPS [1] will be accessible as EPICS (Experimental Physics and Industrial Control System [2]) process variables (PVs). Thus, an analysis tool use the PVs as inputs with ability to calculate and display results in complex ways is needed. This report presents an EPICS integrated with Matlab and LabVIEW as a data processing system which is not only could be used in image analysis but also in other equipments command/data transmission/processing. The hardware configuration and software structure will be summarized in this report.

OVERVIEW OF IMAGING DIGNOSTICS

Many diagnostic devices are used for the implementation and will be deployed in the future to assist commissioning and operating the TPS. The imaging diagnostics devices, includes screen monitor, streak camera, and intensified CCD were used which are described in this section.

Screen Monitor/OTR

For the TPS beam diagnostic application distributed in Linac, LTB, BTS, booster, and storage ring, the screen monitor is responsible for the beam profile acquisition from YAG:Ce/OTR screens and used to analysis to find the beam characteristic data. The location and quantity of the screen monitor is listed in Table 1. The beam profile image has extensive information on beam parameters, including beam center, sigma, tilt angle and etc. The optical system contains screen, lens, and lighting system. The PoE CCD camera with Gigabit Ethernet interface (GigE Vision) will be a standard image acquisition device. The CCD timing trigger clock is locked with TPS injection system, which is produced from a local timing IOC (EVR).

Table 1: Location and Quantity of the Screen Monitor

Location	Quantity
Linac	5
LTB	5
Booster	6
BTS	3
Storage ring	1

Synchrotron Radiation Monitor

The synchrotron radiation monitors are designed in LTB, BTS, booster, and storage ring. In the LTB and BTS, a simple visible light optics at bending magnet captured by external trigger GigE Vision CCD camera is planned for useful routine operation. In the booster synchrotron, near UV optics and synchronized with the machine cycle is planned. The synchrotron radiation light photons emitted by the electron bunches passing through a particular dipole in the TPS booster ring, is reflected from three molybdenum mirrors and passed through the convex lens (F=1000 mm) onto a 1-inch type CCD sensor. The simple optics offers 1:1 image reduction.

In the storage ring, due to the small beam size and emittance (~1 nm-rad), a X-ray pinhole camera with crystal screen and GigE Vision CCD camera is planned, and possible for the feedback signal for beam size feedback. The motorized stage can move the camera in XY direction to scan the beam profile right at the center of the CCD screen and to find the optical focus point by moving the Z direction. A near UV light profile measurement for low light application and visible light synchrotron light interferometer for precision beam size measurement are also planned in TPS storage ring.

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Streak Camera

The streak camera is widely used in synchrotron light source facility for beam dynamic machine study. A new dual sweep streak camera (C10910) with one fast, one slow and two frequency of synchroscan sweep unit is used to perform temporal/longitudinal beam measurements at TPS. The beam motion in the longitudinal direction (phase information) could be observed by using the synchroscan unit (operate at 125/250 MHz). By using the fast single sweep unit triggered by the orbit clock, the single shot bunch length, which is the function of beam current, can be measured in picoseconds resolution. By using the slow sweep unit it is possible to look at the stability of the beam over several milliseconds. The dual time-based unit allow the streak camera to be operated in dual sweep mode. There are many other experiments that can be done such as bunch length measurements with different bunch current and RF gap voltage, synchrotron phase investigation, and instability observations, etc.

Intensified CCD

An Intensified CCD camera (PI-MAX3 1024i) is used to make transverse measurements of the beam. The gate width of 0.2 ns allows a head-on image of a single bunch to be capture in order to analyse the shape and stability of the bunch structure of the beam.

DEVICES CONTROL FRAMEWORK

In the screen image profile diagnostics solution, a Gigabit PoE embedded vision system (ADLINK, EOS-1200 [3]), was used instead of traditional computer and PoE switch. It is a rugged and compact embedded vision system equipped with the 2nd generation CPU (i7) and four independent PoE ports. It also supports a rich I/O capability, including four serial ports (RS232/422/485), two USB 3.0 ports, 32 PNP/NPN isolated digital I/Os, which make it ideal to integrate, and deploy with other subsystem (such as screen position control) for system development.

