Optically Based Charge Injection System for Ionization Detectors.

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Abstract

An optically coupled charge injection system for ionization based radiation detectors which allows a test charge to be injected without the creation of ground loops has been developed. An ionization like signal from an external source is brought into the detector through an optical fiber and injected into the electrodes by means of a photodiode. As an application example, crosstalk measurements on a liquid Argon electromagnetic calorimeter readout electrodes were performed.

I. INTRODUCTION

For the performance tests of ionization based radiation detectors it is desirable to have a system which is capable of injecting a charge of known value in a condition that is as close as possible to the operating environment, where charge is locally generated by the ionization of the sensitive media in the detector. One of the main problems with the conventional approach of the direct injection through an electrical cable connected to the detector electrodes is the change of the detector electrical characteristics[1]. In particular, the grounding configuration of the system can be completely modified by the introduction of the injection circuit new ground path. The use of an optically coupled injection, in which a light to current converter is placed on the electrodes of the detector to generate the ionization signal, allows for a full galvanic isolation between the detector and the test pulser (Fig. 1).

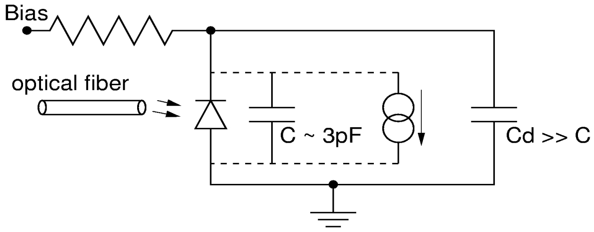

Figure 1: Principle of the optically coupled injection of a test signal to an ionization detector. The capacitance added by the photodiode is negligible.

An optical fiber carries a light pulse, modulated to the same waveshape of a physical signal, to a photodiode connected in parallel to the detector. The photodiode is biased using the same voltage distribution network for the detector bias, using an appropriate voltage, typically 30 V − 50 V. Since no additional electrical connection to the detector is necessary, the electrical environment of the detector, including grounding, is left undisturbed. This makes possible to study on a test bench issues like crosstalk[1] or electromagnetic interference[2] where additional ground loops might taint the results of bench tests.

A photodiode installed on the electrodes and biased by means of the high voltage system achieves the light to current conversion. It has a capacitance of only a few picofarads, small if compared with detector capacitances of the order of nanofarads. The photodiode should also have a fast time response and low dark current. Size is also an issue, as this device may needs to fit in spaces of only a few millimeters. The light, generated by a laser diode stimulated to produce a suitable signal for the detector, is brought to the photodiode using a multimode optical fiber. Fig. 2 and Fig. 3 show the characteristics of two commercial devices which can be used for this application. The laser diode is a VCSEL (Vertical Cavity Surface Emitting Laser) device, capable of generating up to 3 mW of optical power, with a peak wavelength of 860 nm, matching the photodiode maximum sensitivity of 850 nm. The use of a PIN photodiode allows the generation of signals with a rise time of 2 ns, adequate for this application.

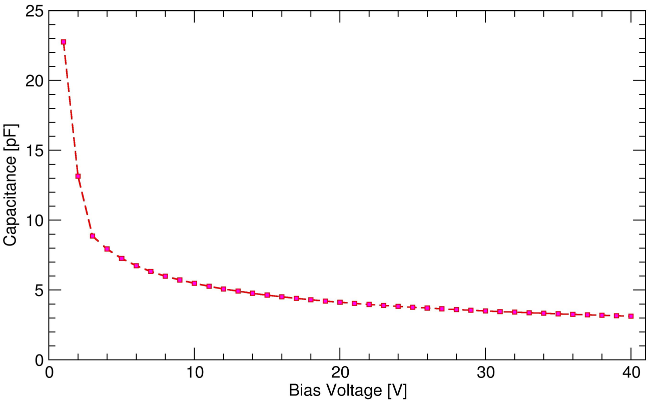

Figure 2: PIN diode capacitance. Capacitance of a PIN diode (Panasonic PNZ334) as a function of the bias voltage. At the operating voltage (28 V) the capacitance is 3.6 pF.

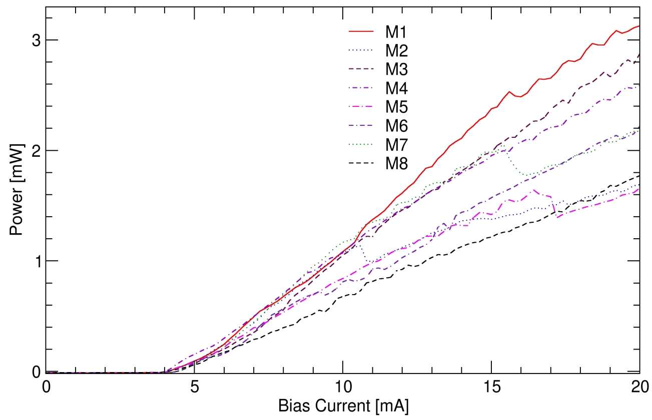

Figure 3: VCSEL power. Power output as a function of the bias current for VCSEL laser diode (MITEL 1A444). Eight different devices (M1 − M8) have been measured.

