Calibration of the Response of Radiochromic Film to Monoenergetic Ion Beams from a 1.7 MV Pelletron Accelerator

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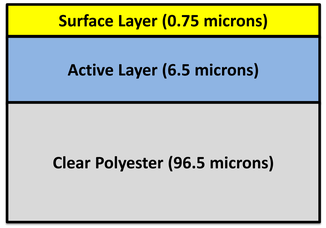
Abstract

Radiochromic film (RCF) is used to study protons and other ions that are accelerated from the rear side of targets illuminated with ultra-intense laser light. An experiment is underway to characterize the response of RCF to protons, deuterons, and alpha particles of various energies using the 1.7 MV tandem Pelletron accelerator at SUNY Geneseo. A monoenergetic ion beam from the accelerator is incident on a thin (0.1 um) gold foil placed in the center of a 28-inch diameter scattering chamber. A strip of RCF is positioned in a circular arc that is centered on the gold foil. The ion beam strikes the gold foil, causing the RCF to be exposed to elastically backscattered ions. The scattered ion fluence on the RCF strip varies as a function of the scattering angle. After removal from the chamber, the RCF is scanned in transmission mode using an Epson 10000 XL flatbed scanner. The red channel of the resulting scan is used to determine the optical density of the film.

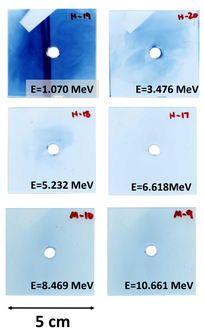
Radiochromic Film (RCF)

Originally developed for photon dose measurements, GAFCHROMIC HD-810 radiochromic film has become widely used in a variety of fields as a detector for energetic ions. The active layer is deposited on a 96.5um polyester substrate before being coated by a thin gelatin surface layer. When struck by a particle, radiation sensitive monomers in the active layer react to form a blue colored polymer. In the first minutes after exposure, the optical density increases rapidly. Due to the kinetics of the reaction, the optical density reaches a constant value after a period of about 24 hours.



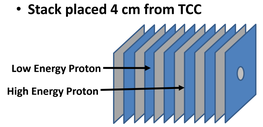
Motivation

Radiochromic film has been used at the Multiterawatt (MTW) Laser Facility at the Laboratory for Laser Energetics (LLE) to study ions accelerated from the rear side of targets illuminated with ultra-intense laser light. By placing RCF in a stack, the energy of incident ions can be determined by measuring how far they penetrate into the stack. Calibrating the response of RCF to ions of a given energy will allow quantitative ion energy spectra to be determined using this technique.



Radiochromic Film (RCF) stack

- RCF film alternates with aluminum foil
- Stack placed 4 cm from TCC



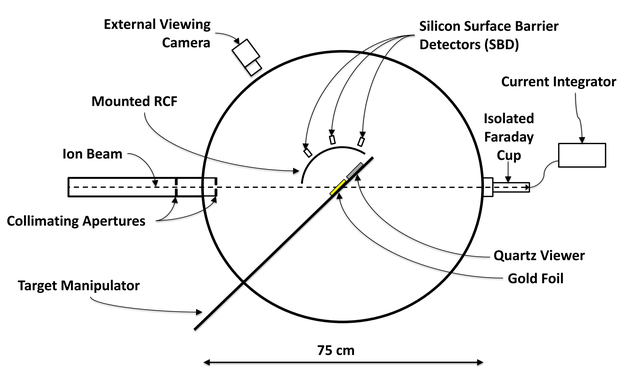
- Laser Pulse: 5 Joules in 1 ps
- Focused spot size: approx 6um x 6um
- Target: 50um x 50um x 2um Copper Foil

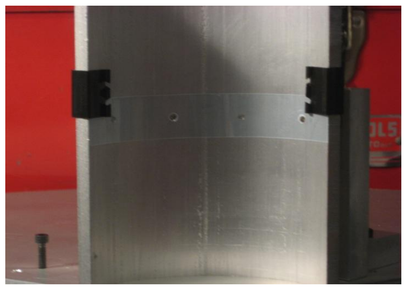
Evidence for proton production with energies above 5.2 MeV, and possibly up to 10.6 MeV

