Extended Abstract with Poster

Two dimensional Maxwell Plots for a single, double, and triple Gas Electron Multiplier (GEM) X-ray fluorescence gas detector

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Extended Abstract

We built a fluorescence gas X-ray detector using a single, double, and triple Gas Electron Multiplier (GEM) enclosed in a multiple Plexiglas flanges. The GEM is made of two thin perforated copper electrodes separated by a Kapton as an insulator [1]. The detector consists of three regions: an ionization, amplification, and collection regions placed one on top of the other separated by the Plexiglas flanges as in Figure1(a, b). All parts of the detector are held together using O-rings to provide gas leak free detector. Argon gas mixed with Carbon Dioxide in the ratio of 80/20, used as a detecting medium, is allowed to flow through the detector at a slow flowing rate. Three electric fields are created in each region of the detector, the highest electric field exits in the amplification region where the GEM is located. When a fluorescence X-ray from a test sample interacts with the flowing gas, ionization of the gas takes place. The primary ionized electrons from the ionization region are drifted by a small electric field into the GEM area where the high electric field generates more electrons by impact ionization. The perforated GEM allows the primary electrons to enter and leave after multiplication in the GEM towards the collection region. We have generated two dimensional Maxwell SV plots that were used to generate both the electric field and the equal potential lines for the three regions of the detector. These differences in magnitudes and functions of the electric fields, in each region of the detector, are made because of the variable values of the potential differences applied between the consecutive conducting electrodes. The lowest negative DC high voltage is applied at the Mylar window as in Figure 1a. The first GEM is placed below the Mylar window. Consecutive GEMs are placed below each other with respect to the Mylar window as in Figure 1a. The voltage at the top of the GEM is always lower negatively than the bottom of the GEM. This is to provide a voltage difference to create an electric field. The direction of the electric field points upward towards the Mylar to allow the negatively charged electrons to flow downwards towards the GEM and finally to the collection region. The first electric field is between the Mylar and the top of the GEM, in the drift region. The second electric field is between the top of the GEM and the bottom of the GEM in the multiplication or amplification region. The third electric field is between the lower electrode of the GEM and the printed circuit board (PCB) known as the collection region.

The intent of this extended abstract is to plot the electric field, equal potential lines [2-4], and to demonstrate how the primary electrons generated from the fluorescence X-ray of the dilute test sample are drifted in the first region of the detector, amplified in the second region of the single GEM or multiple GEMs, and then collected by the third region of the electric field towards the printed circuit board (PCB) for further electronic amplification and processing of the data. For more noise free amplification of the primary ionized electrons multiple GEM are added below the first GEM. Both the equal potential and the electric field lines for each region are plotted using Maxwell SV two dimensional plots for single, double, and triple GEM X-ray fluorescence detector. The software is a free download from the internet [5, 6].The two dimensional Maxwell software helps to provide a physical picture of the electric field and the equal potential lines in the three regions of the detector as in Figure 2 (a, b).

An enlarged and a zoom in plots of the equal potential lines and the electric field within the GEM are shown in Figure 3(a, b). This is the main region of amplification of the primary electrons generated by the fluorescence X ray emitted by the test sample.

Similar plots and results are obtained for the double and the triple GEM detector. For the double and triple GEM detector we add a second GEM below the first GEM for the double and we add a third GEM below the second GEM to form the triple GEM. Each GEM provides its own amplification that is similar to the GEM before it. However, the numbers of the electrons that are amplified in the first GEM are further amplified by the second GEM. Furthermore, the third GEM amplifies the amplified electrons from the second GEM. The intent is to obtain multiple amplifications of the primary electron signal without any noise. This improves the signal to noise (S/N) ratio that is badly needed when testing dilute elements producing very small primary electrons during X-ray absorption spectroscopy (XAS). For lack of space, in this extended abstract, the Maxwell SV plots for the single and triple GEM are not shown.

We obtained results from the actual test experiment using a single GEM X-ray fluorescence detector for a dilute sample, a leaf of tree as in Figure 4. We have used NSLS synchrotron facilities at Brookhaven National Laboratory in Long Island, New York. The single GEM provided a relatively good scan for Iron (Fe) in a dry tree leaf.

