Summary of WG2: Ion beams from plasmas

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Abstract. Working Group 2 was dedicated to presentations on ion acceleration by laser-plasma interaction. This summary reports some highlights on different topics, grouping the presentations in four different areas of interest for the community: (i) ion acceleration facilities, (ii) target engineering and manipulation, (iii) laser-plasma interaction and diagnostics, and (iv) ion acceleration mechanisms.

1. Introduction

The presentations of WG2 spanned over a wide range of aspects of laser plasma-based ion acceleration. Dedicated beamlines at state-of-the-art laser facilities were presented, as well as ion beam transport devices especially conceived for radiobiology purposes. From the targetry point of view, along with the presentation of a novel target delivery systems prompted by the high repetition rate nature of the existing laser facilities, new target designs have been presented showing an increase of laser-plasma coupling, thus enhancing the investigated acceleration mechanisms and imprinting special physical properties to the accelerated ion beams. Large attention was also devoted to the role of pre-plasma expansion and its density profile, which is a key feature of both the laser-plasma coupling and the ion acceleration process. In this respect, several numerical and experimental studies were presented with different target geometries (thicknesses and densities). Laser-plasma interaction diagnostics, playing a major role in these studies, were widely described with a special focus on optical probing. Finally, results from hybrid acceleration scheme (TNSA-RPA) were presented, and enhancement of acceleration performances by changing laser parameters, such as polarization or dispersion, were discussed.

Ion acceleration facilities: status, upgrades and applications

The status of ion acceleration beamlines/target areas was advertised, with a particular stress on radiobiology applications of such unique ion sources, which have recently gathered an increasing interest in the community. The ELIMAIA-ELIMED beamline for multidisciplinary user applications at ELI-Beamlines, developed in cooperation with INFN-LNS, was presented, also highlighting a dedicated Monte Carlo application for dose prediction on user samples [1,2]. The first experiment on ion implantation of SiC samples at the BELLA-LAB target area at LBNL, which now features a long focal line for ion acceleration, was discussed [3], along with experimental results of laser-accelerated proton beam focusing down to few mm spot size by using a plasma lens [4]. Preliminary experimental results achieved at the DRACO-PW beamline at HZDR, using two pulsed solenoids to focus protons on 3D tumor spheroids irradiation, were presented [5].
Novel target engineering and manipulation for ion acceleration

The use of transient plasma gratings is explored at Imperial College to realize a discretized (multi-step) acceleration of ions from such a density-modulated target, and expected results were anticipated by particle-in-cell simulations [6]. A composite target system consisting of a gas jet and a thin solid target was implemented at Weizmann Institute with the goal of optimizing laser self-focusing and temporal compression/steepening, thus to increase the laser intensity onto the thin target of about 10 times [7]. A high repetition rate target positioning system implemented at Tel Aviv University was presented, along with generation of a stable proton source using a thin foil (600 nm) at 0.2 Hz [8]. Polarized targets, typically used in nuclear and particle physics experiments, were implemented in a laser-plasma acceleration environment conserving their polarization at Julich [9].

Laser-plasma interaction and ion acceleration diagnostics

The role of pre-plasma formation and its peculiar density profile created by a non-ideal laser contrast, especially for sub-micrometer thick targets is of paramount importance for laser-plasma ion acceleration, as reported by several speakers. Sometimes a perfect contrast does not correlate to the maximum ion energy achieved in the particular experiment. The presence of a sub-ps ramp was used to enhance TNSA acceleration in numerical simulations at HZDR [10] and optimization of proton energies was carried out at Jena University by varying the laser contrast at 10-ps level and using micrometer thick targets (TNSA regime) [11].

Both optical and ion diagnostics are crucial to find an optimal laser-plasma interaction regime for ion acceleration. An optical probing platform at Jena University allows an extensive parametric study of pre-plasma formation for a wide parameter range (angle of incidence, intensity, polarization) [12]. Optical probing was also a key diagnostic to enable the study of pre-plasma formation from cryogenic hydrogen targets at HZDR, showing an optimal target pre-expansion regime which was beneficial for proton acceleration (up to 80 MeV) [13]. Combination of simultaneous diagnostics of hot electron and ion energy distributions by EOS crystals and diamond detectors, respectively, was performed at INFN-LNF [14].

Ion acceleration mechanisms and insights

Investigation of novel acceleration regimes using ultrathin targets (few tens of nanometers) was also reported. An experiment carried out by the Queen’s University team at the GEMINI laser facility has shown acceleration of carbon ions in the radiation pressure acceleration (RPA) regime [15]. Numerical simulations in similar conditions and with circular polarization of the laser pulse were conducted at Imperial College [16]. Two-fold increase in maximum proton energy was observed at DRACO-PW facility using relatively thin targets with an optimal laser contrast by changing the third order dispersion of the laser pulse [17] (K.Zeil).

References

[1] D. Margarone (ELI-BL, IoP-CAS), Talk on “Laser-driven Ion Acceleration and Societal Applications at the Extreme Light Infrastructure (ELI)”, EAAC 2019.
[2] F. Catalano (INFN-LNS), Talk on “ELIMED: the first Users beamline dedicated to the irradiation studies with laser-driven ion beams”, EAAC 2019
[3] S. Steinke (LBNL), Talk on “Ultra-High Intensity Laser Research at BELLA”, EAAC 2019
[4] J. Bin (LBNL), Talk on “Focusing of laser-accelerated proton beams with active plasma lens”, EAAC 2019
[5] F.E. Brack (HZDR), Talk on “Dose controlled irradiation experiments with laser-accelerated protons at Draco Petawatt”, EAAC 2019
[6] O. Ettlinger (Imperial College), Talk on “Plasma Gratings as a Novel Target for Ion Acceleration”, EAAC 2019
[7] D. Levy (Weizmann Institute), Talk on “Gas-foil target for laser-plasma ion acceleration”, EAAC 2019
[8] I. Pomerantz (Tel Aviv University), Talk on “A Gatling-Gun Target Delivery System for High-Intensity Laser Irradiation Experiments”, EAAC 2019
[9] A. Lehrach (Ulich), Talk on “Polarized Beams from Laser-Plasma Accelerators” EAAC 2019
[10] M. Garten (HZDR), Talk on “Enhanced ion acceleration from a non-ideal laser pulse contrast”, EAAC 2019
[11] S. Keppler (Helmholtz Institute Jena), Talk on “Contrast Dependence of Laser-Driven Proton Acceleration”, EAAC 2019
[12] M. Maeusezahl (Jena University), Talk on “Optical probing of pre-plasma dynamics for laser ion acceleration”, EAAC 2019
[13] C. Bernert (HZDR), Talk on “Off-harmonic optical probing of high intensity laser interaction with cryogenic hydrogen jet target”, EAAC 2019
[14] F. Bisesto (INFN-LNF), Talk on “Simultaneous temporal resolved measurements of protons and fast electrons in TNSA experiments”, EAAC 2019
[15] A. McIlvenny (Queen’s University Belfast), Talk on “Bulk ion acceleration from ultrathin foils in PW-class interactions on the ASTRA GEMINI laser”, EAAC 2019
[16] E.J. Ditter (Imperial College), Talk on “Evolution of relativistic transparency in nanometer-scale targets”, EAAC 2019
[17] K. Zeil (HZDR), Talk on “Ion acceleration from ultra-thin foil targets using a PW-class laser with optimized temporal pulse profile”, EAAC 2019