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IMAGE ACQUISITION SYSTEM FOR THE INJECTION DUMP AT THE SPALLATION NEUTRON SOURCE*

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Abstract

We describe the Image Acquisition system for the Injection Dump. This system visualizes the different beamlets, on the vacuum window after the H- beam is stripped of its electrons by two stripper foils. One beamlet is from H- with its electrons stripped by the first foil and the second beamlet has its final electron stripped by the second foil. We used the PXI platform to implement the data-acquisition including timing decoder. We describe the hardware and software for the system. We use a standard non-radhard GigE camera to acquire the image from the luminescent coating on the dump vacuum window. To lower the radiation damage to the camera, we shield it with stainless steel blocks. We present radiation measurements before and after shielding. We also show the radiation damage over time to estimate the camera's lifetime.

INTRODUCTION

The Ring Injection Dump (RID) needs diagnostics to properly steer two waste beam species, leftover from the charge exchanging injection scheme, to the dump. The Proton Power Upgrade (PPU) upgrades the magnets in the injection region and confirmation is needed of the new trajectories.

The two waste species are referred to as "H^0 beam" (partially stripped H^- beam) and "H^- beam" (the beam that misses the primary foil) see Fig. 1. The width of the beam is up to 20 cm with vertical size slightly smaller. Both species end up as H+ after passing through a secondary stripping foil.

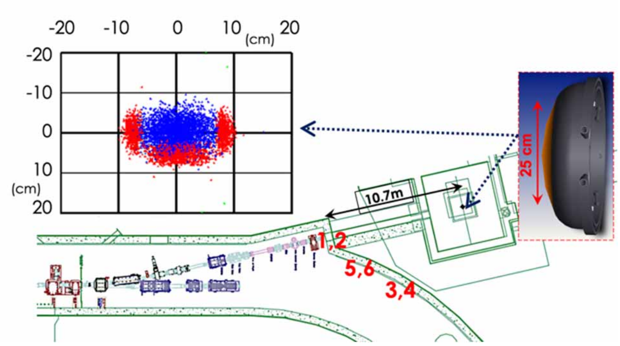

Figure 1: The Ring Injection Dump line along with the calculated projection of beam particles on dump window.

To visualize the waste species on the injection dump window, it has been coated with a luminescent coating made of Al2O3:Cr, similar to the SNS target. An optical system transfers the light to a camera, see Ref. [1]. The requirements include an absolution position accuracy of 10 mm, both horizontal and vertical, and to survive an 16-hour study period to confirm the particles' trajectories. The intention was to install the window with the coating right before the measurement but changes in schedule resulted in installing the coating window but not the optical system. Hence no results with actual beam will be presented in this paper. The coating luminescence will have been reduced due to radiation damage while running beam without the having an optical system but experience with the SNS target coatings indicates that enough luminescence remains to perform the required measurements once the optical system has been installed. The optics are described in Ref. [1].

CAMERA SETUP

The system is based on non-radhard GigE cameras because radhard cameras are expensive or do not have the right features. To use non-radhard cameras we tested the radiation doses during full power beam conditions at different locations, see also Ref. [2]. The results are repeated in Table 1. The odd locations are at ground level and the even locations at about 1.5 m (above the beam plane). Location ES (Electron Scanner) is in a straight section of the ring and is listed as a control reference. Cameras in those locations easily survive multiple years of beam runtime (5000 Hrs/year). We used CERN HiRadMat results from Ref. [3] to convert from dose to Time-to-Death and Time-to-Significant-Event (crash). The calculation confirms that cameras at the ES location can survive for a long time. The results in the table show that locations further from the injection dump beamline have lower doses. However, locations 1 and 2 simplify the optical system and location 1 allows for the system to be installed on the floor. Unfortunately, this location has the highest dose rates, thus we will use shielding to reduce the dose.

