Thin cryogenic hydrogen targets for laser-driven ion acceleration

Targetry Workshop

Munich, Germany | October 10, 2013

TECHNISCHE UNIVERSITÄT DARMSTADT

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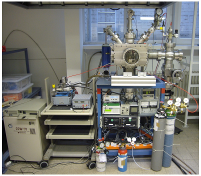
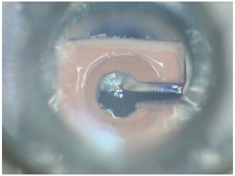
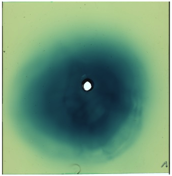
AG Hoffmann







Motivation

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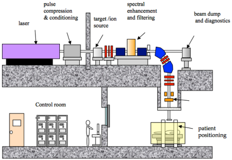
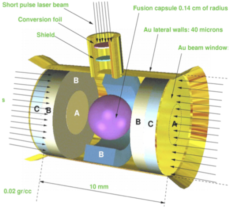
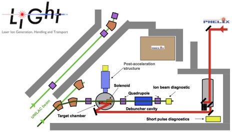


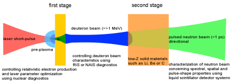
(1) Medical Treatment



(2) Proton Fast Ignition



(3) *LIGHT* project



(4) Secondary Beams

Motivation

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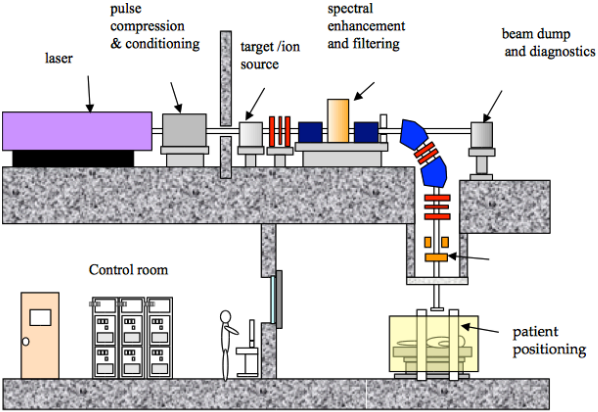

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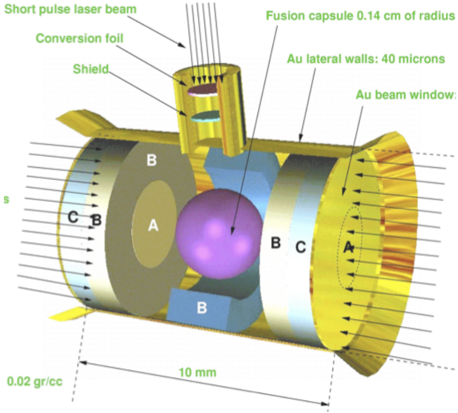

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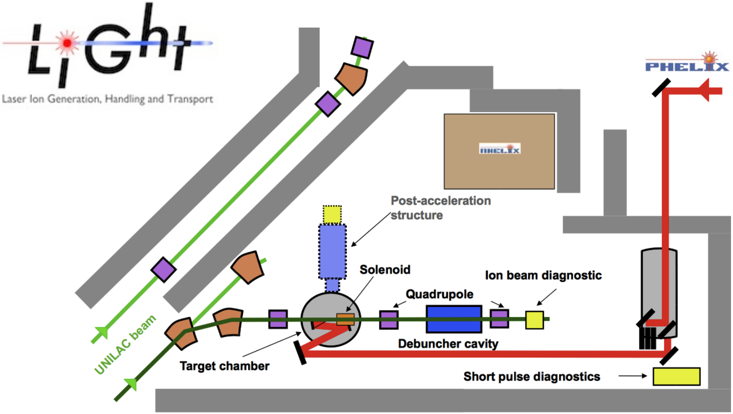

