LANSCE ISOTOPE PRODUCTION FACILITY EMITTANCE MEASUREMENT SYSTEM*

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Abstract

A new beam diagnostic system for emittance measurement is under development for the Isotope Production Facility (IPF) beamline located at the Los Alamos Neutron Science Center (LANSCE). This system consists of two axes; each composed of a harp and slit actuation system for measuring the emittance of 41, 72, and 100-MeV proton beam energies. System design details and project status will be discussed with installation and commissioning of this system scheduled to conclude by February 2017.

INTRODUCTION

In July 2015, research and development efforts were authorized for the creation of additional beam diagnostic systems at LANSCE's Isotope Production Facility. Among these systems was the inclusion of a new beam emittance and transverse profile monitoring diagnostic located in the IPF beamline. Design efforts have culminated in a dual-axis system comprised of four NI compactRIO embedded controllers capable of driving four actuators (2 orthogonal slits and two orthogonal harps) while simultaneously acquiring beam waveform data from 154 harp wires. After deployment in February of 2017, the system will measure the emittance and transverse profiles of proton beams with nominal energies of 41, 72, and 100 MeV [1].

SYSTEM LOCATION AND OVERVIEW

The IPF beamline diverges from the LANSCE main beamline at the transition region after the 100 MeV drift tube linac (DTL) acceleration stage. From there, the IPF proton beam passes through a drift space before impinging on the IPF target. Beam properties at the emittance device are: nominal energy of either 41, 72, or 100 MeV; 4Hz macropulse repetition rate; 150µsec pulse width; and 0.1 to 21mA peak beam current.

Figure 1 shows the IPF beamline where the emittance actuators will be located. Two orthogonally mounted slit actuators will reside 7.5 meters upstream of the two orthogonal harp actuators. The IPF target is located approximately 2.7 meters downstream of the harps.

This emittance diagnostic is one of several systems under development for enhancing the beam measurement capabilities of the IPF from which improvements in isotope production reliability, diversity, and yield are expected [1].

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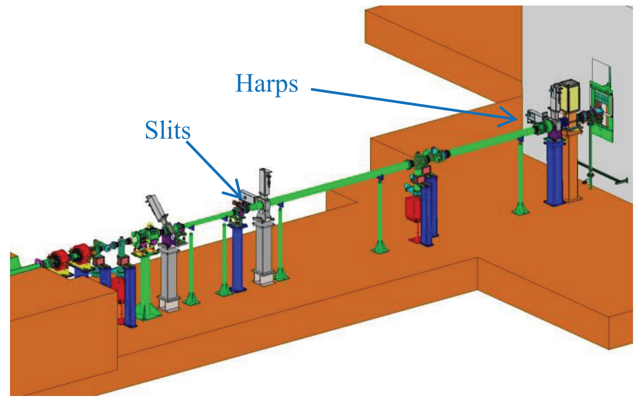

Figure 1: IPF beamline model. Beam direction is left to right.

SLIT DESIGN

Beam emittance measurement begins with the slit. The IPF slits have been designed with a 0.508-mm slit aperture size and a 14-mm slit thickness. The slit size allows for a relatively higher resolution emittance scan relative to the beam spot size of 48-mm (2-RMS) while minimizing slit-induced scattering. The slit thickness of 14-mm (copper substrate) was specified to fully absorb the intercepted beam. An additional provision for slit biasing has been included via an SHV connection. A computer rendering of the slit design is shown below in Fig. 2.

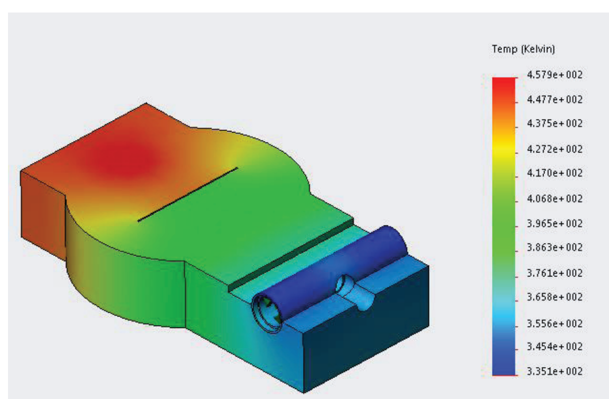

Figure 2: IPF slit model with thermal analysis.

HARP SENSOR DESIGN

The beam characteristics of interest are sensed by the harps. The IPF harps have been designed with 77-lines of transverse beam resolution spanning a 77-mm plane with 1-mm spacing. This configuration places approximately 49 wires within the beam's spot-size envelope of 48-mm. Sensors are composed of 0.079-mm-thick Silicon-carbide

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fibers spanning a circuit board upon which they are retained. A hook, spring, and collet configuration maintains sensor tension and placement on the circuit board while also maximizing sensor density. Signals induced in the sensors travel along the harp circuit board's traces, through two high-density connectors, along kapton-insulated cables, to two mil-spec vacuum feedthroughs prior to interfacing with the harp's facility cabling. A computer rendering of the harp sensor is shown in Fig. 3.

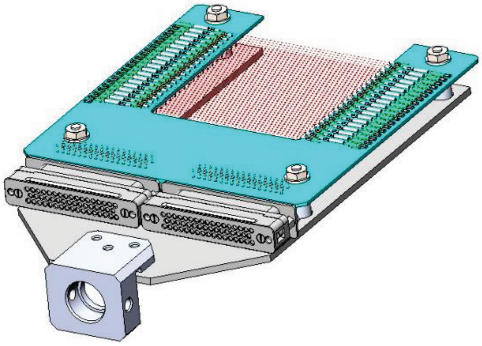

Figure 3: IPF harp fork design model (single-axis).

