Controllable TNSA Deuteron Beams using Deuterated Titanium Targets Toward Generating a Tritium Beam

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Summary

Energetic TNSA deuteron beams were generated using deuterated titanium targets

- A platform for a MeV tritium beam at the Laboratory for Laser Energetics is being developed using deuterium as surrogate

- Tritium-induced reactions like $T(t, 2n)\alpha$ and $^6Li(t, p)^8Li$ allow for the study of exotic neutron rich nuclei relevant to ab-initio nuclear structure calculations

- The deuteron yield depends only marginally on the deuteration conditions

- The deuteron spectra transition from exponential to asymmetric Gaussian with increasing laser energy

- Numerical simulations of the ion-acceleration process help to interpret these puzzling results

- Mean energies between 0.5 MeV (MTW) and 5 MeV (OMEGA EP) were observed

TNSA: target-normal sheath acceleration
MTW: Multi-Terawatt laser
Collaborators

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Titanium targets are exposed to a deuterium atmosphere.

Molecular deuterium dissociates at the surface and migrates into contamination layers.

Deuterium temperature, pressure, and exposure time have only marginal impact on the deuterium yield.

Protons in the contamination layers are isotopically exchanged with deuterium from a pure deuterium atmosphere.

Targets are loaded at 900 Torr of D₂ pressure at 350°C for 24 hours.
The MTW laser accelerates deuterons from a deuterated Ti foil toward a Thomson parabola.
Survey studies were conducted at 1, 5, 7, and 10 ps and varying energies from 1 to 23 J.
For each individual shot, the intensity is binned along each trace to obtain a spectrum.
TNSA experiments at constant pulse duration but increasing energy show the formation of a peak.

Deuterons spectra at 5ps

Simulations for constant timing
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Backup
Boundary conditions for constant laser pulse durations but varying energies

- The ions are accelerated by \( n_e \) electrons with an exponential energy distribution of temperature \( T_e \).

- To first order, \( T_e \) equals the ponderomotive potential,
  \[
  T_e = \frac{e^2}{4m_e\omega^2}E^2 = \frac{e^2}{4m_e\omega^2} \frac{2I}{\varepsilon_0c}
  \]

- To first order, \( n_e \) equals the laser energy divided by the average electron energy,
  \[
  n_e = \eta \frac{E_{\text{laser}}}{T_e}
  \]

- Combining equations reveals that \( n_e \) depends only on laser pulse duration and spot size.

- \( \rightarrow \) Varying only \( E_{\text{laser}} \) should increase \( T_e \) but leave \( n_e \) constant.

** efficiency \( \eta \) changes from ~10% - 15% in our ROI**
The highest observed ion energy was determined and related to the laser energy.

A fit to $\sqrt{E}$ reproduces the cutoff energies of hydrogen and deuterium very well, as observed by other authors.*

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