# DIAGNOSTIC SYSTEMS FOR THE TLS SRF SYSTEM

Yu-Han Lin*, Meng-Shu Yeh, Fu-Tsai Chung,
Choan Wang, Lung-Hai Chang, Ming-Chyuan Lin, Chih-Hung Lo
National Synchrotron Radiation Research Center, Hsinchu 30076, Taiwan, R.O.C.

*Abstract*

To improve the reliability of a contemporary synchrotron as light source, a diagnostic system is crucial. A satisfactory diagnostic system must enable a clear presentation of the reason for a system fault, and provide sufficient information to the data analyzer for system recovery and improvement. To identify a fault and to monitor the operation of a RF system, many diagnostic utilities have been adopted. The architecture for the diagnostics of the TLS RF system is here reported.

## INTRODUCTION

The Taiwan Light Source (TLS) is a 1.5-GeV third-generation synchrotron accelerator. Its 500-MHz single-cell superconducting cavity operated at gap voltage 1600 kV to store a 300-mA beam current has been adopted since 2005 February. Top-up injection has been routinely operated since 2005 October, and a maximum beam current 400 mA for a long-term test was achieved during 2007.

Superconducting RF technology has greatly improved both the flux intensity and beam stability, but system reliability remains a challenge for system operations. Diagnostic systems are thus crucial to identify a system fault and to remedy it during an operational phase. Here we report the diagnostic systems for the TLS RF system, which consists of hardware, home-made software and database servers. Further developments of these aspects are also discussed.

## THE DIAGNOSTIC SYSTEM

The diagnostics of our TLS RF system are divisible into three levels according to the speed of sampling. Figure 1, shows that the diagnostic devices with the greatest rate of sampling are oscilloscopes; these devices not only capture signals, such as arcing and kicker firing, with a very brief period, but also other important signals are monitored in this manner.

Apart from oscilloscopes, diagnostic devices of medium speed (100   500 kilosamples $s^{-1}$) are important for trip analysis. We have at present three data-acquisition machines (Nicolet Vision XP) for analysis of a storage-ring fault; each machine has sixteen channels. For a general storage-ring trip, a fault analysis with this data-acquisition machine is more convenient than with an oscilloscope. Most signals of a SRF system, including forward power and reflected power of the LLRF, kicker-firing signals, beam-current signal and orbit signals, are at present connected to these acquisition systems. Because of the numerous channels, the reason for a fault in the storage ring is quickly identifiable and solvable.

* yuhanglin@nsrrc.org.tw

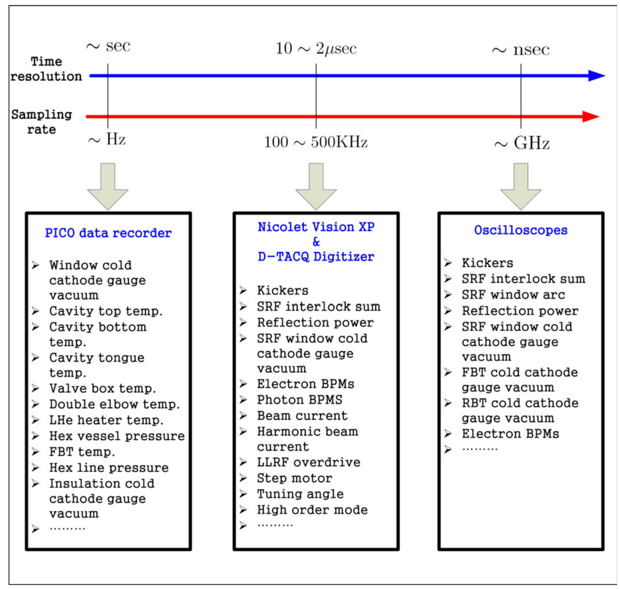


Figure 1: Tools available to diagnose a trip event

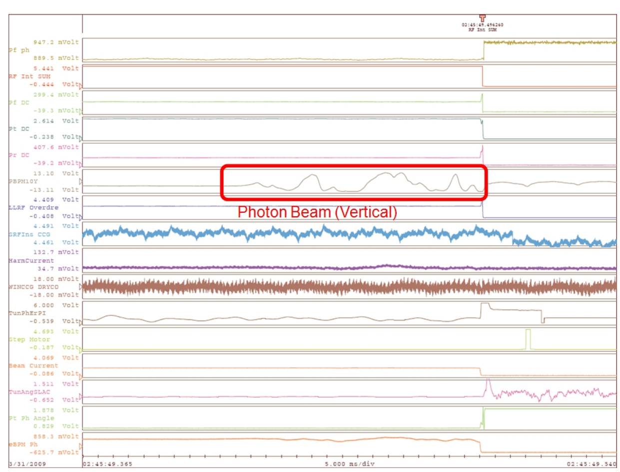


Figure 2: A trip analysis using a data acquisition system (Nicolet Vision XP)

Figure 2 illustrates a trip event captured with a data-acquisition system. According to Figure 2, the vertical photon-beam position signal became wildly oscillatory, which is a major reason for faults of this beam trip, before the SRF interlock failed. This fault a deviation of the vertical position of the photon-beam results from modification of the storage-ring parameters in the machine test interval.