Table 1: Camera Locations, Doses, and Expected Time to Death and Significant Event (SE) at 1.4 MW Beam Power

Location	Total (Gy/MWHr)	Time to Death (Hrs)	Time to SE (Hrs)
1	0.29	285	0.91
2	0.24	339	1.09
3	0.04	2246	7.20
4	0.05	1797	5.76
5	0.08	998	3.20
6	0.08	998	3.20
ES	0.0032	25674	82.29

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We investigated shielding blocks of tungsten and stainless steel. While tungsten is more effective as a radiation shield, it was also a factor of three more expensive, so we chose stainless steel, still at a cost of ~$50k. We also avoided requiring lifting equipment for installation by using smaller blocks that can be moved by hand, including blocks with handles to allow for easy camera replacement. The configuration and blocks are shown in Fig. 2. The shielding was calculated to shield by a factor of around 30, we measured almost a factor of 40 lower dose, but this was at ground level, while in the final installation the camera will be slightly higher. This brings the estimated Time-to-Death to ~11,000 hrs and the Time-to-Significant-Event (SE) to almost 40 hrs. These are very reasonable numbers, our typical beam runtime is 5000 hrs/year, and will allow the system to be maintained and used for many years with minimal replacement cost for the non-radhard camera.

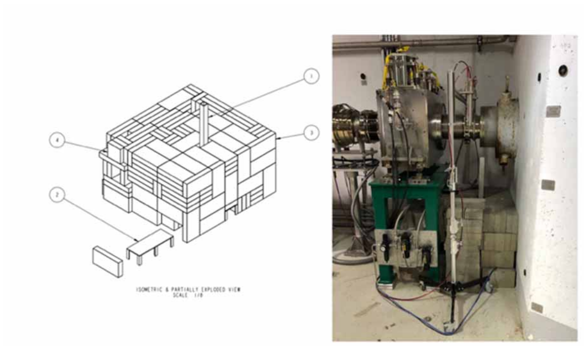

Figure 2: The shielding blocks to protect the camera.

The shielding was installed without the optics to perform testing of the non-radhard camera in place. The camera was a FLIR Blackfly 23S6M-C Mono camera with the Sony IMX249 sensor. The camera was in place for about a year and survived but had to be rebooted multiple times. Figure 3 shows the camera being inserted into the shielding blocks.

Figure 3: The camera inserted into the shielding blocks arrangement.

After 1800 MWhrs of production beam exposure the camera image was checked, see Fig. 4. It shows that we can expect to provide details on the beamlets even after full production beam at 1.4 MW after 50 days.

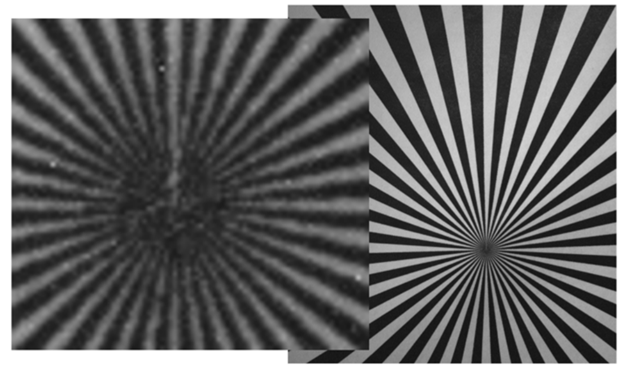

Figure 4: The Camera image after 1800 MWHrs of exposure at 1.4 MW at 1 GeV. Left a close-up of the test image center.

ACQUISITION SYSTEM

The imaging system's requirements are:

- Survive a 16-hour study to document the new beamline's behavior,
- provide position resolution of < 4 mm, and
- interface with the EPICS controls system.

The camera test showed that the system can survive for much longer than needed for the study. The optics have been tested in the lab and has a resolution of 0.2 mm. We estimate the position accuracy to be 2 mm depending on the actual signal-to-noise in the field which depends on how the coating has aged. The acquisition platform is PXI with LabVIEW. The system is shown in Fig. 5.

Figure 5: System Hardware.

The PXIe-840 computer runs Windows OS and connects the control network and the camera through separate ethernet interfaces. The power to the camera is controlled by a PXIe-4112 module to be able to reboot the camera after a crash (Significant Event). To decode the accelerator timing systems, we use a SNS Timing Adaptor board to transmit the timing signals over the PXIe bus to the FPGA board, a PXIe-7971, for decoding of beam triggers and information such as timestamps. To satisfy the position accuracy requirement, we put fiducial markers on the coating of the injection dump window, see Fig. 6. A high intensity lamp, powered through the BK Precision 1687B power supply, makes the fiducials visible for calibration before there is beam on the window.