II. EXAMPLE OF APPLICATION: CROSSTALK STUDY

As an example of this method, the ATLAS Electromagnetic Liquid Argon Calorimeter[3] test stand at BNL has been modified by adding a photodiode on a few calorimeter channels (Fig. 5). The optical signal is created using the VCSEL modulated to produce the same triangular shaped pulse generated by an ionization signal. Crosstalk studies were performed by injecting a signal in one channel at a time and recording the crosstalk pattern on neighbor channels. The output signal is processed using an identical segment of the readout chain of the ATLAS barrel calorimeter: a transimpedance preamplifier (BNL 25Ω IO824 [4]) and a CR−RC^2 shaper, using a time constant of 15 ns (Fig. 4).

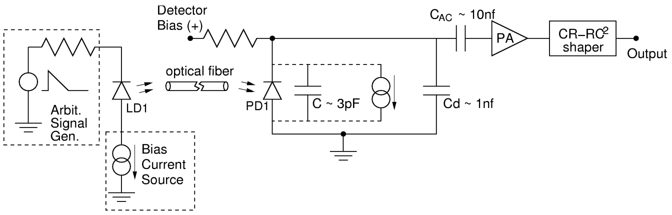

Figure 4: Pulse generation and readout signal circuit. The optical signal is generated by LD1 (MITEL 1A444 VCSEL), biased by a current source (ILX Lightwave LDX−3630) and driven directly by an arbitrary signal generator (Analogic Model 2040) programmed to give out a triangular pulse. The light signal is transmitted by the optical fiber to PD1 (Panasonic PNZ 334). A current is then injected in one channel of the calorimeter test module (capacitance Cd), which is AC coupled by C_{AC} directly to the readout chain.

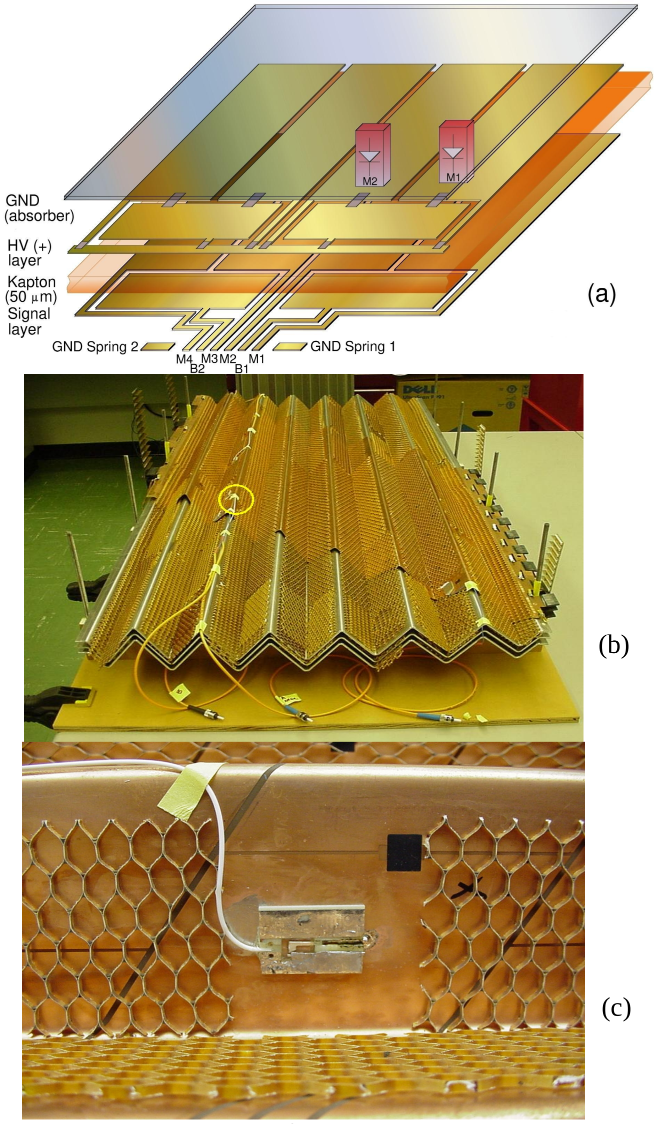

Figure 5: Experimental setup for optically coupled charge injection of the ATLAS barrel liquid Argon electromagnetic calorimeter. A PIN photodiode is connected (a) within the gap from the absorber (ground) to the high voltage layer. M1 through M4 and B1, B2 are readout channels. The signal ground is provided by two points (GND Spring 1 and 2). The optical fiber is run along the tip of the bending of an electrode (b), and brought to the side of the module, where it is coupled to a laser source. The photodiode is mounted on a carrier PC board (c), soldered to the electrode (anode) and contacting the absorber (cathode). An indium foil is used to assure a low resistance electrical connection.