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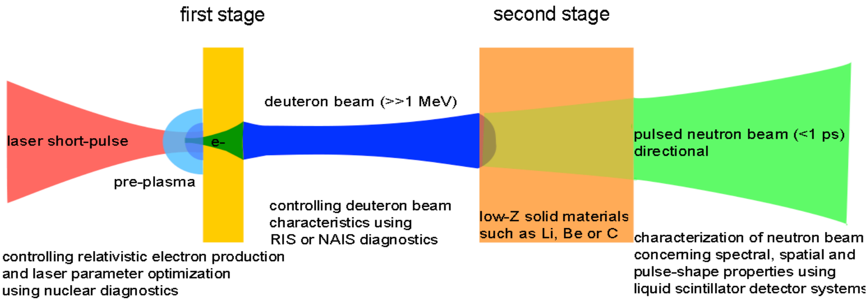
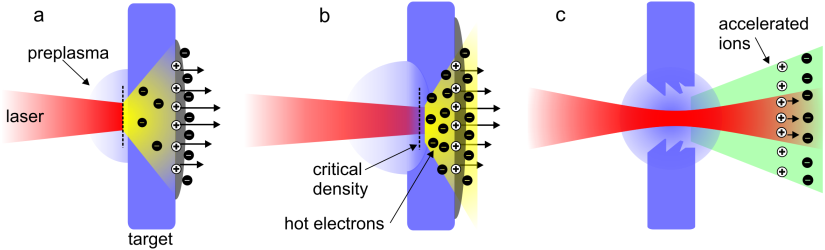


(4) Secondary Beams

Laser Breakout Afterburner (BOA)

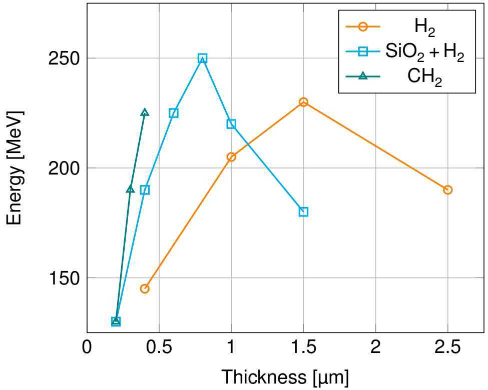


Target Normal Sheath Acceleration (TNSA)

Intermediate phase

Laser Breakout Afterburner (BOA)

BOA – Proton Energy



Laser Parameters

- 120 Joule in 500 fs
- intensity of 10^{21} W cm^{-2}
- contrast greater than 10^9
- linear polarization

Simulation by Lin Yin, Los Alamos National Laboratory

Cryogenic Target Properties

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Advantages

- pure
- free standing
- adjustable thickness (µm to cm)
- large diameter (0.1 mm^2 to 1 cm^2)
- solid state density

Disadvantages

- non-transportable targets
- complex setup & alignment
- low repetition rate

Cryogenic Target

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Cryogenic Target

Setup

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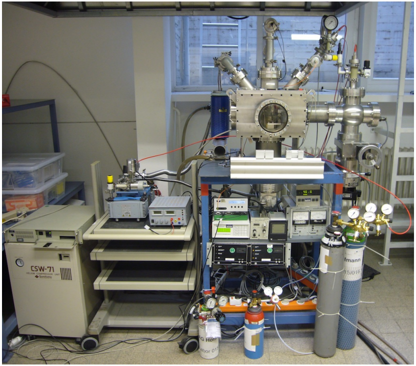
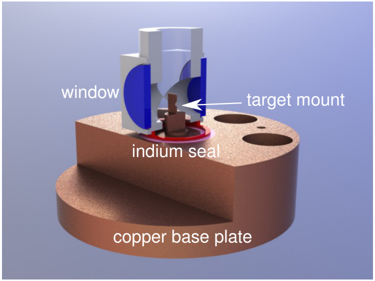
Requirements

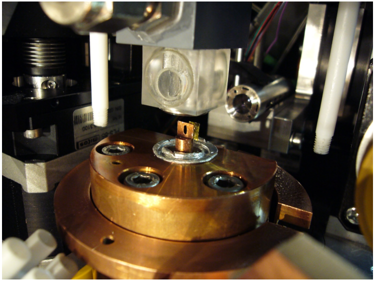
- vacuum chamber
- cryogenic cold head
- pure gases
- pressure control
- temperature control
- target diagnostics



Cryogenic test rig at TU Darmstadt.

