UPGRADES TO THE LANSCE ISOTOPE PRODUCTION FACILITIES BEAM DIAGNOSTICS *

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Abstract

The Los Alamos Neutron Science Center (LANSCE) is currently upgrading the beam diagnostics capability for the Isotope Production Facility (IPF) as part of an Accelerator Improvement Project (AIP). Improvements to measurements of: beam profile, beam energy, beam current and collimator charge are under development. Upgrades include high density harps, emittance slits, wire-scanners, multi-segment adjustable collimator, data acquisition electronics and motion control electronics. These devices will be installed and commissioned for the 2017 run cycle. Details of the hardware design and system development are presented.

INTRODUCTION

IPF Purpose

The purpose of the Isotope Production Facility (IPF) is to produce isotopes, not commercially available, for research, development and treatment in the United States. They currently produce Strontium-82 isotopes for cardiac imaging as well as a variety of other isotopes used for medical treatment and study. The isotopes produced at IPF impact approximately 30,000 patients per month [1]. The facility uses beams at 41, 72 and 100MeV for isotope production.

IPF Upgrades

The IPF facility is planning an upgrade as part of its scheduled beam window replacement in 2017. This upgrade is focused on increasing yield of the facility, reducing programmatic risk and improving beam diagnostics. The improved diagnostics capability will ensure that the beam profile, intensity and incident energy are well understood in an effort to improve target survival at increased beam currents [2].

PROFILE MEASUREMENTS

Three upgrades to beam profile measurements will be completed as part of the IPF upgrade. The existing harp will be replaced with a higher resolution device. An emittance measurement and wire scanner measurement will be added upstream of the harp. These measurements will be placed at three separate locations along the IPF drift length to characterize the beam. The harp will serve a dual purpose as both a profile measurement and a collector for emittance.

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Actuators

The IPF beam line transitions from a 4” diameter beam pipe to a 6” diameter beam pipe after the raster magnets and prior to the target. The challenge for actuators in these locations is the large stroke length required to scan wires and harps. This sets a requirement for actuators to achieve a 20 cm stroke and 1 mm scan resolution. Figure 1 shows three new designs created to meet the profile measurement requirements that all used a common off the shelf (COTS) slide table and actuation stage.

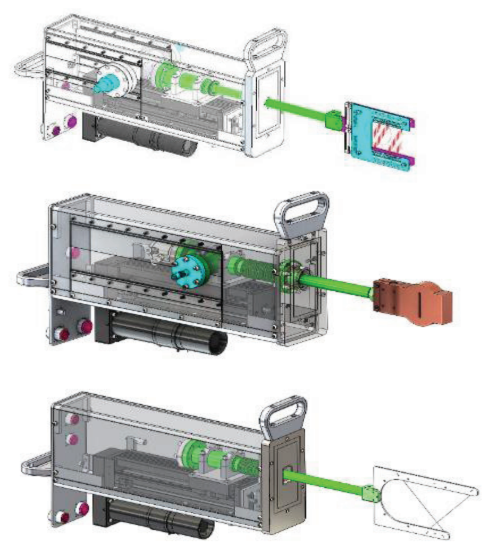

Figure 1: Three Types of Actuators

High Density Harp

Another challenge of the IPF upgrade was the high density harp. The requirements were to design a device with a 7.6cm profile width and 1mm wire resolution. The harp head assembly needs 77 wires in both the horizontal and vertical planes.

The harp head design achieved this high density requirement by using a dual sided printed circuit board (PCB) that spaced wires 2 mm apart on each side. Figure 2 shows how the hook and spring were used to tension a silicon carbide (SiC) wire across the PCB.

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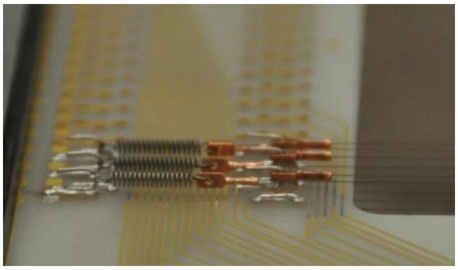

Figure 2: Hook, spring and crimp attached to G10 harp frame.

The signal connections route to an edge connector that transitions the signal to radiation tolerant wiring before exiting through the vacuum feedthrough shown in figure 3.