ACTUATOR DESIGN

Slit and harp actuators were developed on a common actuator platform. This actuator has a stepper motor, brake, and resolver assembly coupled to a linear stage via a synchronous drive gearbelt transmission. Slits and harps are suspended in the beam cavities with a cylindrical support arm coupled to the actuator's linear stage. The support arm is sheathed within a flexible stainless-steel bellows for vacuum isolation from atmosphere. Movement of the support arm via the actuation mechanism allows the sensor to scan the beam in a multitude of positions along a single axis. Computer renderings of the harp and slit are shown in Fig. 4 and Fig. 5, respectively.

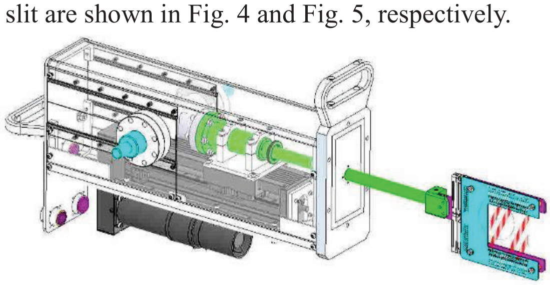

Figure 4: Harp actuator model.

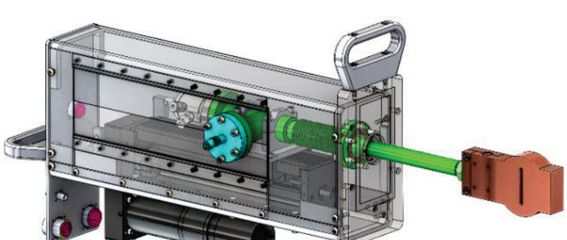

Figure 5: Slit actuator model.

CONTROLLER HARDWARE

Each axis of the emittance-measurement system will be operated by two cRIO-9038 embedded controllers in a master-slave relationship. The first of these is the master controller which will be configured to acquire the 154-channels of harp sensor waveform data, serve as the primary EPICS IOC (Experimental Physics and Industrial Control System Input-Output Controller) for client interfacing, and sensor positional calculator for the slave controller. The slave controller will function as an actuator motion control system by controlling the positioning of the emittance system's slit and harp heads. The hardware diagram of the master controller is shown at the top of Fig. 6 with the slave controller shown below the master.

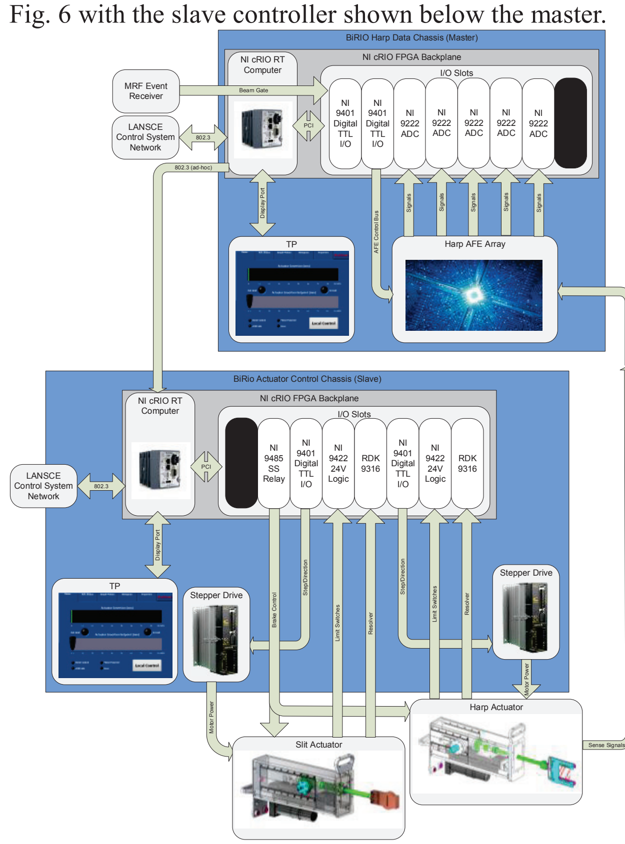

Figure 6: Emittance control system hardware diagram.

The master controller will derive acquisition capabilities deployed recently for the legacy LANSCE emittance systems [2]. These capabilities include: simultaneous, 100 kS/sec, waveform acquisition across all 154 channels; variable pre and post-trigger sampling; and real-time data availability. Furthermore, the master controller will also house newly-developed high-density analog conditioning cards capable of measuring currents from 270 uA down to 3 uA, feature variable gain control, wire bias isolation, and auto-zeroing [1].

The slave controller will derive motion control capabilities developed previously for the LANSCE-RM (Risk Mitigation) project [3]. Locating the motion control functionality for both the slit and the harp within a single controller will provide for the fastest motion control synchronization required of an emittance measurement.

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The synergistic relationship of the controllers allows for high-density sensor waveform acquisition with associated motion control, enabling such data acquisition methods as single-axis emittance measurements, single-axis harp measurements, and, when used in coordination with the controllers of the orthogonal axis; a two-axis, harp-based, transverse profile measurement. Furthermore, the importance of these measurements is compounded by the beam-rastering capabilities of the IPF beamline.

CONCLUSION

Development efforts dedicated to the IPF emittance measurement system's progress are beginning to yield tangible control system hardware and sensor actuation mechanisms. Near-term efforts will focus on the system's software development followed by testing, calibration, and integration with an expected completion by February 2017.

REFERENCES

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