Geneseo Pelletron Accelerator

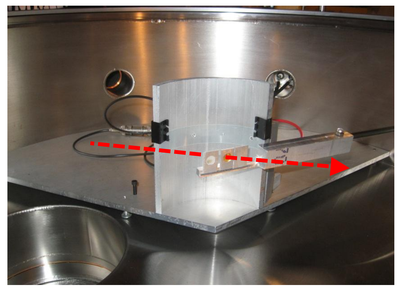
The SUNY Geneseo Accelerator Laboratory consists of a 1.7 MV Tandem Pelletron Accelerator from the National Electrostatics Corporation (NEC). An Alphatross RF Alkali Charge-Exchange ion source produces proton, deuteron, or helium beams which are injected into the accelerator. Maximum beam energies are 3.4 MeV for protons and deuterons and 5.1 MeV for helium beams. This facility was installed at Geneseo in 2007.

Experimental Setup



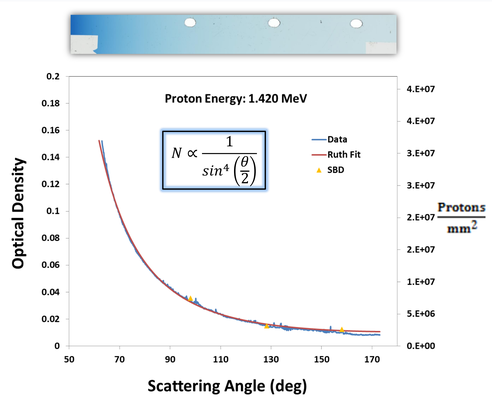


Mounted unexposed RCF shown immediately before placement in the scattering chamber. The area blocked by the binder clips was used for background subtraction. Holes punched through the RCF allow scattered ions to reach a surface barrier detector placed behind the RCF mount.



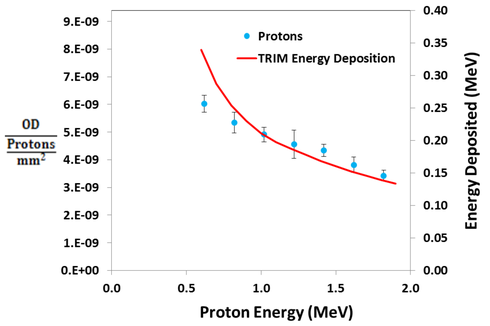
RCF positioned before closing the chamber lid with incident beam direction indicated. The photo shows the gold foil and quartz viewer mounted on the target manipulator. Due to the Rutherford scattering formula, proton fluence falls off sharply as a function of scattering angle.

Data Analysis



Films were scanned in 48 bit negative color at 450 dpi on an Epson 10000 XL flatbed document scanner in transmission mode. The average red channel intensity over a small area was measured at each pinhole. Background values were obtained from the unexposed portion of film behind the clips used to secure the RCF during exposure. The background subtracted red channel value was converted to an optical density before further analysis. Three silicon detectors placed around the film allowed absolute ion fluence to be determined.

Preliminary Results



The optical density was compared to the absolute proton fluence as measured by the three surface barrier detectors. These data were fit with a straight line and the sensitivity of the film was characterized by the slope of this line (OD/protons/mm^2). The sensitivity of the film was then plotted as a function of incident proton energy. As expected, the sensitivity of the film decreases as a function of energy since more energetic ions deposit less energy in the film. The software package TRIM was used to estimate the energy deposited by the protons in the active layer of the film, and the data compares favorably with the measured sensitivity.

Future Plans

- Perform measurements of RCF response to different ion species (e.g. deuterons, alphas)
- Measure response of different types of RCF (e.g. MD-55-v2, EBT)
- Increase maximum proton energy (up to 3.4 MeV)
- Cross calibrate Epson 10000XL scanner versus precision microdensitometer