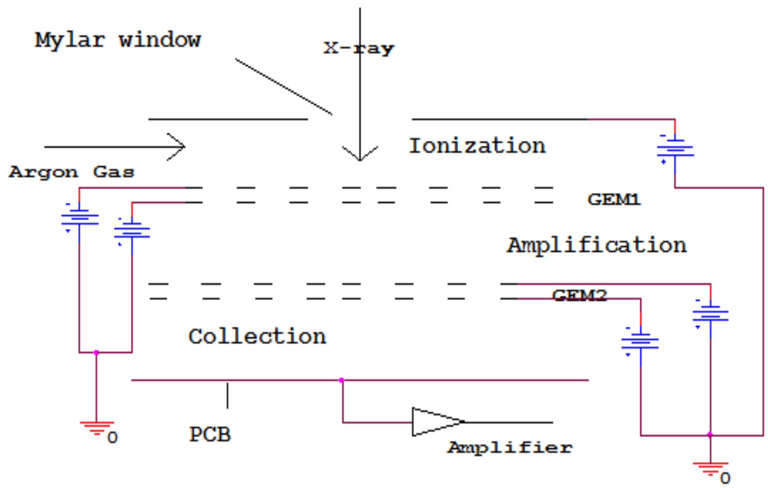

Figure 1a. The double GEM detector sketch showing the Mylar, the GEM and the PCB Board with HV DC biased sources and the electronic amplifier

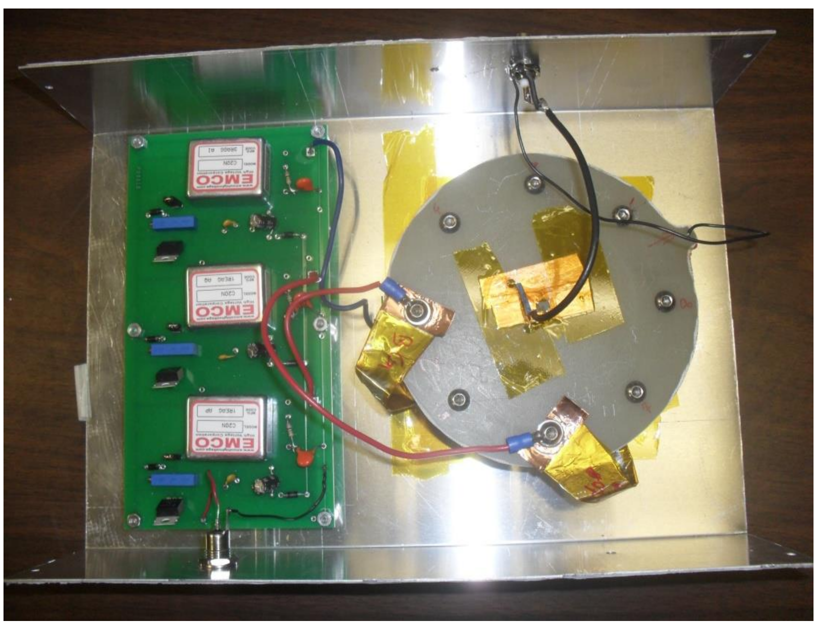

Figure 1b. The actual single Gem detector assembly with a built-in HV DC sources for the Mylar, upper and lower GEM electrodes voltages

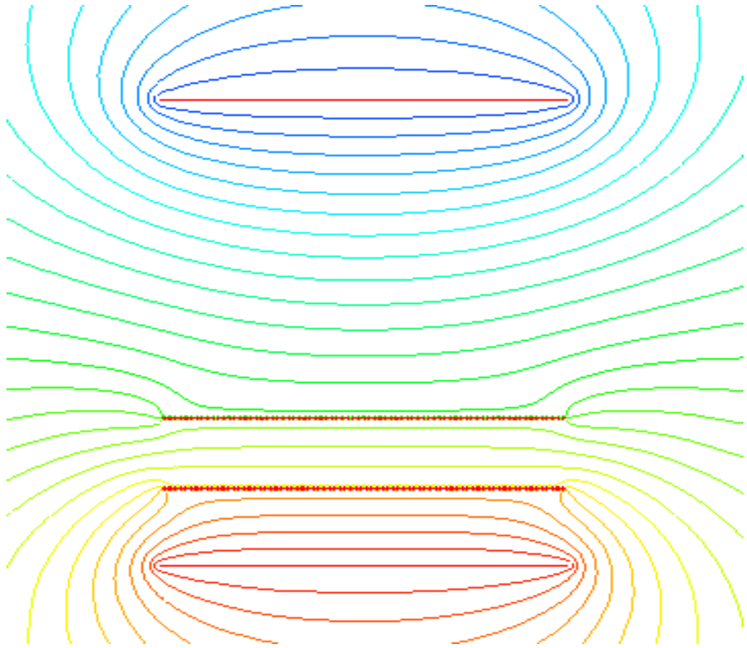

Figure 2a**.**The exact geometrical drawing of Maxwell SV for a double GEM using Maxwell SV showing the potential lines for both the drift and the collection regions.The Mylar, the GEM, and the PCB are shown as horizontal straight lines. The contour lines are the equal potential lines.