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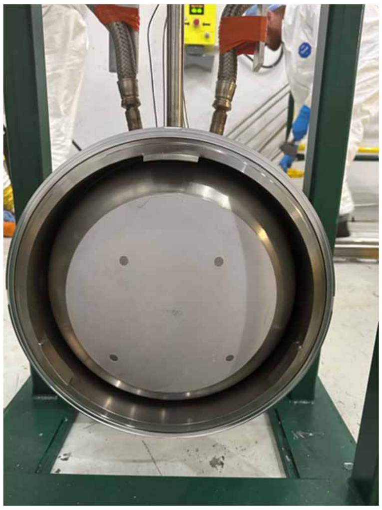

Figure 6: Fiducial markers on the vacuum window.

Software

The software program acquires the image from the camera and provides intensity projections both horizontal and vertical as well as the centroid of the image. Different overlays can be added to the image. A circle that is matched to the edge of the coated area and a crosshair that the user can align with a blob in the image. The LabVIEW program interface is shown in Fig. 7.

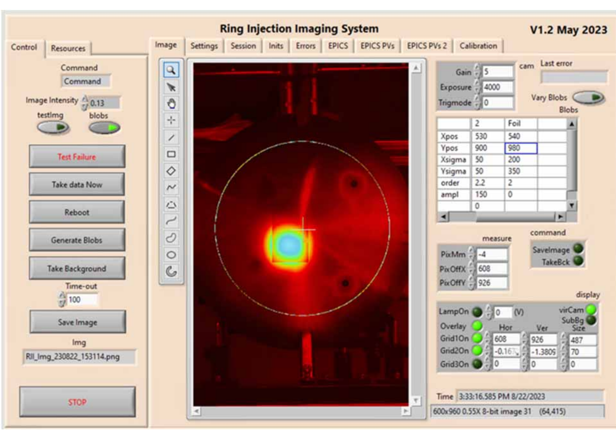

Figure 7: LabVIEW program.

Additional features in the program are to display two generated 2D gaussians to mimic the beamlets, and the stripper foil effect to test the program. Background images can be taken and subtracted from the acquired images.

The LabVIEW program, besides performing the data acquisition and analysis, also functions as an expert screen while a CS-Studio interface is available for use in the control room. We use a SNS LabVIEW native Channel Access (CA) server to interface with the EPICS based control system. The LabVIEW program uses a library on top of this CA Server to generate Extensible Display Manager (EDM) and Control System (CS) Studio files of the published Process Variables (PVs). These files give you a head start with

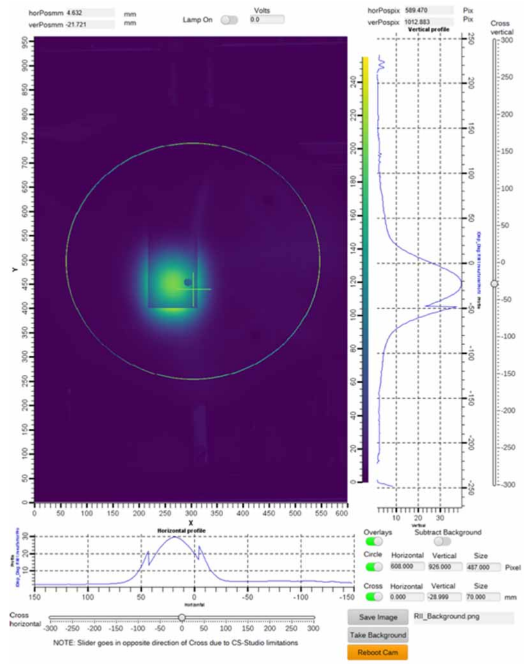

Figure 8: CS-Studio screen.

implementing the operator screens. The CS-Studio screen for the Injection Imaging System is shown in Fig. 8.

CONCLUSION

An image acquisition system has been created for the injection dump to visualize the waste beam from the stripping foil. A non-radhard camera is used but shielded to provide months of operation based on measurements and reference data. The system integrates with the SNS EPICS-based controls system to provide data to studiers in the control room. Unfortunately, the installation of the optics system was delayed due to problems with the installation of the coated vacuum window and no field measurements have yet been taken.

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