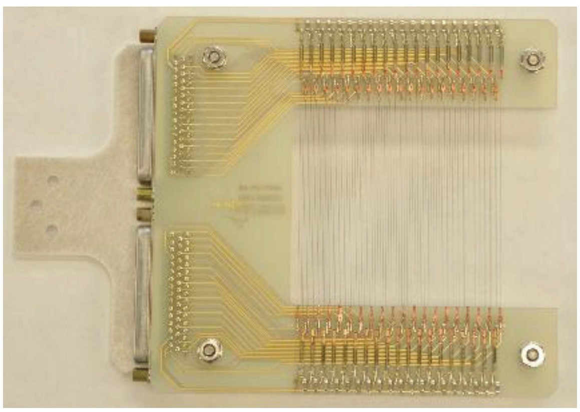

Figure 3: Harp head assembly

Analog Signal Conditioning

The analog conditioning module is used to measure the secondary emission current of the wires. The requirements for the analog circuitry were to measure currents from 270uA down to 3uA during beam tuning along with a 50VDC bias being applied to the wire.

Figure 4 shows the resulting circuit with an AC coupled input with a 2 kOhm load. The signal across the load is then gained up and conditioned by a pair of instrumentation amplifiers cascaded to provide programmable gain from 1-10000. A discrete filter is used to produce a 150kHz corner frequency to limit the bandwidth of the analog front end. An auto zero circuit is used to keep the AC coupled circuit from drifting by integrating the noise when beam is off. A final buffer amplifier is used to output the signal to the data acquisition electronics.

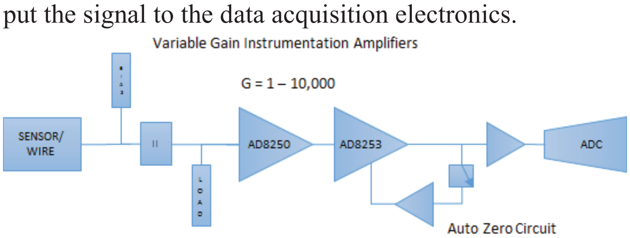

Figure 4: Analog Conditioning Circuit

The analog conditioning circuit is placed on a 3U cPCI card with 16-channels and remote gain control. The channel count matches that of the data acquisition system.

Data Acquisition System

The data acquisition (DAQ) system requirements are to sample and analyze the data at 100KSPS so that profiles can be analyzed across the beam pulse of 150µsecs. A buffer in the DAQ provides both pre-trigger and post-trigger samples. Integration and current calculations are done on board the FPGA hardware and results are then sent across the EPICS control network to the measurement client. The DAQ system also provides analog conditioning control and timing acquisition to coordinate the measurement.

The DAQ controller is based on the National Instruments (NI) 9038 cRIO that includes a real time Intel Atom processor as well as a Xilinx FPGA. The analog to digital converter is a 16-bit 100 KSPS synchronous sample module with 16-channels. The controller is mounted in a 4U chassis that also includes an 8-slot cPCI backplane that interfaces with the sensors.

Figure 5: DAQ Chassis

The chassis in figure 5 is produced by a 3rd party vendor, Bira Systems Inc, who assembles all the specified components and provides a final system that is tested and verified.

Wire Scanner

The final profile measurement is a wire scanner that uses a horizontal and vertical wire on a single fork. A requirement that the wire not be crossed when intercepting beam creates a stroke requirement of 19.4cm to scan both wires through the beam.

The electronics design for actuator and data acquisition are based on a previous wire scanner for LANSCE that uses an NI cRIO platform for the controller. [3]

BEAM ENERGY

Beam energy calculations are important to the IPF facility to determine the isotope production yield for a specific target. The requirement for beam energy is to measure energy at 41, 72, and 100MeV with 50 keV resolution. This measurement will use existing strip line beam position monitors in the IPF line. The measurement will be a phase- based measurement which uses the fundamental

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acceleration frequency of 201.25MHz to determine the time of flight of particles at three separate locations along the beam line.

Long drift lengths have a benefit of providing improved energy resolution as shown in figure 6. The drawback to the long length is ambiguity between different energies since knowledge of the integer cycles between BPMs must be known for a particular energy set point. Having three different drift lengths provides a course and fine resolution measurement where the course measurement can provide evidence of cycle mis-calculations and the long drift lengths provide fine resolution as shown in figure 7.