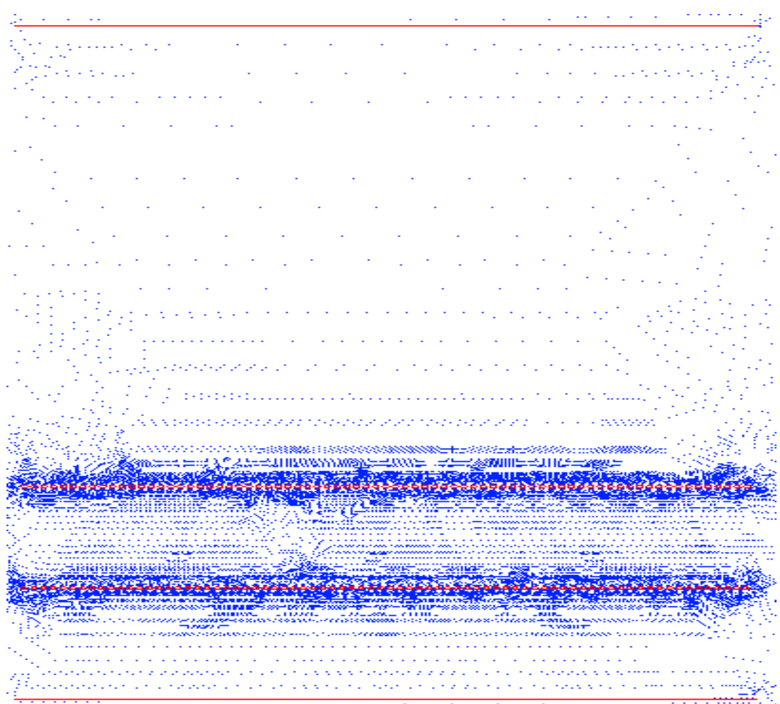

Figure 2b. The electric field lines for a double GEM showing the drift, amplification, and collection regions. Notice the concentration of the Electric field within the GEM holes. The Mylar, the GEM and the PCB are shown.

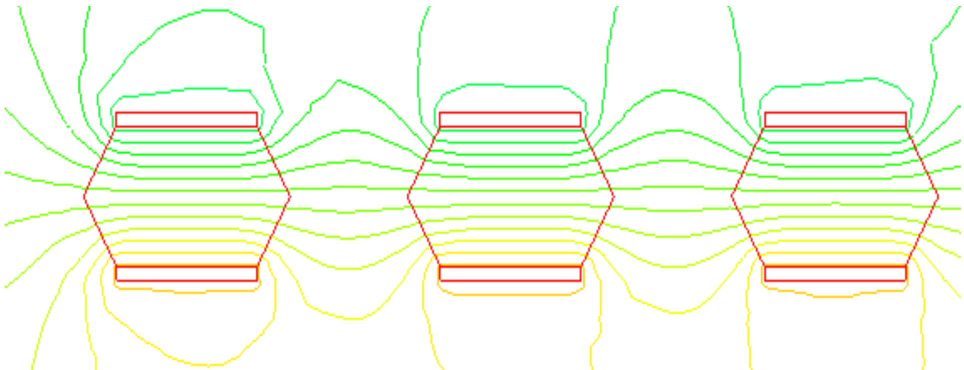

Figure 3a.The equal-potential lines within the GEM enlarged.

