Laser proton acceleration of mass-limited-targets of different materials

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**Motivation – Laser driven ion therapy**

*in vitro* irradiations can be performed with lasers [Kraft *et al.* (2010), Yogo *et al.* (2011), Zeil *et al.* (2012)]

next step:


PW laser Projects @HZDR
PW laser status at HZDR – Draco PW upgrade

Draco dual-beam schedule:
150TW (4J in 30fs on target) with
improved contrast in new target areas operational
PW (30J / 30fs) amplifier installation running, on target summer 2015
PW laser status at HZDR – Draco PW upgrade

Output energy at 800nm, J vs. Pump energy @ 532nm, J

- Experiment
- Theory

Vertical profile

1.5J seed

Penelope lab

Electron / X-ray lab

Ion acc. lab

Penelope diode pumped PW
PW laser status at HZDR – Draco PW upgrade

- Compressor / beamline installed
- Target areas operational

72nm @ 28J
in vitro irradiations can be performed with lasers \cite{Kraft2010, Yogo2011, Zeil2012}

next step:

TNSA at large foil

- electrons laterally spread along the target surface

RMT

- electron reflection at target edges
- $T_e$ and $n_e$ increased
- time averaged hotter and denser sheath

$\Rightarrow$ increased proton energies

AuCu disks and ultra-short pulses

- Maximum proton energy
  - + 87%!
  - Absolute gain in proton energy and yield for given laser parameters!!
  - Time averaged hotter, denser and more homogenous sheath

AuCu disks and ultra-short pulses

- Maximum proton energy

Laser: 3 J, 30 fs, $10^{21}$ W/cm$^2$
Diameters: 20 – 100 µm
Thicknesses: 100 nm – 1 µm

2 µm Ti foil average 13.3 MeV


- Obvious target material dependence
- Complex interplay between target parameters relevant for TNSA
Disk targets of different material

≈ 0.5 µm thickness

very preliminary

similar to DLC/CH foils

max proton energy [MeV]

Ti Kα Images at backward direction (near OAP)

ø 50 µm

ø 100 µm

ø 200 µm

ti

au

al

1 µm
Disk targets of different material

- Similar performance for difference in size, thickness, material
- Robustness against laser contrast fluctuations
- Profit from robust acceleration performance and enhanced proton number
- Very small targets (focus size)?

→ Electron recirculation during acceleration
Target edge & stalk effects at DRACO

Proton beam profiles, $E \approx 9$ MeV

- Similar field strength at edges as in focal region
- Edge fields prevent efficient plasma expansion
- Further investigation using 3D PIC simulations required
Accessing target dynamics at critical density?

2 µm Ti foil with ≈ 1 µm of photo resist, $E_L \approx 84$ mJ

-3.5 ps
≈ pump pulse arrival
+23 ps

Pump
- $t_p = 30$ fs
- $E_L = 40 - 220$ mJ
- $I_{\text{max}} = 4 \cdot 10^{19}$ W/cm²

Probe
- $t_p \approx 130$ fs
- $E_L = 0.1\%$ of pump
- $I < 3 \cdot 10^{12}$ W/cm²
Accessing target dynamics at critical density?

2 µm Ti foil with ≈ 1 µm of photo resist, $E_L \approx 84$ mJ

-3.5 ps

≈ pump pulse arrival

+23 ps
Optical probing – influence of the geometry

probe @ 400nm
33°
plasma

pump @ 800nm

target imaging

Si RMT target design

1) Si membrane @ +1.9 ps
2) Si RMT 50 μm @ +1.9 ps
3) Si RMT 20 μm @ +1.9 ps
4) Si RMT 20 μm @ +1.9 ps

50 μm
Profit for application

- Similar performance for difference in size, thickness, material
- Profit from robust performance enhancement (energy and proton number)
- next: material test at DRACO, optical probing (at high intensity)
multiple filamentation of freely propagating 100 TW beam in air