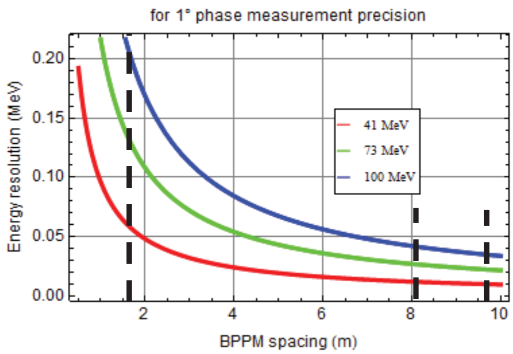

Figure 6: ToF Energy Resolution vs Spacing

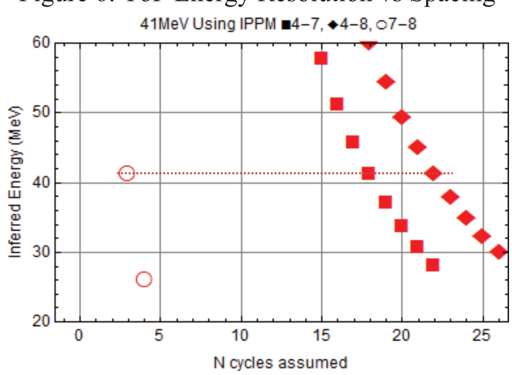

Figure 7: Energy vs Cycles

Time of Flight Electronics

The electronics for the time of flight measurement consists of an analog signal conditioning unit that takes in four electrodes from the BPM and band pass filters the 201.25 MHz fundamental frequency. A 240 MSPS digitizer then samples the four electrodes plus a reference frequency channel to make phase measurements using an I/Q demodulator technique embedded in a Stratix IV FPGA. All the hardware is COTS except for the analog card. Figure 8 shows hardware contained in a hybrid VPX/cPCI chassis.

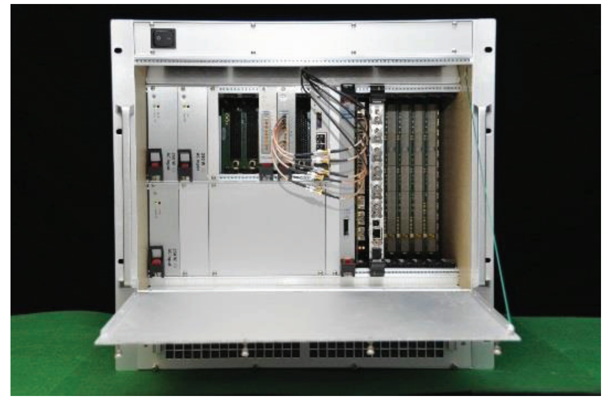

Figure 8: Beam Energy Chassis

BEAM CURRENT

Beam monitors exist in the IPF beam line however their sensitivity is limited to average beam currents of 2-5 μA minimum. Experimental isotope production sometimes requires average beam currents of 100 nA be delivered to IPF. The lower limit boundary of the current measurements is set by the electronics used for measuring the peak current from the toroid current monitors.

A high sensitivity current module is being evaluated as an alternative to the system that is in place today. The high sensitivity module would not cover the entire range of measurements but would become active when peak currents dropped below 1mA.

Challenges

The challenge with the high sensitivity current monitor is interferers. There are two main interference frequencies that are picked up by the current monitor. The two frequencies of concern are 5 kHz and 72 kHz. The source of the 5 kHz interferer is understood. The IPF beam is rastered around the target by two steering magnets. These magnets are set to raster the beam at a 5 kHz frequency which is also picked up by the current monitor. The 72 kHz interferer is of unknown origin. Additional testing is planned to pin point the source of this interference and efforts will be made to mitigate its impact on the current monitors.

COLLIMATOR

The last diagnostic to be upgraded at IPF is the active and adjustable collimator. The existing collimator is not adjustable and beam current on the segments is not measured. The new design will provide an adjustable aperture from 1.4 to 2.3 inches with a 500 Watt limit per segment. Beam impinging on the collimator will be measured as well as temperature monitoring of the segments.

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Segments

The collimator will have eight graphite segments designed to completely stop beam. Four segments will be fixed and four will be adjustable. The charge on each segment will be monitored by remote electronics along with biasing of each segment. Figure 9 shows the range of aperture size the collimator will provide.

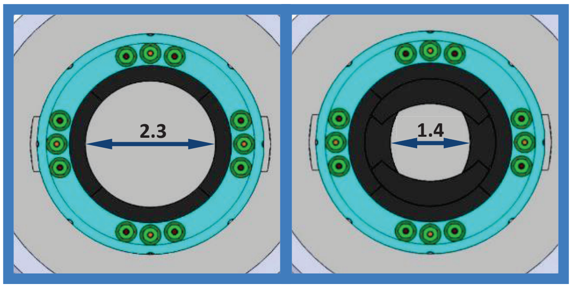

Figure 9: Collimator Aperture Sizes [4]

Temperature

IPF has had issues in the past with the collimator being damaged thermally. Therefore, this design will include a temperature sensor on each segment. Temperature information will be logged to gain knowledge of the thermal levels encountered during beam delivery to the IPF target.

Actuation

The collimator will be actuated by pull straps mounted upstream of the segments. A flexure is used to translate the strap displacement to collimator aperture adjustment. A slide table and motor assembly similar to the profile monitors will be used along with a chassis controller that will include DAQ and motion control.

CONCLUSION

Commissioning of these diagnostics is scheduled in Q2 2017 during the maintenance outage at LANSCE. The design and procurement stages of the project have been completed. Current work is assembling and testing of the various components needed to complete each diagnostic.

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