WIRE SCANNER BEAM PROFILE MEASUREMENTS FOR THE LANSCE FACILITY *

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Abstract

The Los Alamos Neutron Science Center (LANSCE) is replacing beam profile measurement systems, commonly known as Wire Scanners (WS). Using the principal of secondary electron emission, the WS measurement system moves a wire or fiber across an impinging particle beam, sampling a projected transverse-beam distribution. Because existing WS actuators and electronic components are either no longer manufactured or home-built with antiquated parts, a new WS beam profile measurement is being designed, fabricated, and tested. The goals for these new WS's include using off-the-shelf components while eliminating antiquated components, providing quick operation while allowing for easy maintainability, and tolerating external radioactivation. The WS measurement system consists of beam line actuators, a cable plant, an electronics processor chassis, and software located both in the electronics chassis (National Instruments LabVIEW) and in the Central Control Room (EPICS-based client software). This WS measurement system will measure H^- and H^+ LANSCE-facility beams and will also measure less common beams. This paper describes these WS measurement systems.

INTRODUCTION

The beam profile measurement's primary purpose is to provide transverse (horizontal and vertical) projected beam distribution measurements. The beam profile measurements allow the facility operators and beam physicists to measure and verify that the beam traversing the linear accelerator is properly tuned. Wire scanners used within the linac and the transport beam lines consist of beam line actuators that precisely move a wire or fiber through the beam and then detect the amount of secondary electrons leaving the wire or fiber as beam impinges on the wire. The transverse beam distribution displayed is the secondary electron charge leaving the wire for each wire location or distribution bin within the horizontal or vertical beam distribution.

The LANSCE-Risk Mitigation project is replacing the beam profile measurement systems that are presently installed throughout the LANSCE facility [1]. The existing and new beam profile measurement systems consist of a beam line actuator, a cable plant, a set of electronics and additional software. In many cases, the older present beam measurement systems were installed and operated > 30 years so many of the existing parts are either antiquated or unobtainable components [2].

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Beam Profile Measurement Requirements

The wire scanner beam profile measurement overall requirements are shown in Table 1. Since LANSCE produces both H^- and H^+ beams, the WS will provide beam distributions for both species.

All wire scanner beam profile measurements will meet these overall requirements such that a particular bin in a distribution will be acquired within a single beam macropulse.

Table 1: WS Measurement Systems Overall Requirements

Parameter	Value
Projected Distribution Measurements	Vertical & Horizontal
Axis of Actuation	π/4, 3π/4, 5π/4, 7π/4
Sensing Wire or Fiber Materials	W or SiC
Sensing Wire or Fiber Diameters (mm)	< 0.15
Min Distribution Width, RMS (mm)	1
Min Projected Distribution Bin Width (mm)	0.1
Typical Minimum Beam Macropulse Length (μs)	150
Min Repetition Rate w/o skipping macropulses (Hz)	4
Min/Max Peak Secondary Electron Emission Current (μA)	1/2000
Distribution Min Peak-to-Edge Ratio	100:1
Amplifier Response Time Constant (μs)	10
Max Sampling Rate (MS/s)	0.5
Linear Peak Actuator Velocity, under Closed Loop Control (mm/s)	>8
Expected Beam Gates	LBEG, MPEG, H-GX, H+IP
Wire Location Repeatability or Precision (% RMS distribution width)	<10
Absolute Wire Location Accuracy (+/- mm)	1
Peak Beam Current Range (mA)	21 to 0.9
Timing System Resolution (ns)	100

Eventually, 87 WS beam profile measurement systems will be replaced throughout the LANSCE facility. Thirty-nine linac WS measurement systems and fifteen switchyard WS measurements systems will be replaced. The final 33 will be replaced in the beam lines more downstream from the switchyard where the H- beam impinges on the 1L target. Additionally, since beam position measurements are being implemented throughout the Coopled Cavity Linac (CCL), 23 WS measurement systems will be removed and not supported.