The main infrastructure of imaging diagnostic devices is developed by using an EPICS IOC integrated with Matlab/LabVIEW program to build up a command/data transmission/processing system. The Linux OS plus EPICS IOC infrastructure is employed for the screen monitor CCD camera as shown in Fig. 1. The Linux OS computer system based on EPICS 3.14.10 (Linux, 2.6.18) can act as a soft IOC (Input / Output Controller) which is used to communicate to devices and collect images data via Ethernet. Image acquisition will be done on EPICS IOC via PV channel [4] and analysis the properties by using Matlab tool to evaluate the beam profile (sigma), beam size position and tilt angle et al. The Matlab was chosen as the candidate computational tools, due to it offers a familiar environment and easy communicated with EPICS PVs.

The LabVIEW has the ability to communicate with other devices and software using the EPICS standard protocols. Since the intensified CCD camera is controlled

through the LabVIEW under Windows OS, the LabVIEW Datalogging and Supervisory Control module [5] was used to create the PVs or communicate to PVs through the Server and Client I/O server functions, as shown in Fig. 2.

For the streak camera, it is controlled through the RemoteEX and HPDTA program which is developed by HAMAMACHI under Windows OS. The TCP/IP command is used to directly control the device and get image data. The overview of the infrastructure is shown in Fig. 3.
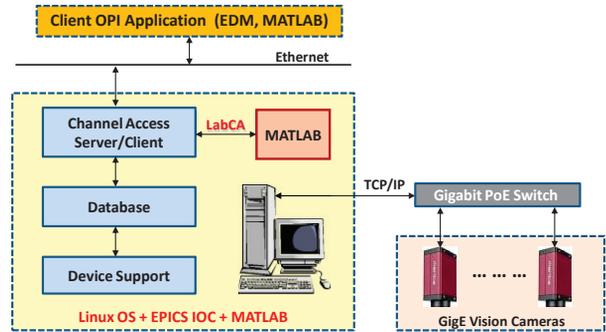

Figure 1: Overview of the infrastructures for the screen monitor CCD camera.
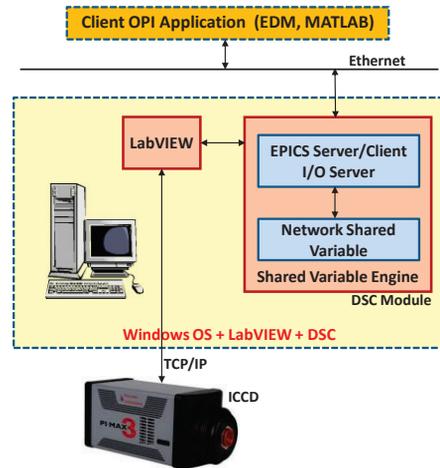

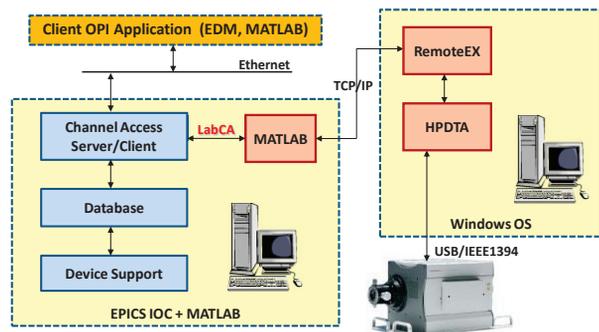Figure 2: Overview of the infrastructures for the ICCD camera.

Figure 3: Overview of the infrastructures for the streak camera.

