Diamond Detector: Measuring Beam Intensity

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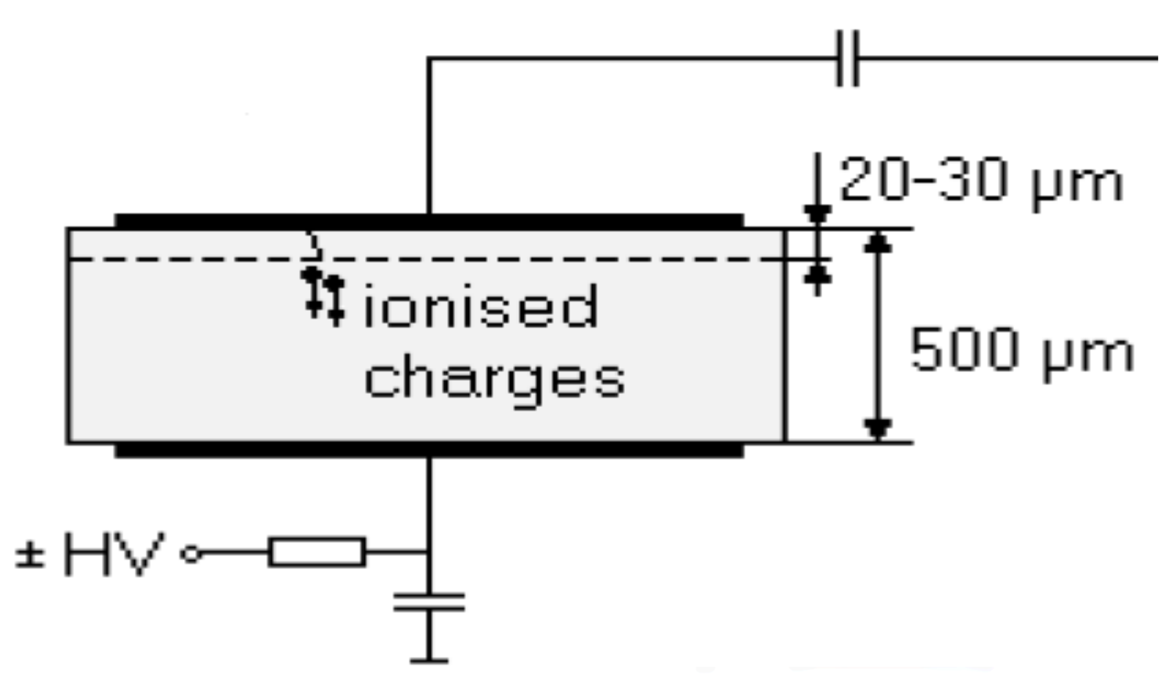
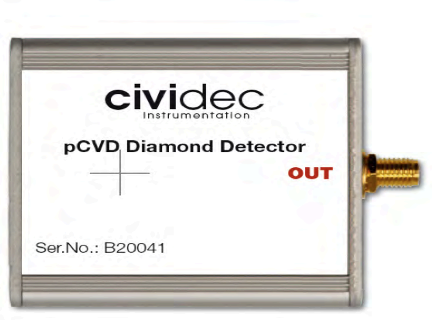
About the Diamond Detector

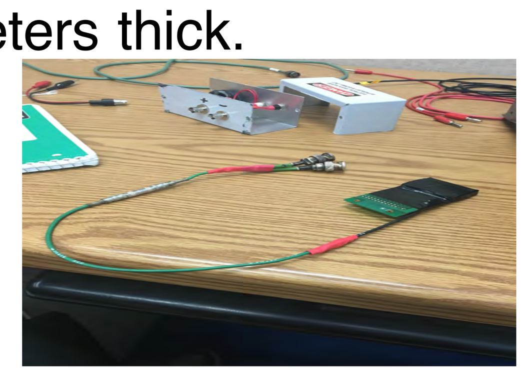
This beam instrumentation device can be used for measuring beam intensity, counting particles and measuring the energy of the beam. Its main purpose in this case is for measuring beam intensity. The diamond detector offers a better and less expensive way than the current method of measuring the beam intensity at the Switchyard beamline. The diamond technology is based on chemical vapor deposition (CVD). A CVD diamond is produced in a vacuum with carbon atoms supplied from gases like methane. The ability to control the gas purity makes the diamond effective for applications in particle detectors and other precise instruments. CVD diamond detectors also have a high radiation tolerance, which makes it useful to use in an accelerator beamline.