Growing Chamber





- copper base plate features good heat conduction
- high tightness due to indium seal
- windows for real time optical diagnostics
- motorized polycarbonate growing chamber

Target Geometry

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Different growing chambers. [J. Menzel]

- target geometry is determined by the geometry of the target mount and the growing chamber
  - thickness: µm to cm
  - diameter: mm to cm
- growing process takes about 1–30 min
- thickness can be reduced by controlled heating

Growing Procedure

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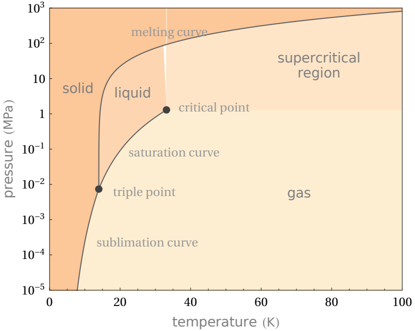
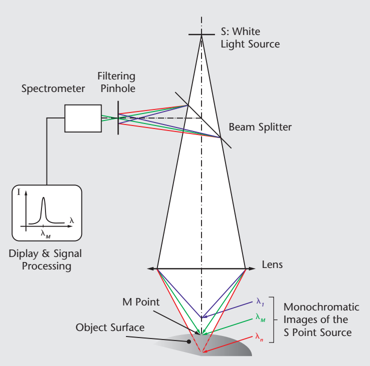


Phase diagram of hydrogen. [*Wolfram|Alpha*]

1. ensure vacuum better than 10^{-5} mbar
2. cool copper base plate down to less than 10 K
3. attach growing chamber to base plate
4. adjust temperature and gas pressure
5. fill growing chamber with target gas
6. wait for target to solidify

Target Thickness Measurement



Chromatic confocal distance measurement. [*Polytec*]

Capabilities

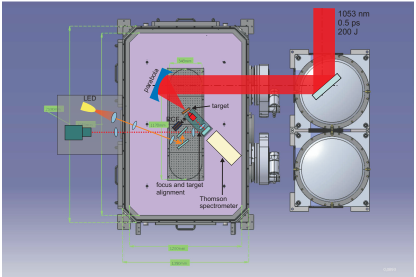
- chromatic confocal sensor
- lateral resolution 3 µm
- vertical resolution 10 nm
- measuring range 2–300 µm

Experimental Campaign at PHELIX
Overview

Goal

First experimental campaign to use thin foil-like cryogenic hydrogen targets for laser-driven ion acceleration.

- *PHELIX* laser, *GSI* Darmstadt
- 200 J, 500 fs, 1053 nm, 5 µm focal spot, 10^{20} W cm^{-2}, 10^{9} contrast, bad off-axis parabola (20 % on target)
- 10 days, 32 shots
- chromatic confocal sensor, RCF spectrometer, Thomson parabola
- solid hydrogen on plastic substrate
- pure solid deuterium



Experimental setup on *PHELIX*.

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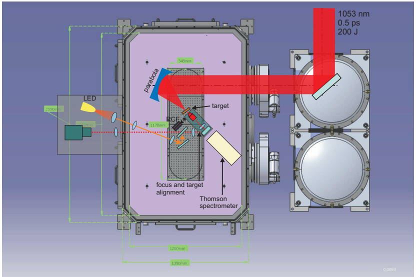
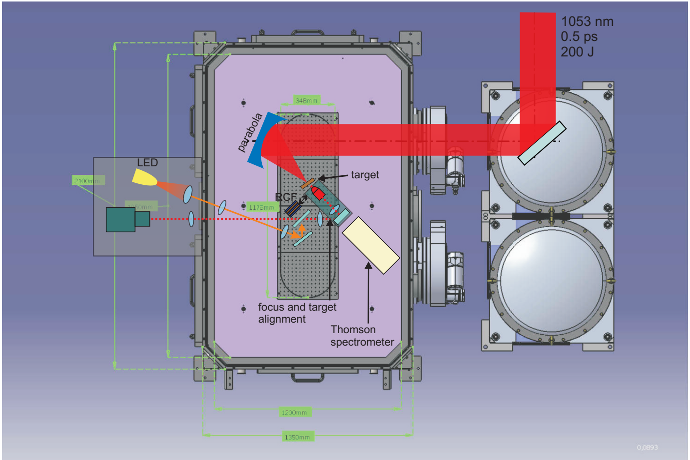


Experimental setup on *PHELIX*.