PICO recorders [1], which are data acquisition systems with a small sampling rate, serve mostly to record the variation of temperature, vacuum and pressure signals. As signals of these kinds typically vary slowly, prolonged observation is required to register the variation of a level. We use several PICO recorders with sampling rate 0.1 – 1 Hz to record such data.

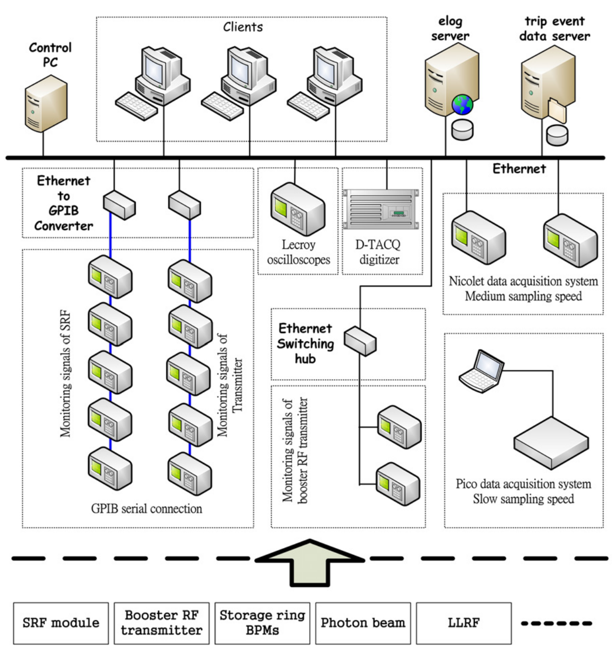


Figure 3: Architecture of the diagnostic system for the TLS RF system

## *Automatic oscilloscope control and trip data storage*

Figure 3 shows the architecture of the TLS RF diagnostic system. To avoid interference to the variation of the signal level, most monitoring signals are connected to a buffer, and a diagnostic device connects to that buffer to collect the signal.

For remote and automatic control of diagnostic devices, most devices are connected to an Ethernet, except the PICO recorders with a small rate of sampling. Oscilloscopes with no Ethernet port available are serially connected with a GPIB link that is then connected to Ethernet via a GPIB-To-Ethernet converter. Pictures of the trip event data captured with oscilloscopes and the data-acquisition machines (Nicolet Vision XP) thus become stored in the SRF elog server. The clients or analyzers can remotely access a screen snapshot of any trip event data using browser software (Internet Explorer) to analysis a system fault. Figure 4 shows a snapshot of a SRF elog web page.


Figure 4: A snapshot of the SRFelog

A program to monitor the oscilloscope status was developed and executes in the control computer (see Figure 3). The monitoring program tests the status of all oscilloscopes via Ethernet. For an oscilloscope listed in the address book of the monitoring program, the program sends query messages to the oscilloscopes every 10 s until an oscilloscope returns atriggermessage. Once the monitoring program receives such a trigger message from an oscilloscope, the program asks the triggering oscilloscope to print a hard copy to the SRF elog server. In addition, the monitoring program connects to a triggered oscilloscope to download binary curve data of the active channels, and to store these binary data in the hard disk of the control computer. If further analysis is required, these binary curve data can be inversely uploaded to an oscilloscope via Ethernet.

## *High-performance Data Acquisition*

A data-acquisition facility provides an effective tool to diagnose a system fault, but one facility provides only 16 channels for data logging and monitoring. To analyze the reason for a trip of a system with hundreds of signals, such as a SRF system, the limitation to 16 channels is evidently inadequate. We currently seek to employ a high-performance and high-density digitizer as a data-logging system for trip events, and to develop software for this data-acquisition system. The characteristics of this digitizer are [2]

1. high channel density 96 channels in a single board,

2. great bit resolution and simultaneous sampling 16-bit resolution ADC for each channel,