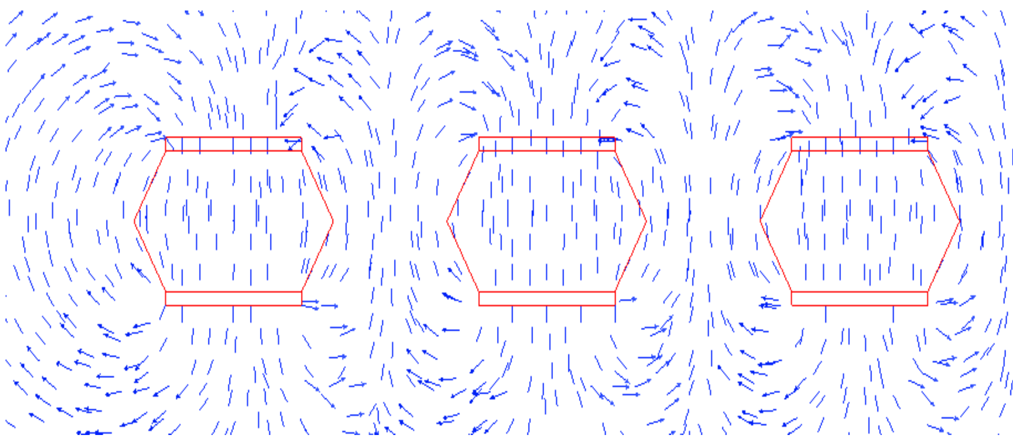

Figure 3b.The Electric field lines and direction within the holes of the GEM enlarged.

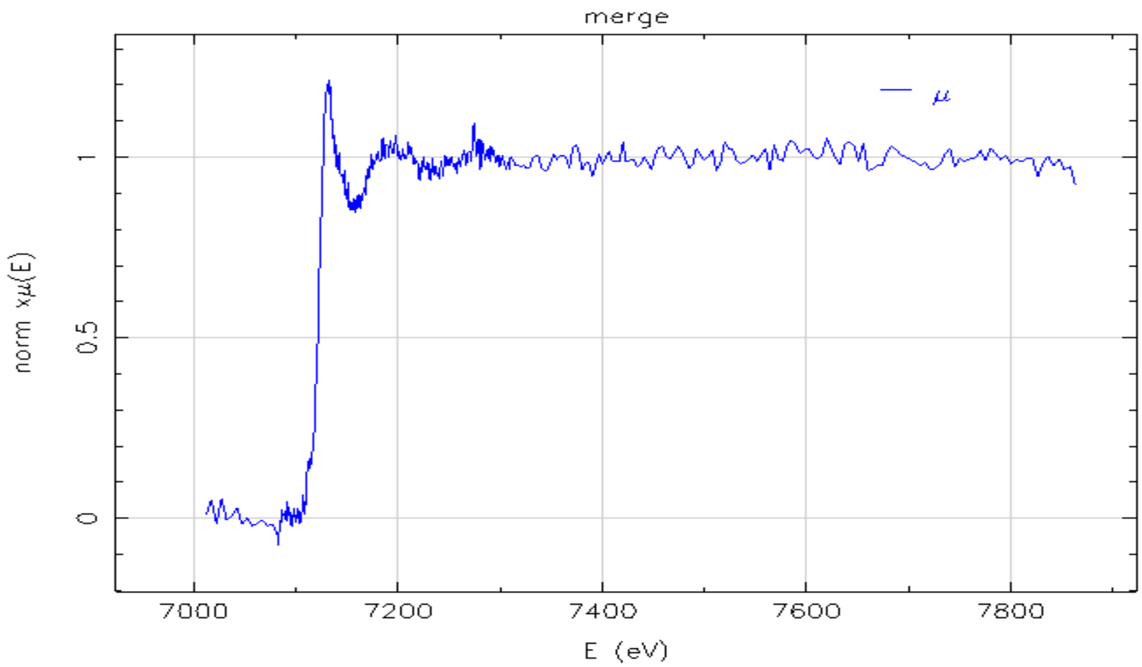

Figure 4. A single GEM 10 cm x 10 cm, X-ray fluorescence detector scan for an arbitrary leaf of a tree.

Summary and Conclusions

In this paper we have made a detailed plotting of both the electrical field distribution and the equal potential lines for a double GEM X-ray fluorescence detector using Maxwell SV software. These plots show clearly the concentration of the electric field in the amplification region within the GEM holes. Multiple GEMs allow further amplifications as the amplified electrons move from one GEM area holes to another GEM area holes. The advantage of multiple GEM is that we can decrease the magnitude of the Electric field in each GEM so as to avoid gas discharges breakdown and the creation of sparks that completely destroys the GEM and voids its use as an amplification region.

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