BEAM LINE ACTUATORS

One of the design goals was to minimize the number of designs that are used throughout the 87 WS beam profile systems. Therefore, the beam line actuators will consist of at least two different types. Those actuators used in the Drift Tube Linac (DTL), Transition Region (TR), and CCL will have a stroke that is capable of traveling more than 100 mm and will be predominately mounted at a 135-deg angle with respect to the beam line Z axis. The second actuator type is a "Slide-table" device that is presently being designed.

A typical actuator that is will be used in the linac is pictured in Figure 1. It was designed to operate with a resolver that determines the sense wire's location in a 1st-order feedback control system. A stepper motor and its associated ball screw provide the linear drive. A brake automatically stops the sense wires from proceeding further into the beam if power is withdrawn. Since the ball screw is pre-loaded, backlash has been measured to be less than 0.025-mm. Also, the ball screw and associated gear use no liquid lubrication.

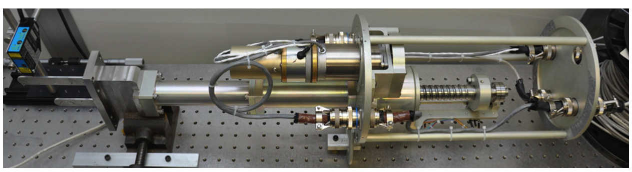

Figure 1: This picture shows a typical linac WS actuator. A 1.8-degree stepper motor with its associated 10-mm-per-turn ball screw provides the linear translation.

A testing method of the orthogonal projected-axis stability was devised. A vertical-axis laser position measurement provides a distance to within < 0.003 mm [3]. This measurement has been carried out on the WS actuator prototypes to verify their positional stability during a WS insertion. The Acuity AR200 laser measures the fork stability in the orthogonal direction to the insertion axis. These data are raw and do not include errors, such as reduction terms for the actuation axis angle of $\pi/4$ to the projected axis. However, the raw data do show the fork holding the sense wires stability in the projected orthogonal axis is <0.2 mm. For further information, please refer to these references [4,5,6].

ELECTRONICS PROCESSOR

The electronics processor has been initially reported at BIW10 and PAC11 and is further reported in these references [7,8,9]. Figs. 2 and 3 show a newer version of the WS electronics chassis.

The electronics processor has undergone several revisions since the PAC11 report but the core of the WS measurement system is the National Instruments Compact Reconfigurable I/O (cRIO) [10]. Shown in Fig. 5 is the block diagram of the WS measurements. The cRIO modules in its 8-slotted crate continue to be the NI9401, 9422, 9489, 9222, and 9870 plus the RDK 9314 and the BiRio 3443. There is no longer an included event receiver module, but a timing "gate" signal is cabled to the electronics processor via a separate EPICS timing system. The gate signals for each "flavor" of beam come in as a "gate" and are valid signals with respect to the injector releasing charge.

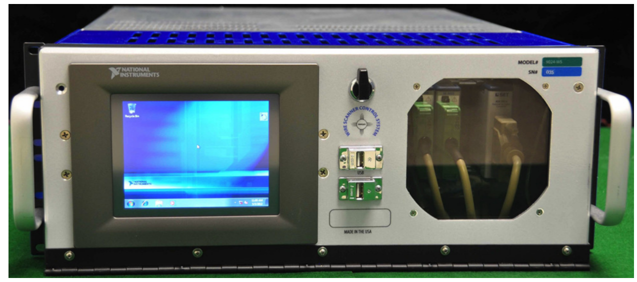

Figure 2: The above picture shows the front view of the electronics processor that includes the National Instruments cRIO crate.