USER INTERFACES DEVELOPMENT

EDM Camera Control Panel

Based on the areaDetector module (R1-9-1) [6-7] which provides a general-purpose interface for area (2-D) detectors in EPICS, it is easy to construct a camera control panel by using the EDM tool. The screen monitor user interfaces for the TPS Linac, LTB, BR, BTS, and SR are shown in Fig. 4, which can switch in between in one GUI. The camera parameters of exposure time and gain can be configured in this panel, the camera location also shown below. The trigger mode selection include that the Free-Run for simply monitor the image and Sync-In for synchronization of linac injection (3 Hz). This EDM panel only offer lunch the screen, control the CCD parameters and simple monitoring features but do not perform any calculations. The image analysis work is mainly performed by using Matlab GUI as shown in the below section.
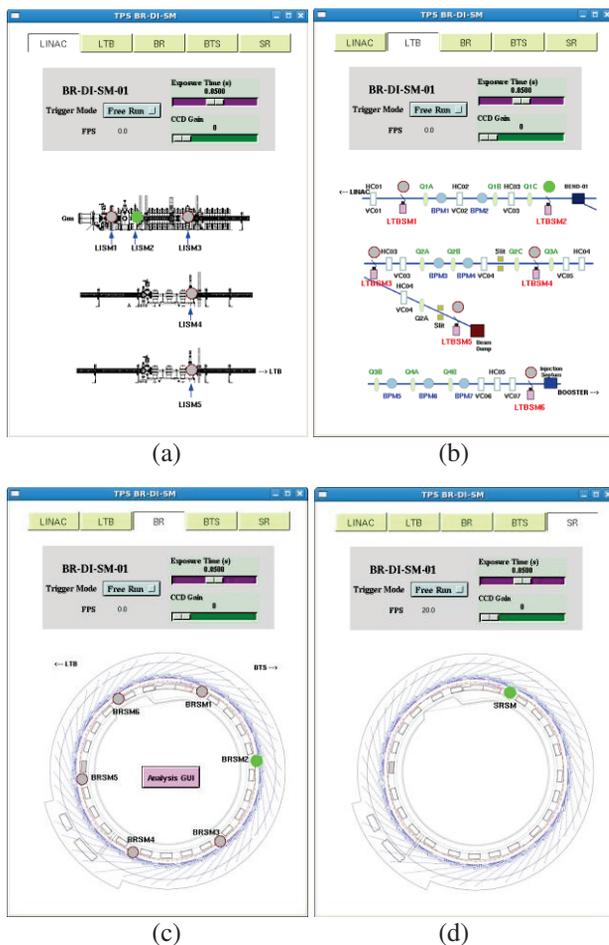

Figure 4: The EDM camera control user interfaces for the screen monitor of (a) Linac, (b) LTB, (c) BR, and (d) SR. The top bar can switch in between the five pages, and the cameras location shows in below.

Matlab GUI

The image analysis work is mainly performed by using Matlab GUI [8-9], the layout as shown in Fig. 5. The GUI can run in multiple clients simultaneously and read the analysis results from EPICS IOC and display them in the window.

The GUI contains six parts: menu, toolbar, control panel, fitting results, projected profile, and raw image. The menu and toolbar provide save data, colormap change, ROI specify, simulation, reset and close program, and zoom in/out functions. In the control panel it contains active the program, 3D viewing, multi-exposure, and background subtract functions. The fitting results area contains sigma and center in the units of pixel and mm, and beam tilt angle. Two directions, horizontal and vertical, of beam projected profiles of raw data and fitting curve are predrilled in two axes. The camera raw image with the colorbar is integrated into the display GUI. The function of export the raw image data and analysis results can be done. It also can create a simulated beam image for the purpose of evaluating the fitting correctness.

The Matlab analysis program runs in IOC's PC as a background task which can do a complex analytical work to analyze the beam parameters, including the beam center, sigma, and tilt angle. It can specify the region-of-interest (ROI) for clipping the image of each individual camera, and do an optional background subtraction and software multiple exposures. All the analyzed data will store into the EPICS IOC as PVs.
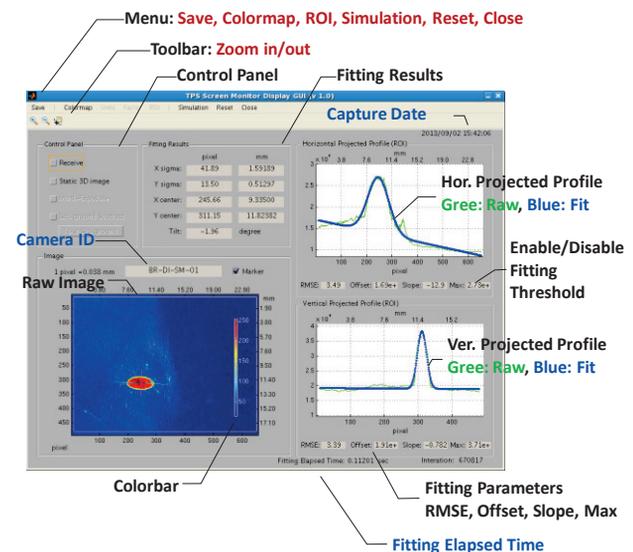

Figure 5: Layout of the Matlab analysis display GUI for screen monitor.

