Working Group 2 Summary

Ion Beams from Plasmas

Alessandro Flacco (LOA/ENSTA)
Louise Willingale (University of Michigan)
WG2: ion beam presentation themes

- Energy scaling and beam quality
- External transport and focusing for applications
- Neutron generation
- TNSA for Applications

- High-rep-rate targets

- Novel / advanced mechanisms
  - Relativistically induced transparency
  - Near-critical targets

- Neutron generation

Novel / advanced ion acceleration mechanisms
Cascaded laser acceleration of carbon ions from double-layer nanotargets

Wenjun Ma (Peking University)

Near-critical plasma lens enhanced RPA


Cascaded acceleration

Laser shaping and electron flow generation

Stage 1:
Radiation pressure acceleration
Sheath field acceleration

Stage 2:

CLAPA laser
New concept of light ion acceleration from low-density target

A.V. Brantov, V. Yu. Bychenkov (P.N. Lebedev Physical Institute of the Russian Academy of Sciences)

Proton acceleration: maximum energy vs. thickness & density of the target.

Synchronized proton Acceleration by ultraintense Slow Light (SASL)

Proton acceleration by ponderomotive potential

Kinetic and finite ion mass effects on the transition to relativistic self-induced transparency in laser-driven ion acceleration

Evangelos Siminos (Chalmers University of Technology, Sweden)

- Complex transition physics
- Fast electron escape triggers propagation
- Ion motion mitigates electron escape by inducing widening of separatrix
- Dynamic transition: Short time transient $\rightarrow$ long time effect on ion spectra
- Transverse instabilities need to be controlled

In HB regime no electrons escape

In RSIT regime electrons escape continuously

Transition to Light Sail Acceleration from Ultrathin Foils
Aodhán McIlvenny (Queen’s University Belfast U.K.)

- Linear polarisation produces higher energies for thicker targets – TNSA. Circular polarisation produces higher carbon and proton energies for targets thinner than 25nm indicative of a transition to radiation pressure acceleration
- Gemini laser (UK) campaigns produced a maximum of 25MeV/u C$^6+$ (2013) on 10nm amorphous Carbon
- Thinner targets produce lower energies as they become transparent and radiation pressure stops.
- Structure seen in proton beam profile shows how electron density is affected by transmitted laser pulse

C. Scullion et al  PRL 119, 054801 (2017)
B. Gonzalez-Izquierdo et al Nat. Com. 7:12891 (2016)
Exploring Energy Absorption in Ultra-Thin Targets
Emma-Jane Ditter (Imperial College London)

- Transmitted beam showed proof of RTA at 25nm, as confirmed through simulation
- Transmitted beam showed proof of pinhole effect as observed previously on the same laser system\(^1\)
- FROG traces showed proof of optical shuttering for the thinner targets
- Temporal measurements of optical transition radiation for thick targets (50-100 nm) achieved

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Observation of ultrafast solid-density plasma dynamics using femtosecond X-ray pulses from a free-electron laser
Melanie Rödel (Institute for Radiation Physics, Helmholtz Zentrum Dresden-Rossendorf)

SAXS is a versatile tool to investigate laser target interaction on a few nm- to µm scale at a 10fs to ps temporal resolution.
SAXS experiments help to understand:
• Instabilities
• Target front surface expansion
• Hole boring
• plasmons
Target Normal Sheath Acceleration (TNSA)
Using PW, short laser pulse for ion acceleration in TNSA regime

Sargis Ter-Avetisyan (ELI-ALPS)

- The observed about 0.05 coefficient of back reflection is measured - it can have serious consequences when using PW laser systems in the interaction experiments.

- **it is found:**
  - Rear side protons energy scaling $\sim / 1$
  - Front side energy scaling $\sim / 0.5$

- **proton source and beam properties**
  - e.g., proton image of the mesh

  - It is demonstrated that proton beam has distinct different emission characteristics along and perpendicular to the laser polarisation directions.

  - The normalized emittance of 6.5 MeV proton beam:
    - $2.2 \pi \text{ mm mrad}$ in laser polarisation direction
    - $1.6 \pi \text{ mm mrad}$ perpendicular to laser polarisation direction

There is still life in the established TNSA mechanism
Sheath acceleration up to $5 \times 10^{21}$ W cm$^{-2}$ @ Kansai Photon Science Institute

N. P. Dover, KPSI, QST, Japan

- Upgraded J-KAREN-P $\rightarrow$ ~PW (30 J, 30 fs) on target
- Commissioning expt.: sheath acceleration 250 TW, $5 \times 10^{21}$ W cm$^{-2}$
- Max. proton energy regularly $>$ 40 MeV, up to $\sim$54 MeV @ 2 µm foil
- Measured sheath intensity scaling @ $\sim$0.1 Hz – increasing energy gives $E_p \sim I_L^{1/2}$ scaling
- Electron temperature saturates at ultra-high intensity & small focal spots $\rightarrow$ insufficient acceleration length

Electron temperature intensity scaling

Proton energy intensity scaling
Parametric study of proton beams driven by 200 TW laser system using a tape driven target system

Muhammad Noaman-ul-Haq$^{1,2}$, Thomas Sokollik$^{1,2}$, Hamad Ahmad$^3$, X.L. Ge$^{1,2}$, Fang Yuan$^{1,2}$, Xiaohui Yuan$^{1,2}$, Liming Chen$^{1,2}$, J. Zhang$^{1,2}$

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$^3$School of Mathematics and Physics, Queen's University Belfast, Belfast, BT71NN, UK

For laser energy variation

For pulse duration variation

For focal spot variation
Isochoric heating of solid gold targets with the PW-laser-driven ion beams
Sven Steinke (LBNL)

First study at 1PW with statistical significance—Large laser spot size ($f\backslash 65$) yields ions beams with reduced divergence and unprecedented charge densities.