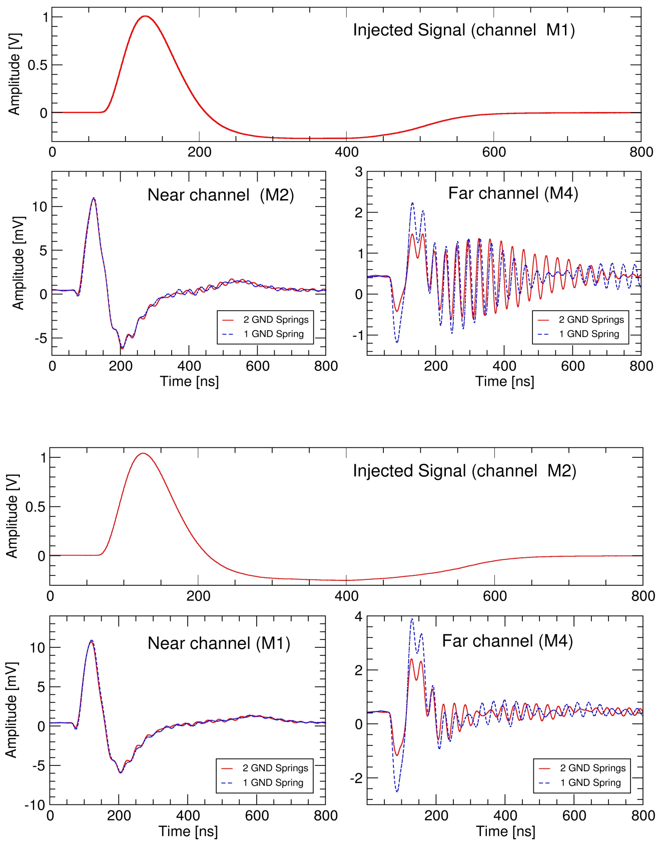

Figure 6: Measured crosstalk. A signal is injected in one channel (Fig. 5a M1 or M2) and the crosstalk is observed in the closest and in the farthest neighboring channels with ground springs both to the left (GND spring 2) and to the right (GND spring 1) of the connector (continuous trace). Removal of the ground springs to the left of the connector increases the distant crosstalk (dashed traces).

In this example, one of the ground connections between the electrodes and the absorbers on the left side of the signal connector (GND Spring 2 in Fig. 5a) was removed, and the change in the crosstalk pattern observed by injecting a signal in two different neighbor channels (M1 and M2). The results (Fig. 6) show that the nearest neighbor crosstalk is unchanged. The distant crosstalk (channel M4) is indeed affected by the removal of the ground springs, but remains always less than 0.2%. The optical injection allows to reliably detect differences in crosstalk signals of less than 1 mV and to rule out any ground loop effect as the cause of these small differences.

III. Conclusions

We showed that an ionization−like signal can be injected by optical means, allowing measurements of small amplitude signals in large systems without disturbing the grounding configuration of the detector. Since the capacitance of the photodiode is much smaller than the detector capacitance, there is no change in the electrical characteristics of the system. Most important, the undisturbed ground configuration makes possible to systematically study small amplitude effects that otherwise would be masked by interferences caused by differences in the ground path.

This setup can be expanded for injecting signals in multiple channels simultaneously. This may be accomplished by the use of a direct current injection of the laser (Fig. 7) and direct coupling to the fiber without optical connectors, allowing injection and inter−calibration of several channels. With this method it is possible, for example, to reproduce the charge distribution of an EM shower over many cells of a calorimeter, thus allowing a more complete study of the crosstalk of the system.

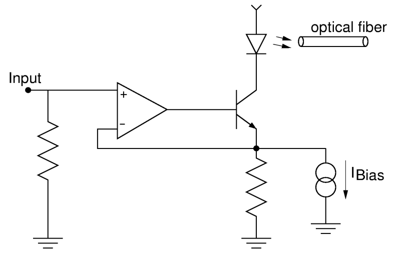

Figure 7: Fast voltage−to−current converter for direct laser modulation. This simple driver circuit allows to build many compact driver−laser−photodiode assemblies which can be inter−calibrated before installation on the electrodes. The optical connections could be simply made with optical glue, thus avoiding optical connectors and the variation in attenuation inherent in the mating of optical connectors.

IV. Acknowledgements

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V. References

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