Matlab Streak Image Data Analysis GUI (Offline)

The offline streak image data analysis program was developed by the Matlab tool, as shown in Fig. 6. Finding the bunch length for the specify ROI was implemented in this GUI, the analysis results as a graph and table as shown in Fig. 7. It is helpful for batch file analysis.
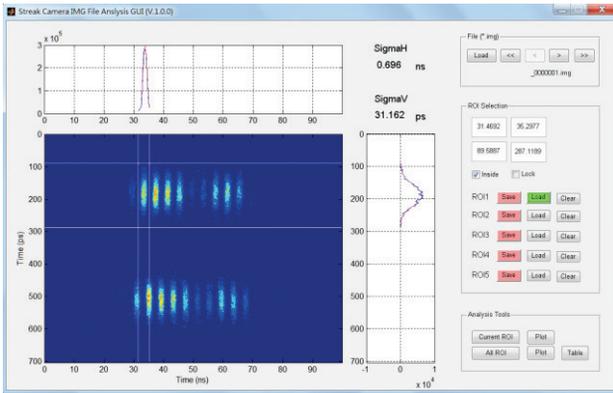
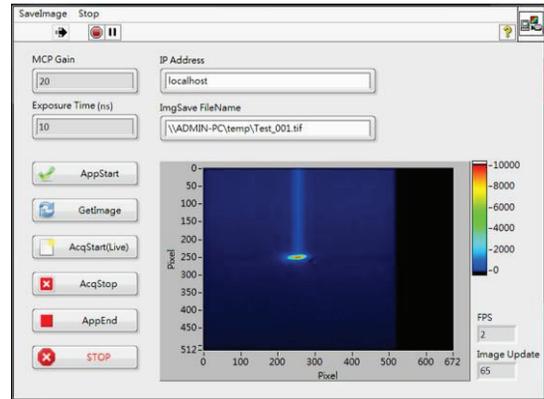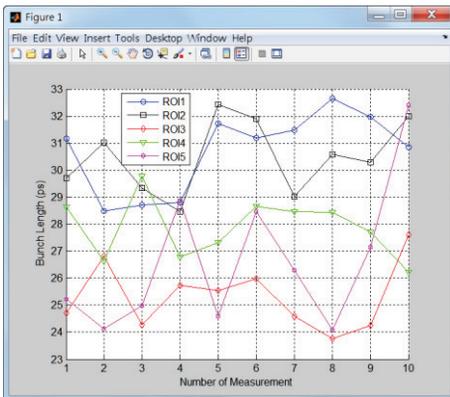Figure 6: The Matlab analysis GUI for streak image batch file analysis.

(a)

(b)

Figure 7: Analysis results of the streak images display in (a) Graph and (b) Table.

LabVIEW GUI

The LabVIEW GUI was developed for the gated ICCD control and display. The layout of the LabVIEW GUI is shown in Fig. 8. It contained a EPICS IOC by using the LabVIEW Datalogging and Supervisory Control module which can create the PVs or communicate to PVs through the Server and Client I/O server functions.

Figure 8: The LabVIEW control/display GUI for ICCD.

SUMMARY

The imaging diagnostics devices, includes screen monitor, streak camera, and intensified CCD are used and its user interfaces are plan to develop. The windows OS based system, such as SC and intensified CCD, are controlled respectively through the Matlab (combined with LabCA module) and LabVIEW (combined with DSC module) tools and share the data as EPICS PVs. The main user interfaces and data analysis are constructed by Matlab GUIDE toolbox. This solution can be extended to other applications, such as beam lifetime calculation, filling pattern measurement, real-time oscilloscope waveform analysis, and other equipments data processing.

REFERENCES

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