WIRE SCANNER BEAM PROFILE MEASUREMENTS: LANSCE FACILITY BEAM DEVELOPMENT *

J. D. Gilpatrick#, Y. Batygin, F. Gonzales, M. Gruchalla, V. Kutac, D. Martinez, C. Pillai,
S. Rodriguez, J. Sedillo, B. Smith, LANL, Los Alamos, NM, USA

Abstract

The Los Alamos Neutron Science Center (LANSCE) is replacing Wire Scanner (WS) beam profile measurement systems. Three beam development tests have taken place to test the new wire scanners under beam conditions. These beam development tests have integrated the WS actuator, cable plant, electronics processors and associated software and have used H^- beams of different beam energy and current conditions. In addition, the WS measurement-system beam tests verified actuator control systems for minimum profile bin repeatability and speed, checked for actuator backlash and positional stability, tested the replacement of simple broadband potentiometers with narrow band resolvers, and tested resolver use with National Instruments Compact Reconfigurable Input and Output (cRIO) Virtual Instrumentation. These beam tests also have verified how trans-impedance amplifiers react with various types of beam line background noise and how noise currents were not generated. This paper will describe these beam development tests and show some resulting data.

INTRODUCTION

Three beam development tests were performed during the past 17 months to test a newly proposed WS beam profile measurement system. The WS measurement system include a beam line actuator, cable plant, electronics processor and associated software and firmware.

While there are official requirements shown in another paper, the goals listed guided the WS design and implementation [1].

- Replace antiquated electronic and mechanical components.
- Use off-the-shelf components.
- Install sense wires that do not cross within the beam's aperture.
- Implement WS that can provide valid beam projected profile information.
- Reduce the beam-line-actuator mechanical designs from ~7 to possibly 3.
- Continue to use sense wire mounting schemes that do not depend on individual technique.
- Increase the WS data acquisition speed.
- Acquire waveforms at bin locations without skipping a single macropulse.
- Use resolver position or velocity feedback.
- Acquire greater detailed secondary electron emission data types, i.e. current and charge.
- Reduce electrical noise during WS.
- Provide for computer-assisted maintenance.
- Use no electronic multiplexing of stepper motor controllers or power supplies.
- Continue to communicate with the central control room via Experimental Physics and Industrial Control System (EPICS)

DECEMBER 2010 BEAM DEVELOPMENT

The first tests of this new LANSCE WS measurement system were at location 10WS001, nominally 186-MeV beam energy, is within the Coupled-Cavity Linac (CCL). The beam line actuator used was a simple slide table-based design with a stepper motor and resolver attached associated attached ball screw. No brake was used on this assembly.

The 1.8-deg stepper motor provides 0.9-deg angular-movements based on what the Parker E-AC defined as 400 "½-steps" per 2π shaft rotation [2]. With a provided 10-mm-per-revolution pitch lead screw, the linear resolution was 0.025-mm. The fork was configured with a SiC fiber and a W wire. A resolver was used to sample the angular shaft position attached to the stepper motor shaft [3]. A National Instruments Compact Reconfigurable Input and Output (cRIO) system was used to create the step and direction [4].

Initially installed in the cRIO system was an Analog Front End (AFE) c-RIO module, a dual-channel trans-impedance amplifier. The vertically- or horizontally-projected wire signals were digitized as electron-emission charge left the sense wires using a NI cRIO 16-bit ADC.

All WS beam data were acquired with a 4-Hz repetition rate and a 0.15-ms macropulse length. The H^- beam currents of both 0.9 mA_{pk} and 7 mA_{pk} were used with two different beam gates.

The beam distributions acquired showed no cross coupling of beam-related currents when using wires that do not crossed beam-sensing wires in the beam aperture. The inter-scene dynamic range was > 100:1. No intra-pulse averaging was necessary for either of the gated beams, therefore, decreasing the total scan times. As can be observed in Fig. 1, there is information both in the logarithmic and linear graphs of the beam distributions.

As was previously stated, the resolver and stepper motor used the same shaft. A narrow-band pulse rate signal of between a few-pulses-per-second to a maximum pulse rate of 5000-pulses-per-second is fed to the LabVIEW-based controller. A Parker E-AC amplifies the instantaneous current of each pulse sufficiently to drive the Empire Magnetics stepper motor with enough torque to respond within the 4-Hz beam macropulse rate [5].

---

*Work supported by the U.S. Department of Energy
#gilpatrick@lanl.gov

Backlash, usually found in the angular-to-linear position conversion provided by the lead screw, was measured to be < 0.025-mm or 1 LSB of the resolver.

