

Deuterium Ionization For Pyroelectric Crystal Accelerators

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INTRODUCTION

Researchers have reported that pyroelectric crystals may be used to achieve DD fusion.^{1,2} Current research is concentrated on increasing the neutron yield for potential homeland security applications. An important aspect in realizing pyroelectric fusion is to ionize and accelerate deuterium gas toward a deuterated target. This research includes development of a novel mass spectroscopy system to characterize D₂ gas ionization due to a pyroelectric crystal-generated electric field.

A lithium tantalate (LiTaO₃) crystal with a 70 nm tip was used to ionize and accelerate D₂ gas through a magnetic field. An ion detection system including a zinc sulfide screen and a Starlight Express® camera was used to measure the deflection of the ions through the magnetic field in order to resolve whether D₂⁺ or D⁺ ions are being produced. Measurements were compared to expected deflection calculations to corroborate results.

THEORY

The force on a charged particle in a uniform magnetic field and the force on a particle with centripetal acceleration can be combined to determine the radius of curvature of a charged particle in the magnetic field. The radius of curvature (*R*) equation can be converted into units of interest to be

$$R = \left(\frac{144}{B} \right) \left(\frac{mV}{n} \right)^{1/2} \quad (1)$$

where *V* is the electric potential in volts, *m* is the particle mass in amu, *B* is the magnetic field strength in Gauss, *n* is the number of charges, and *R* is in cm.³

Using trigonometry, the deflection distance caused by the magnetic field can then be determined using

$$d = \frac{x^2}{2R} \quad (2)$$

where *d* is the deflection distance, *x* is the length of the magnet and *R* is the radius of curvature from eqn. 1 above.⁴ The angle at which ions exit the magnetic field can be found using

$$\theta = \arcsin \left(\frac{x}{R} \right) \quad (3)$$

Assuming no additional forces act on the ions, total deflection can be calculated using the exit angle from the magnetic field and the distance between the magnets and the screen.

DESCRIPTION OF THE ACTUAL WORK

A 20 mm diameter, 10 mm thick LiTaO₃ crystal was mounted on a thermoelectric heater with a 2 mm long 70 nm tip on a 13 mm diameter, 1 mm thick copper disk. The crystal was placed in a vacuum chamber evacuated to approximately 1 μtorr and then filled to between 1 and 8 mtorr of gas. In addition to deuterium gas, air, argon, or nitrogen were used to establish a reference point and helium gas was used to verify deuterium displacement.

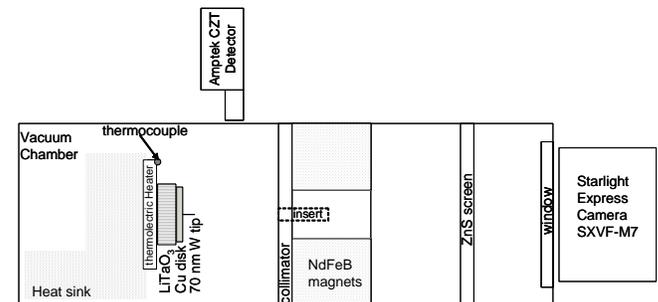


Fig. 1. Experimental Setup.

The crystal was heated to approximately 130 °C and allowed to cool to ambient temperature through radiative heat transfer. An Amptek XR-100CT, cadmium zinc telluride (CZT) semiconductor diode detector was used to monitor x-ray emission and a Starlight Express, SXVF-M7, 16 bit mono-camera was used to take pictures of the ZnS screen when the x-ray emission peaked.

Several configurations of the collimator including with and without an insert were used in these experiments. Mathcad® was used to analyze pictures for location and intensity of the light measured from the ZnS screen. Mathcad was also used to calculate the expected deflection distance for ions.

RESULTS

Based on measured and expected results, D_2^+ was being produced and accelerated to between 65 and 80 keV. There was no evidence that D^+ ions were being produced in large quantities. Helium results verified the relative D_2^+ positions and indicated that a relatively small amount of doubly ionized helium was being produced. Heavier gas such as argon and nitrogen was also used to verify relative deflection distances.

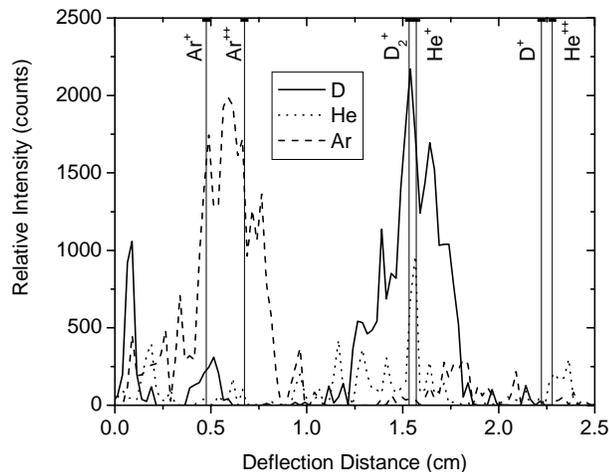


Fig. 2. Collimator with insert results.

CONCLUSIONS

A novel mass spectroscopy system was constructed using pyroelectric crystals as an ion source. No evidence for D^+ ions was found. DD fusion neutron yield from a pyroelectric accelerator using tip ionization sources should be calculated using D_2^+ ions. As a result, the DD interaction energy is half that of the accelerated ion energy.

ACKNOWLEDGMENTS

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