## Recent Advances in Pyroelectric Radiation Generation

Jeffrey Geuther, Yaron Danon, Kamron Fazel

*Rensselaer Polytechnic Institute, 110 8th St., Troy, NY 12180. geuthj@rpi.edu*

### INTRODUCTION

Pyroelectric crystals have been shown to be a useful tool for producing x-rays, positive ions, and fusion neutrons. [1 - 4]. We have previously shown that the k-shell characteristic x-rays of any element up to Z = 90 (Thorium) can be produced with a paired-crystal pyroelectric x-ray source [1], and that >140 keV electrons and ~90 keV ions can be produced with a single crystal [2]. Our research culminated in the first independent verification [3] of the pyroelectric fusion results published by Naranjo *et al.*, in which pyroelectric accelerators were shown to produce fusion neutrons [4].

Recently, our focus has been twofold. First, we have experimented with several ways of increasing our neutron yield from our fusion experiments. Methods we have tried include optimizing the emitting tip diameter and changing to a higher deuterium density plastic target. Second, we have begun to explore alternative uses of pyroelectric accelerators. Specifically, we have shown that >80 keV electrons can be extracted from our vacuum chamber in a semi-stable beam.

### DESCRIPTION OF THE ACTUAL WORK

Fusion neutrons were produced by heating and cooling two 20 mm diameter x 10 mm thick $LiTaO_3$ crystals to produce a strong electric field. The crystals were oriented such that the positively-charged face of one crystal would face the negatively-charged face of the other crystal. The field, which was on the order of 10 MV / m, was enhanced using a variety of nano-scale metallic tips mounted to the positively-charged crystal. The enhanced field caused the ionization of a deuterium fill gas near the tip. The ions were then accelerated toward the negatively-charged crystal, which was covered with a deuterated target. The resulting D-D fusion reactions were recorded using a 5" x 3" liquid scintillator with pulse-shape discrimination.

Several methods were used to optimize the neutron yield. First, the original target of deuterated polystyrene $-(C_8D_8)-$ was replaced with a deuterated polyethylene $-(C_2D_4)-$ target to improve the deuterium number density. Next, the metallic tips were modeled as charged spheres to determine the tip radius which would result in the greatest deuterium fill gas ionization. It was determined that a 200 nm-radius tip would ionize more deuterium than our original 70 nm tip, so we replaced the tip accordingly.

The electron production experiment was performed by aligning a 5 mm diameter x 10 mm thick $LiTaO_3$ crystal with a 25.4 μm beryllium window, with the crystal oriented such that it emitted electrons toward the window during cooling. The crystal was heated to ~180°C over 500 seconds and then was allowed to cool to room temperature. A Faraday cup was mounted to the outside of the window, and a LabView program controlling an HP 3458A multimeter was used to measure the electron current transmitted through the window as the crystal cooled.

### RESULTS

The optimization of the neutron production experiment yielded a slight increase (14000 ± 500 counts per cycle versus 10000 ± 600).

The electron beam experiment resulted in an 88 keV (maximum energy) beam which steadily decayed in current from several tenths of a nanoamp to zero over the course of an hour. As the cooling phase progressed, an equilibrium was reached in which the emission current closely matched the charge generated by the pyroelectric effect [See Figure 1].

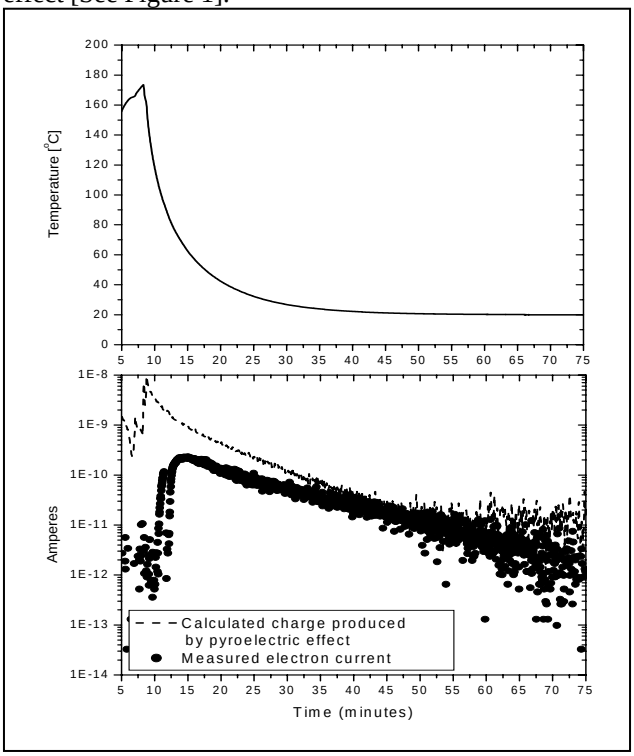


**Figure 1** - Electron current transmitted through 1-mil Be window as a function of time versus charge created due to the pyroelectric effect and temperature.

## CONCLUSIONS

The optimization of the neutron production experiment was expected to yield a greater improvement over the previous results than we observed. There are several possible contributing factors, but the greatest challenge which must be counteracted is the frequent occurrence of electrostatic discharge. The discharge effect, which is due to the large potential (100 - 200 kV) and small separation distance (~2 cm) between our crystals and ground, causes us to lose our accelerating potential, often before it can reach useful levels.

The initial results from the electron emission experiment are encouraging, and demonstrate that a sealed pyroelectric source can be used to deliver a usable beam.

## ACKNOWLEDGMENTS

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