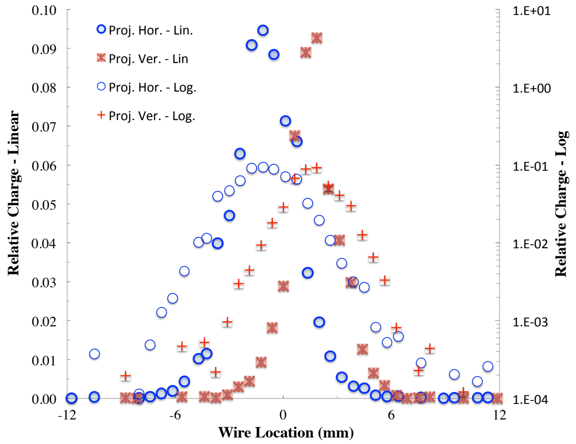

Figure 1: Using an initial prototype WS profile measurement system, this graph shows the horizontal- and vertical-projected beam distributions of a typical H^- beam.

Since the actuator movement is guided by 1st-order closed-loop feedback dynamics, the resulting error wire position is always reduced to a minimum and was within the +/- 0.05-mm target wire-location band. Therefore, the closed-loop system verifies that the wire will be located within required target location band.

A final test of this beam development was to unexpectedly remove power from the actuator by removal of power from the electronics chassis. Then, turn back on the electronics chassis power, and verify the correct operation of the internal-cRIO crate and actuator operation. All portions of this test operated as expected.

JULY 2011 BEAM DEVELOPMENT

The same experimental prototype WS measurement system was used for this beam development and very similar beam currents were used. This experiment's primary goals were successfully acquiring secondary electron emission data from the W-wires and SiC-fibers using the transimpedance amplifier.

One goal was to better estimate the overall gain and low noise currents of the transimpedance channels used. AFE signals from the cRIO module were digitized at the spatial center location of the beam distribution and >1 rms width away from this central point. The affect resulted in a lower amount of beam impinging on the sense wires, thereby artificially causing a lower signal-to-noise condition.

As seen in Figs. 2 and 3, the transimpedance gain was measured to be 4400 V/A and the noise-floor current and charge of 2- to 5-μA and of 5- to 20-pC were extrapolated. The S:N ratio at the two "tangential noise" or noise floor locations are approximately 100:1 in current and 3500:1 in charge, respectively. These ratio numbers are based on the shortest bandwidths (or longer integration times). Of course, if one integrates the signal for a shorter time, 0.05 ms versus the full 0.15 ms, the S:N charge ratio will be lower. Also, one should remember that we will be acquiring and displaying the distribution bin data using the integrated charge information, so it is the larger charge S:N ratio that is important.

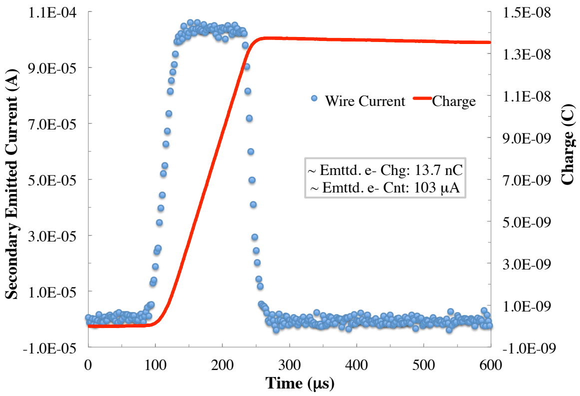

Figure 2: The current and integrated charge from the horizontal sense wire that samples the vertical axis near the distribution's spatial peak is displayed. The measured H^- beam current was 7.94 mA_{pk}.

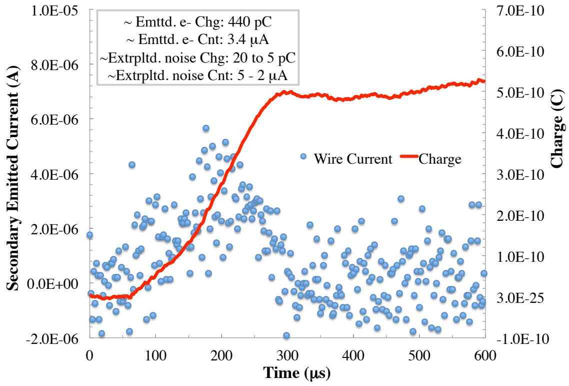

Figure 3: At this sense wire location, approximately 440 pC of secondary electron charge (3.4 μA) per macropulse emits.

With the success of the AFE noise measurements, closed loop 4-Hz operational data were acquired. However, the beam development experiment was unable to acquire data under a synchronized beam condition, i.e. beam-induced secondary-electron-emission current was not acquired while H^- beam was impinging on the wire. Since the synchronization conditions must also be met, this goal was deferred to the next beam development experiment [3].

Applying the Sternglass theory, commonly used at LANSCE, to that of the vertical-axis W-wire secondary-electron-emission current of 100 μA approximately agrees with the measured current of 103 μA [6]. However, the horizontal-axis SiC-fiber shows considerably more measured secondary-electron-emission current than can be calculated from the Sternglass theory. This difference is still an unresolved question.

NOVEMBER 2011 BEAM DEVELOPMENT

The third-beam-development experiment operating conditions were similar to the previous experiments EXCEPT the WS was located at a Switchyard location. A different beam gate was used with an initial peak current of 1.0 mA. The beam pulse consisted of a 150−μs micropulse and a 4-Hz repetition rate.