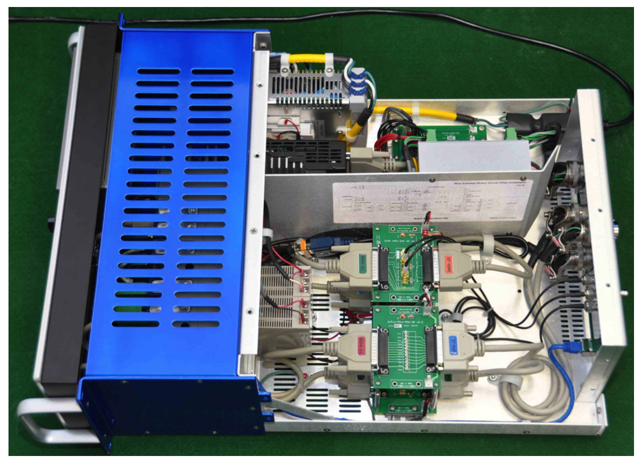

Figure 3: The above picture shows the latest version of the WS chassis with a Parker E-AC stepper motor driver for the components.

One design improvement is the implementation of the Analog Front End (AFE) transimpedance amplifier. This cRIO module is a 2-channel current-to-voltage converter with an approximate 5000 V/A gain. This AFE has a bandwidth of ~ 35 kHz and can measure electron currents flowing on the sense wires as low as 1 μA. As electrons are emitted from the sense wire due to beam impingement, the electron flow is sensed. The NI9222 500-MS/s ADC digitizes the AFE module output [11]. The BiRIO-3443 AFE module is acquiring its NI Alliance Certification [11].

Another improvement to the electronics processor is the addition of the Motor-Driver Filter (pictured in center of Figure 3). This filter uses the drive power supply and the stepper motor driver to equalize the currents going to and returning from the actuator. Since the coupling from these pulsed currents are equal, the noise from these currents is cancelled, resulting in lower motor noise coupling to the AFE module signals.

Figure 4 describes the block diagram of how the WS measurement system operates. The core of the WS is the National Instruments cRIO system. Within this cRIO crate there are seven modules used to perform several sequential tasks. These seven modules communicate with

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and perform various tasks; such as moving closed-loop actuator to the next distribution bin before the next macropulse occurs, or acquiring low sense-wire currents, turn bias to the sense wires "on" and "off", or accumulate and analyze the current and charge sense-wire signals.

The block diagram also shows the use of a standard off-the-shelf pulse amplifier from Parker [12]. The E-AC amplifier sends the appropriate pulse size and rate through the Motor Driver Filter and ~60 meter cables to the actuator's stepper motor.

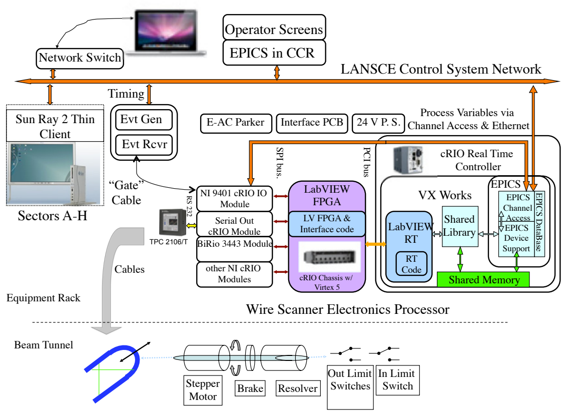

Figure 4: The block diagram shows how the National Instruments cRIO crate is the core of an operational WS measurement system.

SOFTWARE AND FPGA FIRMWARE

The NI cRIO LabVIEW VI's provide both the real time (RT) software and the field programmable gate array (FPGA) firmware for the WS measurements [13,14,15]. The FPGA LabVIEW firmware provides a method for the control of the cRIO module hardware as has been previously discussed. One example of the control speed and accuracy is to measure how quick the actuator moves under closed-loop operation. We have done so under beam conditions and have observed typical actuator speeds of >15 mm/s. The result shows that the sense-wires attain the next distribution-bin location without missing a single macropulse under normal 4-Hz operation. Using process variables, the RT software communicates with the EPICS-based client software. Fig. 5 block diagram shows the relationship between EPICS and LabVIEW RT. The EPICS and LabVIEW communication will continue as preparation of the WS systems are tested during the beam development periods during the next schedule beam run.

SUMMARY

Under beam conditions, designs have been developed, prototypes fabricated and tested with good results. Production-quality WS measurement systems for the linac are presently being ordered. Installation is expected to start in January of 2013.

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