UPGRADES TO THE SPEAR3 SINGLE-PHOTON BUNCH MEASUREMENT SYSTEM

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Abstract

The SPEAR3 accelerator uses a Single Photon Time-Correlated Counting (TCSPC) system to accurately measure the time profile of electron bunches circulating in the storage ring. The detection hardware uses the PicoHarp 300 TCSPC processor module initially equipped with a Hamamatsu H7360-01 photon counting head. The H7360-01 was replaced with a PicoQuant Hybrid-06 PMA to decrease single-photon arrival time measurement jitter. At the same time we adopted an EPICS-based TCSPC software package developed at DIAMOND for robust data acquisition and display. In this paper we report on recent beam profile measurements and upgrades to the data acquisition software system including installation of a local EPICS IOC for real-time access to the bunch profile from SLAC's centralized Accelerator Control Room (ACR). High-level operator interface and monitoring applications developed in Python are discussed.

INTRODUCTION

The 3 GeV SPEAR3 storage ring at SLAC provides x-ray light to a variety of synchrotron radiation beamline users including pump-probe timing mode experiments which require a single, isolated charge bunch. The synchrotron light monitor (SLM) is a diagnostic optical hutch which houses experiments in the visible spectrum for accelerator diagnostics. The hutch contains visible light diagnostics to monitor longitudinal and transverse beam size as well as measurements of injector performance and the Time-Correlated Single Photon Counting (TCSPC) system to monitor the bunch current distribution and spilled charge. Previously TCSPC measurements [1] were conducted during time-sensitive user runs to measure unwanted satellite bunches. Implementation of the new acquisition system allows the TCSPC system to run continuously and provide timing information remotely on demand.

TCSPC HARDWARE

Since 2014 TCSPC measurements have used a PicoQuant Picoharp 300 [2] to process signals from an available Hamamatsu H7360-01 PMT detector. In the SLM hutch a portion of the visible light beam is captured with a pickoff mirror and transported into a light tight box which contains the detector assembly. The beam is collimated, filtered to 540nm, and attenuated with an ND4 filter to achieve an effective ratio of 0.05 photon counts per revolution to avoid pile up during the Picoharp 300 deadtime. Figure 1 shows a block diagram of the data acquisition layout. The PicoHarp 300 is clocked with a 1.28 MHz bunch revolution frequency signal generated from the 476MHz master oscillator. The 1.28 MHz ring clock creates a trigger for the bunch timing histogram profile over 781 ns with 16 ps bin resolution. In 2015 the Hamamatsu H3760-01 detector was replaced with a PicoQuant Hybrid PMA [2], a peltier cooled detector with 50 ps timing resolution. The new detector has greatly increased the measurement accuracy of the system by reducing timing jitter in the single-photon arrival time. Figure 2 shows a comparison between the bunch profiles measured with the two detector heads. Profile fitting shows a factor of 10 reduction in the measured bunch pulse length. The spacing between buckets for the PMA profile becomes distinct with little noise between peaks. The improvement provides a cleaner signal for bunch purity measurements.

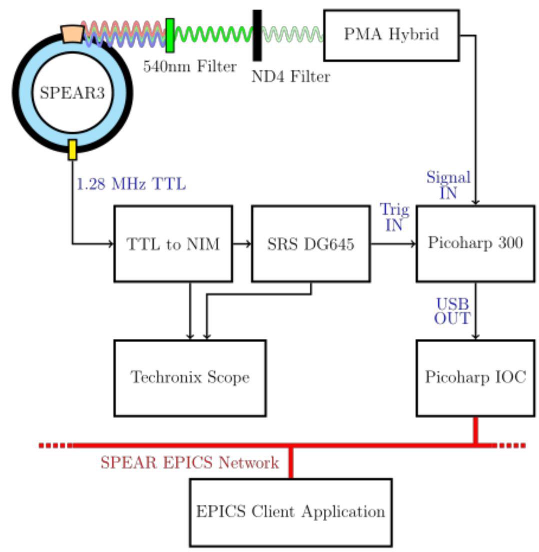

Figure 1: Block diagram of the TCSPC hardware and signal layout

EPICS IOC UPGRADE

To further improve data the acquisition system an EPICS IOC was built to interface with the PicoHarp 300 hardware. A software package created by the Diamond Light Source controls department [3] was installed on a linux PC in the SLM lab. The DIAMOND software allows remote control of the Picoharp 300 hardware, and serves to upload raw and processed data to client applications though the EPICS network. The IOC processing includes built in TCSPC pileup correction and fitting routines to measure photon counts in all 372 possible buckets. The counts are then normalized to the SPEAR3 beam current monitor to provide beam current/bunch. Waveforms PVs are then created for the full data set (65536 bins) and processed data set with 372 elements, one for each charge bucket. The database contains waveform PVs of this data for integration times of 5, 60