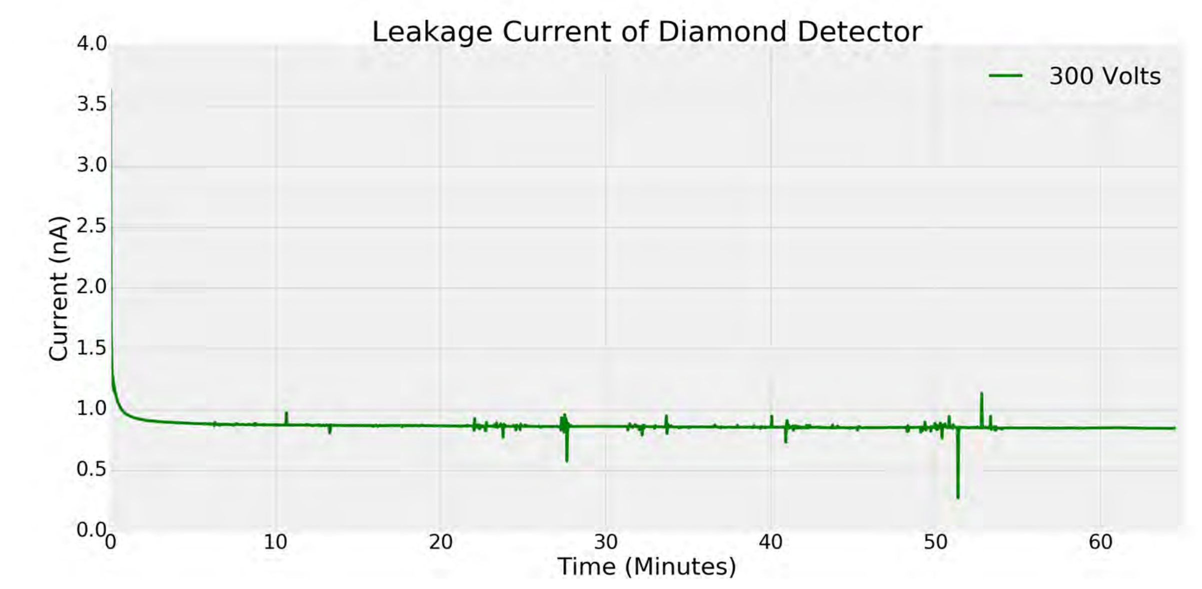


How a Diamond Detector Works

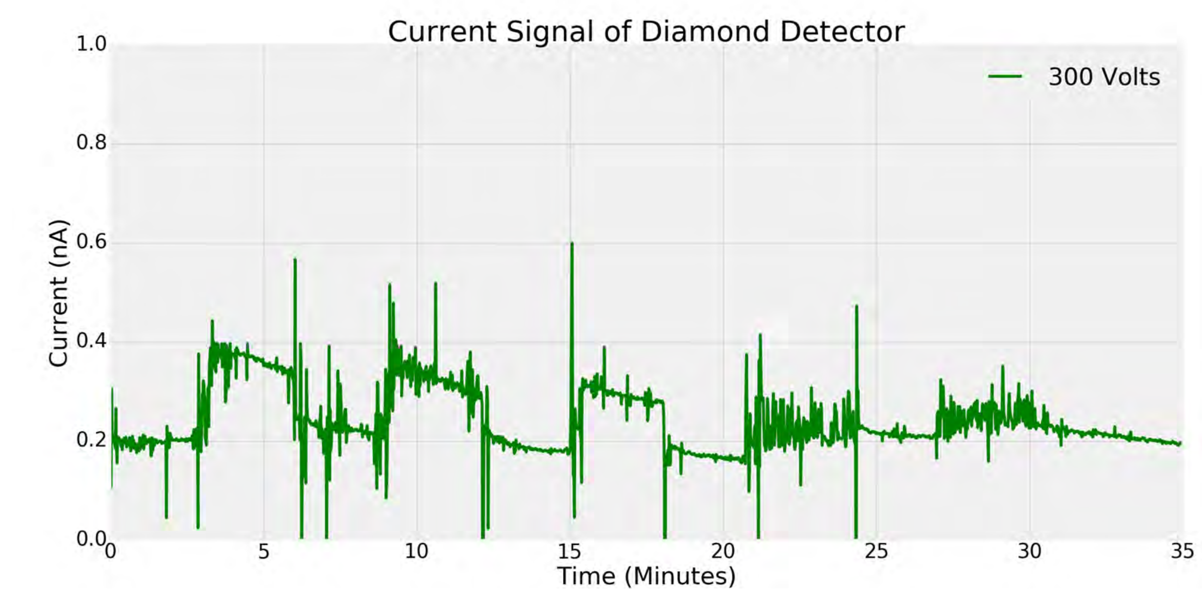
The diamond detector is a charged-particle solid-state detector. A bias voltage has to be applied across the diamond material so that when incoming charged particles hit the diamond material, they will ionize the material and create electron-hole pairs. The drift in these charges (electron-hole pairs) generates a current signal, which can be measured by a precise instrument. The diamond detector that I tested measures 1 x 1 cm^2 and was 500 micrometers thick.