With the use of the "Wire Park Mode", the wire was relocated to the side of the beam's distribution, resulting in a lower emitted-electron sense-wire current. From the sense-wire's beam-induced current measurements, a total a total beam current noise floor was extrapolated to be 0.6 μA. This extrapolation also agrees with the measured bench test noise floor of ~1 μA with a bandwidth of 35 kHz [7].

A goal was also to verify that using the "Sequential Beam Mode" was completely operational by verifying that the actuator, measurement and controls operate under at least a sequential 4-Hz, closed-loop synchronized operation and at what pulse rate did skipped pulses occur.

As can be seen from Figure 4, beam distribution samples were acquired without skipping a single beam macropulse. The proportional feedback system was operating as expected and acquires the next position within typically 0.1 s

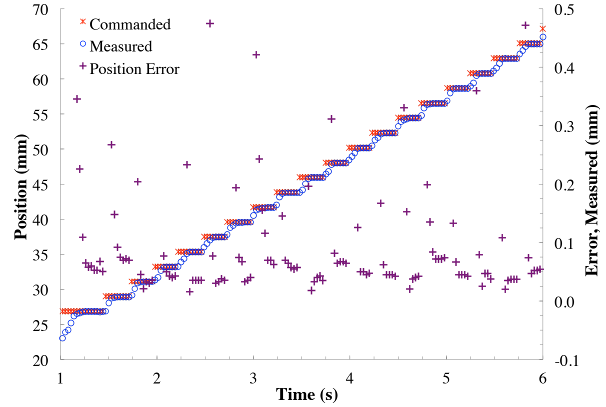

Figure 4: This graph shows the detail of how the actuator moves as it acquires each bin location of a projected beam distribution.

Fig. 5 shows the velocity and position profiles of the actuated wire/fiber as it reached the commanded bin locations. The minimum time step was 0.030 s. This velocity profile graph showed the actuator linear velocity was initially between 40- and 20-mm-per second. Within the 0.1 seconds it takes for the proportional feedback to move the wire within the position dead band position [8].

Several other wire scanner operational goals were successfully completed, such as successful brake and limit-switch operation. A "Maintenance Mode" of a 2-mm movement of the actuator without moving the sense-wire into the actuator's clear aperture was verified operational. A "Fly Mode" was also tested and its ability to acquire the beam's limited position of the beam.

ACKNOWLEDGMENTS

During the WS installation, the authors appreciated the efforts of Alfred Maestas, Joe Rabun and Felix Olivas.

SUMMARY

Each of these three beam development experiments verified the successful operation of various key performance aspects of the new LANSCE WS measurement systems. We have another beam development experiment in the upcoming that will include interfacing with the central control room via the use of EPICS and verifying the operation of the linac actuators under beam conditions.

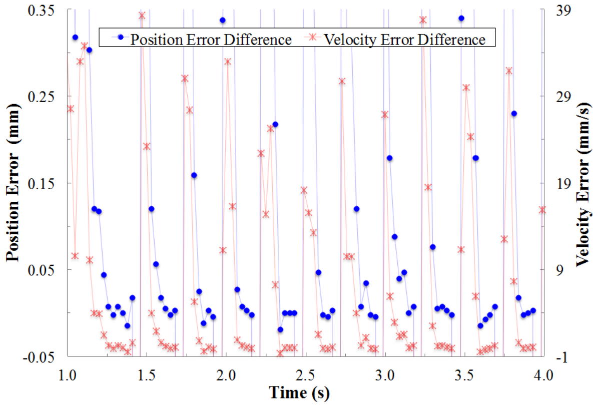

Figure 5: The measured wire position and velocity errors are displayed - note the initial error correction rate is typically > 15 mm/s.

REFERENCES

[1] J. D. Gilpatrick et al., "Wire Scanner Beam Profile Measurements for the LANSCE Facility," MOPPR081, these proceedings.

[2] Parker E-AC Stepper Motor Driver; http://www.parkermotion.com/products/Stepper_Drives_and_Motors__5325__30_32_80_567_29.html

[3] S. Rodriguez et al., "Mechanical Design and Evaluation of the MP-11-like Wire Scanner Prototype," MOPPR083, these proceedings.

[4] National Instruments cRIO; http://www.ni.com/compactrio/

[5] Empire Magnetics Inc. Stepper Motors, Resolvers & Brakes; http://www.empiremagnetics.com/prod_rad/prod_rad_stepper.htm

[6] S. J. Sternglass, "Theory of Secondary Electron Emission by High-Speed Ions," The Physical Review published by the American Physical Society, Second Series, Vol. 108, No. 1, October 1, 1957.

[7] M. Gruchalla et al., "Wide-bandwidth Capture of Wire-scanner Signals," MOPPR082, these proceedings.

[8] J. Sedillo et al., "Software Development for a CompactRIO-based Wire Scanner Control and Data Acquisition System," MOPPR084, these proceedings.