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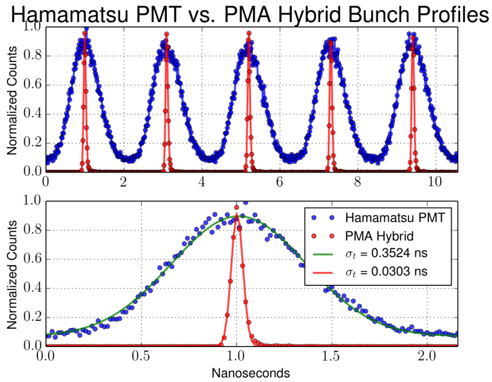

Figure 2: Bunch profile comparison of the Hamamatsu H3760-01 vs PicoQuant Hybrid-06 PMA detectors. The H3760-01 initially in service was not designed for this application.

and 180 seconds. The original DIAMOND software was modified to split the charge-normalized waveform PV into individual PVs for separate readback of each bunch. The bunch by bunch charge measurements easily integrate into the Matlab middlelayer system and will be recorded in the SPEAR3 archive system for tracking. The linux-based IOC has proven a stable platform for long periods of time without fault. The TCSPC system has allowed for long term monitoring capability. For example, the bunch train profile can be measured in 5 minute top up increments over several days during timing bunch experiments. A slight diurnal drift on the order of picoseconds has also been observed likely due to temperature changes in the length of the cable delivering the 1.28MHz ring clock to the PicoHarp 300

PYTHON INTERFACE

A new TCSPC GUI interface was created using the Python/PyQt framework to monitor the bunch profile from SLAC's accelerator control room (ACR). The software acts as a continuous update display for TCSPC data to be monitored by control room staff. It includes a display of the live high resolution TCSPC waveform, a difference profile from the last top up fill, and Gaussian fitting on the single timing bunch. Changes or drifts in the injector chain timing can result in top-up injections for the timing bunch which are partially captured in adjacent buckets, the magnitude of which is measured and displayed. Bunch purity is calculated by taking the ratio of the timing bunch charge to adjacent satellite bunch charge. This is displayed below the timing bunch profile in the interface. Typical values for the measured bunch purity are 1e3 with 180 seconds integration time. Since 2015 operations for SLAC's LCLS and SPEAR3 facilities have shifted to the ACR requiring remote access to diagnostics and control. Python/PyQt user interfaces have developed as part of the common control room displays, offering faster startup time than Matlab, and improved scripting ability over EDM type displays. Speed of development, simple EPICS integration [4], and an open source license have made python an attractive choice for similar high level interfaces (Fig. 3).

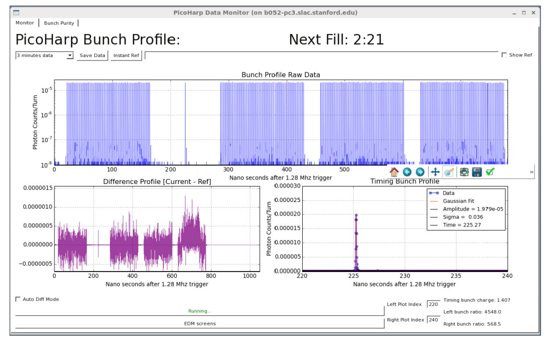

Figure 3: GUI layout for control room monitoring of bunch trains, timing bunch fitting, and new fill difference profile.

CONCLUSION

A stable TCSPC data acquisition system has been installed for SPEAR3 enabling continuous monitoring of bunch train charge. The previous Hamamatsu PMT was replaced with a PicoQuant PMA yielding improved measurements from a reduction of timing jitter. The software system improved from a commercial application to an EPICS IOC, which has enabled monitoring of the bunch purity from the accelerator control room. Future plans for TCSPC include integration of single bunch charge PVs into the SPEAR3 PlotFamily Matlab application, investigation into optimizing counting efficiency using reverse counting mode [5], and robust timing solutions to minimize satellite bunch charge.

REFERENCES

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[5] Reverse counting mode, `http://scitation.aip.org/content/aip/journal/rsi/86/11/10.1063/1.4934812`