Data



This is the leakage current from the diamond detector that happens over a 60 minute phase. Leakage current is caused by the limited electric conductivity characteristic of semiconductor materials.



A Strontium-90 radioactive source was applied on the diamond material in several increments to test the detection of charged particles.

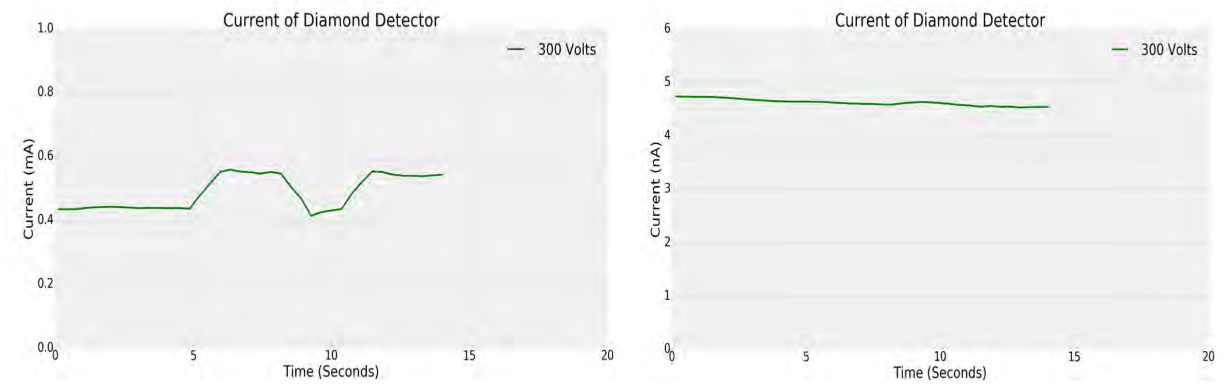
Readout Hardware and Programming

Keithley 1765B picoAmmeter: Supplied a voltage source of 300 volts, and measured current down to the picoamp range.

GPIB to USB Interface: Gives the capability to communicate with the picoAmmeter in order to collect data using various terminals and programs.

Fermilab Test Beam Facility

We tested the diamond detector at the Fermilab Test Beam Facility (FTBF), where there is open access to test beam for particle detectors. Through our experience we learned a very valuable piece of information that assisted us in achieving a very high signal to noise to ratio. That information dealt with the instrumentation of our set up, as shown in the picture above.



These two graphs show the difference of picking up a lot of noise through our readout hardware to the measuring of the leakage current in the nanoamp range with the new instrumentation that fixed our signal to noise ratio.

The problem with our previous instrumentation set up was that we used only one coaxial cable to both apply the high voltage and return the current signal from the diamond detector. Thus, it caused a lot of noise to be picked up by the cable. To improve the instrumentation, we had to have better shielding for the high voltage and the readout from the diamond detector. So, we used two coaxial cables. The first coaxial cable supplied the high voltage, while being grounded. The second coaxial cable readout the current signal from the diamond detector, while also being grounded. As a result of having both coaxial cables grounded, there was better shielding for the instrumentation, which then made our signal to noise ratio higher.

Going Towards the Future

We are planning to use the diamond detector as a beam intensity monitor that can see the microbunch structure of the Switchyard beam through the current signal of the diamond detector. We are also looking to discover the dynamic range of the Diamond Detector.

References

R.M. Zain et al. Leakage current measurements of a pixelated polycrystalline CVD diamond detector. *IOPscience.* 1-6., 2012

E. Griesmayer et al. High-Resolution Energy and Intensity Measurements with CVD Diamond at REX-ISOLDE. *CERN.* 1-12, 2009.