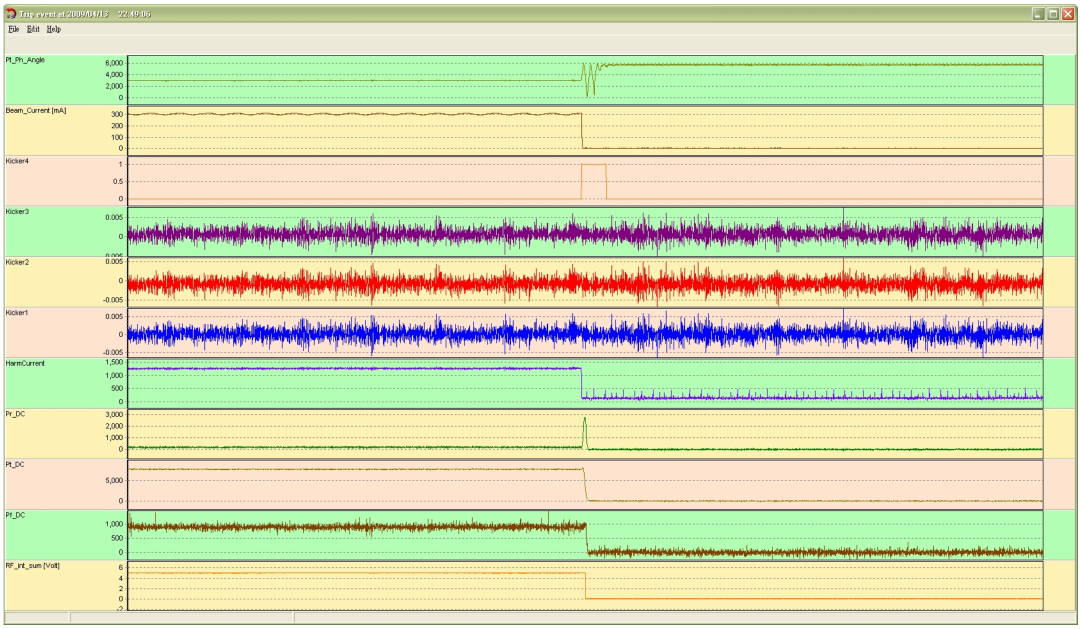


Figure 5: Result of analysis of software under development for the D-TACQ digitizer

3. large sampling rate maximum rate 500 kilosamples s-1 is possible,

4. differential input for each channel, with a large common-mode range,

5. Ethernet module for data exchanging,

6. CPU (400MHz RISC) on board, running embedded Linux, in an easy and flexible system configuration,

7. maximum 1Gbyte DDR memory on board;

8. backplane PCI interface of width 64 bits and speed 66 MHz.

Because the D-TACQ digitizer runs an embedded operating system (Linux), the functionalities of the high-performance digitizer are readily configured simply on writing a shell script. A rear module with a 10/100 based Ethernet port facilitates data storage and exchange. An input-output controller (IOC) for an experimental physics and industrial control system (EPICS) is also implemented on the digitizer by the vendor, which greatly improves the ability for remote control and data exchange.

The D-TACQ digitizer is classified as a data-acquisition device of medium sampling speed, and serves to capture data, including the pre- and post-trigger data, of a trip event. The data length of the pre-trigger and post-trigger signals can be configured with a system start-up shell script, and the maximum data length depends on the size of the memory on board. When the Interlock Sum signal of the SRF system is active, all data are first collected from the ADC and stored in the on-board SDRAM memory. When the digitizer completes the captures of all post-trigger data, the digitizer loads the post-processing script to try to connect to the trip-event data server (as shown in Figure 3). When the connection is established, the digitizer transfers the captured binary data to the trip-event data server, and then resets the status and automatically awaits the next trigger event.

The trip event data server is a ftp server (based on Linux), which collects the trip-event binary data from all D-TACQ digitizers and provides a ftp service to the clients. We are developing the software to run in the client computers to download the trip-event data from the ftp server and to analyze the data. Figure 5 illustrates an analysis result using software under development. In Figure 5, the beam-current signal (second row from the top) decreases to zero immediately; the reason for the trip is found in the third row, namely that kicker 4 misfired to cause this beam trip.

## SUMMARY

To stabilize the operation of a synchrotron light source, analyses of reasons for a beam trip are essential. The SRF diagnostic system is well integrated and provides an effective tool for analysis to discover the reason for a trip, to avoid dangerous operation and to make the system reliable. With these tools, we expect that the reliability of the TLS can be further improved, and such knowledge learned from TLS will be applicable to the future TPS.

## REFERENCES

[1] Pico technology, `http://www.picotech.com/`.

[2] D-TACQ solution, `http://www.d-tacq.com/`.