PIN DIODE DETECTORS AT DARHT II*

Jeffrey B. Johnson, LANL, Los Alamos, NM 87544, USA

Abstract

PIN diode detectors are a useful diagnostic tool for accelerator operations. The DARHT Axis II electron beam accelerator utilizes an array of twelve PIN diodes to detect the location of high voltage column electron emissions during abnormal injector events. The PIN diodes are located outside the injector vacuum vessel and detect the x-rays that are produced when the -2 MeV column electrons strike the vacuum vessel wall. This paper describes the PIN diode selection, calibration and use on the accelerator.

INTRODUCTION

An array of twelve PIN diode detectors is used on the DARHT Axis II accelerator injector to monitor for abnormal high voltage events. The injector consists of a Marx bank pulse generator, high voltage column, thermionic cathode and a vacuum vessel as shown in Figure 1.

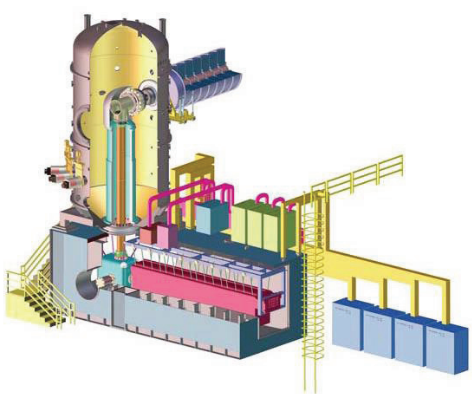

Figure 1: DARHT Axis II Injector.

During operation of the injector, abnormal events may occur. These include explosive electron emissions from the cathode and injector voltage droops from high voltage breakdowns of the cathode region or column. To help identify the precise location of such events, a PIN diode detector system was developed and installed on the injector. The PIN diodes detect the Bremsstrahlung radiation created when high energy electrons emitted during an abnormal event intercept the vacuum vessel wall. The array of twelve detectors is evenly spaced around the outside of the vacuum vessel.

PIN DIODE SELECTION

The sensitivity required for the PIN diodes was determined experimentally. A PIN diode detector assembly made by Emerge Semiconductors (100-PIN-250-HN-BG) was initially used as a single channel monitor for abnormal events. Data collected during a few abnormal events showed that this diode had the appropriate sensitivity to make the measurements. Unfortunately, the Emerge PIN diode assemblies are no longer available. An equivalent PIN diode assembly needed to be identified or built in order to construct the detector array. A market survey was conducted for a silicon PIN diode assembly similar to the Emerge detector and none could be found. This lead to the development a LANL designed detector assembly which uses a low cost commercial PIN diode chip and a custom made housing shown in Figure 2. The PIN diode chip selected was the OSI Optoelectronics PIN-RD-100. This chip has similar geometry (area and Si depth) compared to the Emerge diode. A steel housing was designed to hold the chip and provide some degree of collimation and shielding.

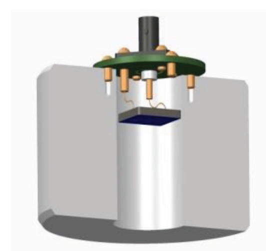

Figure 2: LANL PIN diode assembly.

CALIBRATION

The LANL PIN Diode detector assembly was calibrated against the Emerge detector using the DARHT Axis II accelerator Beam Clean up Zone (BCUZ) [1] as a radiation source. The BCUZ, shown in Figure 3, is an energy filter which absorbs beam energies below 3 MeV which occur during the rising and falling edges of the accelerator beam pulse.

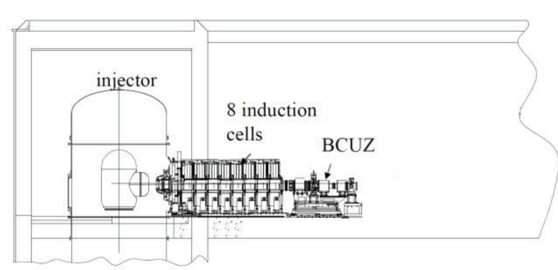

Figure 3: BCUZ region used for calibration.

The absorbed energy creates a pulse of broad band X-rays for the calibration. The central portion of the signal from the rising edge was used for the calibration. During calibration, the detectors were placed downstream from and just above the BCUZ. Detector reverse bias voltages

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johnsojb@lanl.gov

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were 1000 volts for the Emerge detector and 100 volts for the LANL detector. Calibration data in Figure 4 shows that the LANL detectors are more sensitive to the middle of the calibration pulse than the Emerge detector. The LANL detector response is not as fast due to the lower reverse bias voltage [2]. The sensitivity for the LANL detectors is 1.53×10^{-7} A/(R/s) for the lower dose rates from the BCUZ X-ray source.

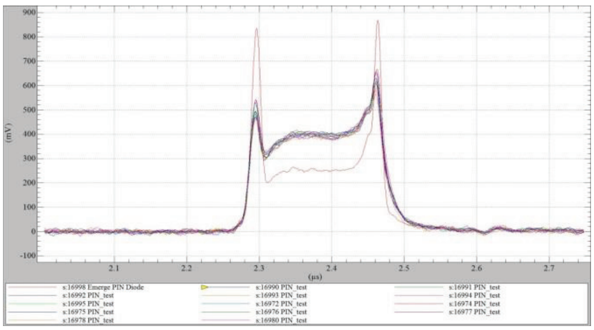

Figure 4: Calibration waveforms.