Experimental Campaign at PHELIX
Setup



Experimental Campaign at PHELIX
Setup

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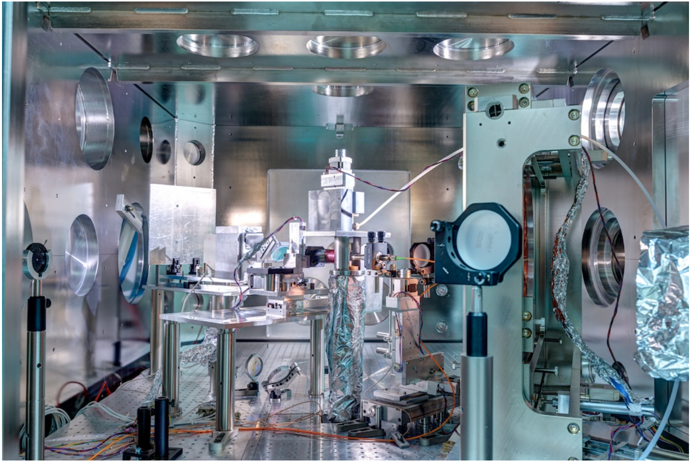
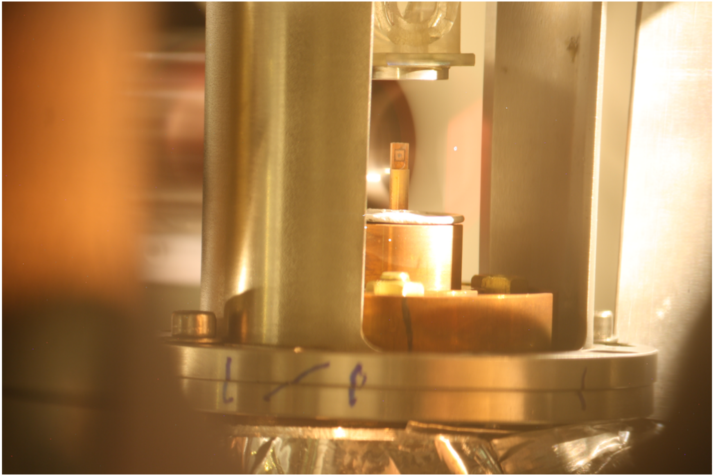


Solid Hydrogen on Plastic Substrate



Solid Hydrogen on Plastic Substrate

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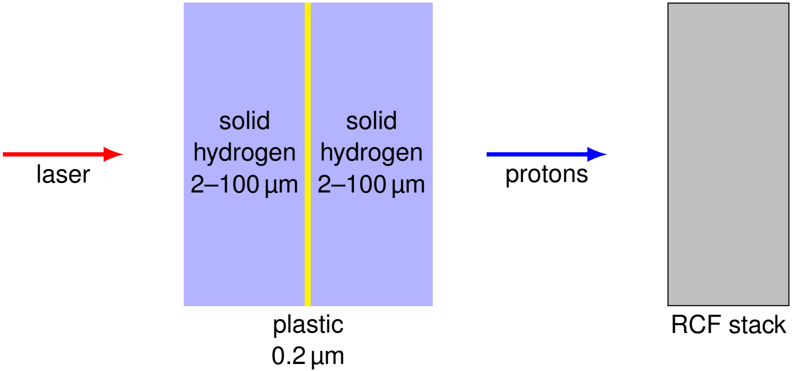