$\sim 10^{11}$ protons total with energies up to $(6.2 \pm 0.4)$ MeV

70 shots, 5 micron Ti tape target
Features within sheath accelerated proton beams

- Interaction of $a_0 \sim 10$ laser with 10 micron thick Au foil produced a sheath accelerated proton beam with ring-ed structure.
- Concentric rings persist over broad energy range with little change in divergence.
- While broadly centred around rear surface target normal, the ring centroid drifts away from laser axis at high energy.
- Results do not seem consistent with filamentation, beam hollowing, magnetic fields at the rear surface or in the bulk.
- Hot electron recirculation under investigation as a possible explanation.

Hot electron recirculation:
- Modification of electron density at the target rear surface observed in simulations of planar foils.
- Modulations suppressed by use of cone target design which prevents recirculation of hot electrons inside the target.
- Simulations to study temporal evolution and influence of target thickness on the modulations are ongoing.
TNSA beam transport and focusing...
... towards applications
High-performance proton acceleration from a renewable cryogenic hydrogen target

Proton acceleration studies with ultrashort PW pulses at DRACO


- DRACO: a 150 TW / 1 PW dual beam laser facility
- Status of proton acceleration at DRACO
- Highly efficient proton beam transport with pulsed solenoid coils
- Spectral and spatial beam shaping for in-vivo radiobiology studies

Dose profiles vs. depth, w/ 25µm brass and aperture
Generation of highest peak intensities of ultrashort MeV proton bunches and going towards applications


- time compression
- beam transport to 6 m
- bunch FWHM = 209 ps
- focal spot: $2.5 \times 3 \text{ mm}^2$
- $N_p = 6.8 \times 10^8$
- $I = 520 \text{ mA}$
- ultrashort sub-ns pulses are useful imaging
- mid-Z ion acceleration
- going towards energy loss

EAAC 2017 | LIGHT | Diana Jahn
Laser driven ion beam for multidisciplinary applications at ELIMAIA beamline

Valentina Scuderi

ELIMED dosimetry section

Successful dosimeter test (SEM, IC and FC) with laser-driven protons @ LOA: High rep-rate

On line TOF based diagnostics for high energy ion beam successfully tested @ PW class laser facility

High-Repetition-Rate Advanced Petawatt Laser System, 1 PW, 10 Hz delivered by LLNL installed this week at ELI

Advanced targetry for ELIMAIA: p acc. From cryogenic solid-H2 ribbon (ELISE) at PW class laser facility.

Vacuum, EMP: OK
Stability: to be improved
Pure proton beam (no contaminants): OK
Max proton energy: ~55 MeV

PMQ delivered last July @ INFN-LNS
Optics study performed with 60 MeV p beam @ INFN-LNS

Expected delivery @ INFN-LNS December 2017

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Spectral and spatial shaping of a laser-accelerated proton beam for radiation biology applications
Alessandro Flacco (LOA / ENSTA)

Stable irradiation conditions
- 0.7 Gy/shot for *in vitro* 2D
- stability: 6 % rms
- uniformity: 20 % rms
- duration: ~ns
- peak dose rate: $10^8$ Gy/min
- repetition rate: 1/1.5s (*quasi-automated*)
Neutron generation
Laser-plasma acceleration inducing nuclear fusion reactions

Danilo Giulietti	extsuperscript{a,b}, D.Batani	extsuperscript{c}, G. Boutoux	extsuperscript{c}, F. Burgy	extsuperscript{c}, M. Cipriani	extsuperscript{b}, F. Consoli	extsuperscript{b}, R. De Angelis	extsuperscript{b}, J.E. Ducret	extsuperscript{c}, F. Ingenito	extsuperscript{b}, K. Jakubowska	extsuperscript{d,c}, C. Verona	extsuperscript{e}, G. Verona-Rinati	extsuperscript{e}

This experiment shows how it is possible, with a small size, a few TW Ti:Sapphire laser, to induce fusion processes and to study them in detail, making to glimpse the possibility of creating an unique, high-repetition-rate source of mono-energetic, high-energy neutrons.

\[ ^2_1D + ^2_1D \rightarrow ^3_1T (1.01\text{MeV}) + p (3.02\text{MeV}) \quad 50\% \]

\[ ^2_1D + ^2_1D \rightarrow ^3_2\text{He} (0.82\text{MeV}) + n (2.45\text{MeV}) \quad 50\% \]
Laser-driven neutron sources and their applications
Seyed Reza Mirfayzi (Queen's University Belfast)

- Laser-based sources are fast approaching a crucial stage in their development for neutron science and applications to complement large-scale facilities.
- The current flux is adequate for many applications such as eV neutron spectroscopy, activation, BNCT in a closely coupled beam line.
- Development in laser facilities around the globe such as ELI, can lead to higher neutron fluxes.
- The future of a laser-based approach would be reliant on the progress in diode-pumped technologies, such as the DiPOLE and HAPLS projects, aiming towards developing 10 Hz, Petawatt-class laser systems.

Epithermal Neutron Source
WG2: ion beam presentation themes

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Near-critical targets

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