Development of a Pyroelectric Neutron Source

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INTRODUCTION

Since Brownridge reported x-ray production from the heating or cooling of a pyroelectric crystal in 1992[1], pyroelectric sources have been developed which can produce x-rays with energy of over 200 keV[2] using only a few watts of power. This technology has enabled the manufacture of battery-powered x-ray sources for field and laboratory use[3]. When a pyroelectric crystal is heated or cooled in a vacuum, a surface charge appears due to the uncompensated change in the crystal's polarization. X-rays are generated when the high potential caused by this surface charge causes electron emission and accelerates the electrons into a target. In addition to electron acceleration, the field also causes ionization of the fill gas, and can accelerate the positive ions to ~100 keV.

Recently, it had been proposed that the strong field from pyroelectric crystals could also be used to cause field ionization of a dilute deuterium gas, and accelerate the deuterons into a deuterated target to cause fusion[4]. This technique, which was successfully implemented by Naranjo, Gimzewski, and Putterman[5], may eventually be used to create miniature low-power neutron sources similar to the pyroelectric x-ray source currently on the market.

Here we present results showing the production of fusion neutrons using a paired-crystal source.

DESCRIPTION OF THE ACTUAL WORK

Two 10 mm thick by 20 mm diameter $LiTaO_3$ crystals were mounted to copper plates with thermally conductive epoxy. The copper plates were mounted with screws to aluminum heat sinks, with thermoelectric heaters sandwiched between the copper plates and the heat sink. Silver paint was used to improve the thermal conductivity between the surfaces. The backs of the crystals were grounded through the copper plate and heat sink.

The crystals were oriented to face each other and were separated by 17 mm. The z+ surface of one crystal was oriented to face the z- surface of the other crystal, such that, when subjected to the same heating cycle, the crystals would form a nearly-uniform electric field of twice the strength available from a single crystal.

A small amount of deuterated polystyrene (DPS) was dissolved in toluene at 120°C. The solution was dripped onto the surface of the crystal with the exposed z- surface and allowed to dry, thereby creating a thin (~50 μm), smooth deuterated target on the crystal surface. A tungsten "catwhisker" probe tip with an apex radius of 70 nm was mounted to a 15 mm diameter copper disc, which was attached with silver paint to the surface of the opposing crystal. The entire experiment was mounted to an aluminum block and placed in a vacuum chamber with <10 mTorr of deuterium gas.

A 3" diameter Eljen EJ-301 liquid scintillator detector was located in a lead shield outside of the vacuum chamber, at a distance of 9 cm from the center of the DPS-coated crystal. A 2 mm lead sheet was held between the scintillator and the vacuum chamber to shield against x-rays. The signal from the anode of the photomultiplier tube was processed for pulse-shape discrimination to eliminate background counts due to gamma- and x-rays. The background count rate was 0.22 +/- 0.02 counts per second [CPS]. The crystals were simultaneously cooled to 10°C, heated to 110°C, and then allowed to cool naturally to 40°C. During the cooling phases, the crystal holding the catwhisker tip was positively charged, allowing it to accelerate positive deuterium ions toward the DPS-coated crystal, which was negatively charged.

RESULTS

Neutrons were observed during cooling at thirty times the background count rate. The production of fusion neutrons was found to be a repeatable occurrence. As further verification of the presence of neutrons, the energy of the edge in the neutron spectrum was compared to the 314 keV and 1019 keV Compton edges of ^{22}Na , and was found to correspond to ~700 MeVe, which is as expected for neutrons in an EJ-301 scintillator[6]. A ^{252}Cf source was used to verify that the pulse-shape discrimination completely eliminated the source gammas while allowing the neutrons to be counted. Finally, to verify that x-rays were not causing the increase in detector count rate, the system was run without the deuterium fill gas, and the observed count rate was seen to remain at the background level despite the presence of abundant x-rays.

REFERENCES

1. BROWNRIDGE, J. D., "Pyroelectric X-ray Generator," *Nature*, **358**, 287, (1992).

2. GEUTHER, J., DANON, Y., "High-Energy X-ray Production with Pyroelectric Crystals," *J. Appl. Phys.*, **97**, 104916, (2005).
3. www.amptek.com/coolx.html
4. GEUTHER, J., DANON, Y., "Electron and Positive Ion Acceleration with Pyroelectric Crystals," *J. Appl. Phys.*, **97**, 074109, (2005).
5. NARANJO, B., GIMZEWSKI, J. K., PUTTERMAN, S., "Observation of nuclear fusion driven by a pyroelectric crystal," *Nature*, **434**, 1115, (2005).
6. KNOLL, G. F., *Radiation Detection and Measurement, 3rd Ed.*, John Wiley and Sons, New York, p. 228 (2000).