SYSTEM OPERATION

The PIN diode detectors must be operated with a reverse bias voltage applied across the P-I-N junction. To achieve this, a DC power supply is connected to the detector cable using a LANL designed bias tee as shown in Figure 5.

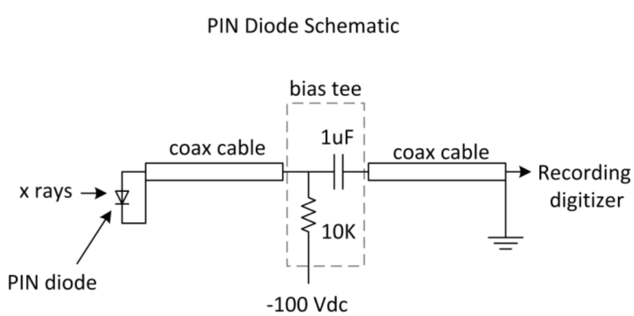

Figure 5: PIN diode schematic.

The bias tee can operate to 1000 VDC and has 1 microfarad of coupling capacitance. The large coupling capacitance provides extended low frequency response for slower signals produced during slower changing X-ray fluxes. There is one bias tee for each detector. A single DC power supply provides the bias voltage for all twelve detectors through a simple fan-out box. The detectors are operated with a 100 VDC reverse bias at DARHT to eliminate the electrical hazards associated with operation at greater voltage levels. Each detector output signal is recorded on its own high speed digitizer channel each time the injector is fired. The PIN diodes I layer is completely depleted at 80 volts reverse bias and the sensitivity will remain constant at any reverse bias greater than 80 volts as long as the output voltage stays less than half of the bias voltage. Increasing the reverse bias voltage increases the time response of the PIN diode.

RESULTS

On 9/25/2012, (shot 19274) an abnormal event occurred while operating the injector. The injector voltage pulse displayed a droop as shown in Figure 6. This occurred after the vacuum environment of cathode was accidently compromised which may have degraded the cathode surface leading to explosive electron emissions during pulsing. When this happens, it is likely that some of the emitted electrons do not enter the accelerator beam tube and instead impact the vacuum vessel wall.

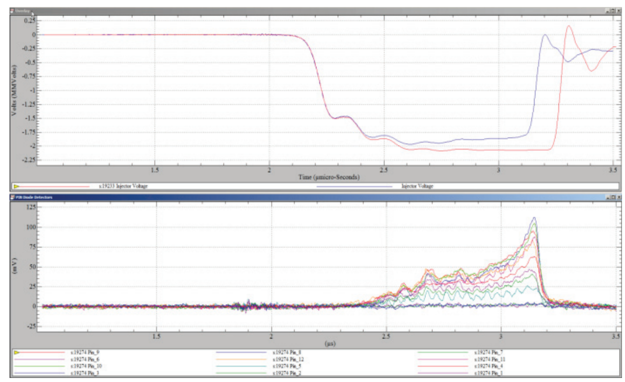

Figure 6: Injector voltage waveforms. Top waveform showing normal (red) and droop (blue) conditions. Bottom waveform shows PIN diode signals recorded during injector voltage droop.

A circular plot of the peak PIN diode signals shown in Figure 7 provides azimuthal information as to where electron emissions occurred inside the vacuum vessel.

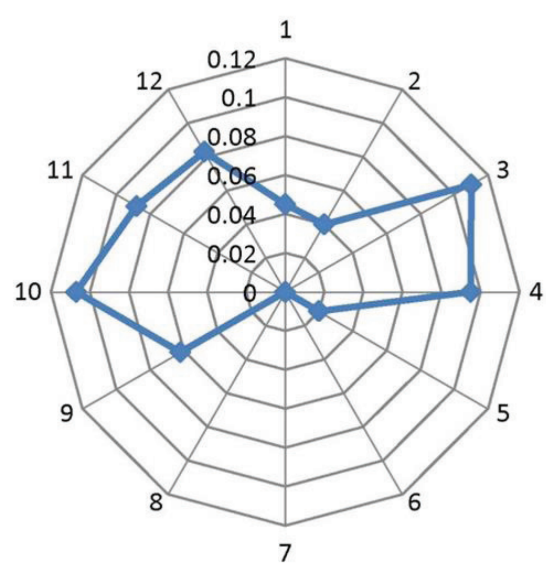

Figure 7: Circular plot of peak PIN diode signals during an abnormal injector event.

CONCLUSIONS

A comparison of the PIN diode signal intensity shows that the LANL detectors are able to identify where electron emissions occur inside the vacuum vessel. The time response of detectors is limited by the low reverse bias voltage used with the system, but is adequate for the X-ray dose rates generated during abnormal injector events.

ACKNOWLEDGMENT

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REFERENCES

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