PRELIMINARY RESULTS

42 J/208 J @ 200 nm plastic + two layers of solid hydrogen

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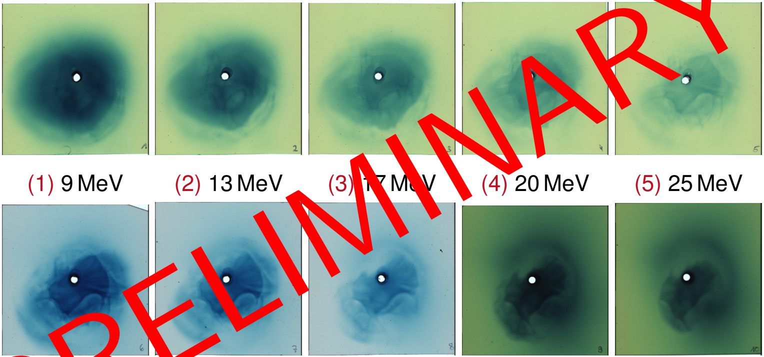
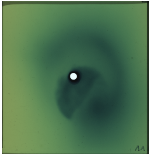


(1) 9 MeV (2) 13 MeV (3) 17 MeV (4) 20 MeV (5) 25 MeV

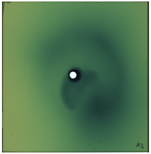
(6) 28 MeV (7) 32 MeV (8) 37 MeV (9) 41 MeV (10) 45 MeV

PRELIMINARY RESULTS

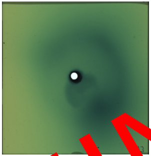
42 J/208 J @ 200 nm plastic + two layers of solid hydrogen (continued)



(11) 49 MeV

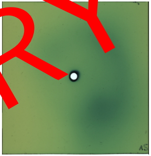


(12) 52 MeV



(13) 54 MeV

(14) 57 MeV



(15) 69 MeV

PRELIMINARY

Pure Solid Deuterium

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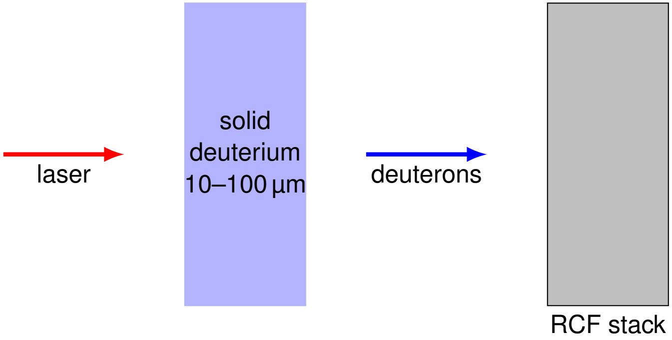
Pure Solid Deuterium



PRELIMINARY RESULTS

32 J/160 J @ pure solid deuterium

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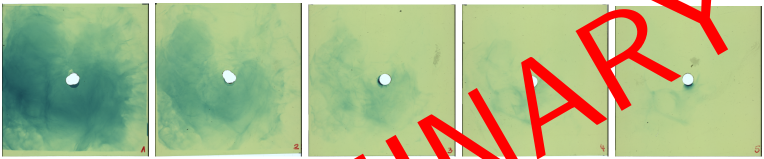

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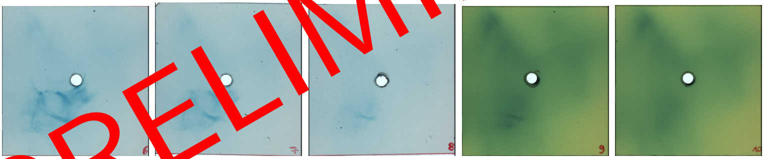

(6) 28 MeV (7) 32 MeV (8) 37 MeV (9) 41 MeV (10) 45 MeV

Summary

- pure targets
- homogenous solid state density
- growing process takes 1–30 min
- target thickness adjustable (µm–cm)
- setup can be implemented at any target chamber
- targets can be made from arbitrary gases
- first experimenal campaign performed at *PHELIX*, *GSI* Darmstadt
- possible applications: proton fast ignition, oncology, secondary beams

Outlook

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Future Goals

- more precise online surface/topology characterization
- optimize target structure for higher particle energies
- accelerate protons/deuterons to energies greater than 100 MeV
- measure the energy loss of heavy-ion beams in a fully ionized plasma

Acknowledgements

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The End

Thank you for your attention!