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Summary of WG7—High brightness power sources: From laser technology to beam drivers

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ABSTRACT

In this paper we summarize the contributions presented during the Working Group 7 (WG7) sessions, dedicated to high brightness power sources. In this context we have tackled several topics of high relevance to novel accelerators, including laser technology for laser driven accelerators, the state of the art of high peak and average power lasers, the laser beam quality, contrast and stability. A number of novel results were presented especially in the area of laser beam characterization and control, advanced laser concepts, target control and electron beam diagnostics currently under development at a range of labs engaged in the development of advanced accelerator concepts.

1. Introduction

Many novel acceleration techniques, such as the Laser Driven Plasma Wakefield Acceleration (LWFA) [1], rely on the use of high repetition-rate, high peak power laser drivers. In this working group special attention was given to the use of such driver lasers in view of future user applications.

In the current framework, aimed at the establishment of a reliable operation of LWFA, the high power lasers used to reach high acceleration gradients in the plasma also need to exhibit high repetition rates in order to drive applications; the laser control also needs to be improved through the implementation of feedback systems. All this leads to high average power lasers capable of delivering kW scale output on the target.

The control and the characterization of many parameters of the laser, such as its longitudinal shape and transverse contrast also are fundamental for controlling the wake-field generated in the plasma, which influences the quality of the accelerated electron bunches. These are some of the key areas where development is needed to finally deliver reliable operation of laser drivers as envisaged in the EuPRAXIA project [2].

2. Overview of research topics

Feedback Control. The feedback control of the spatio-temporal properties of high-intensity laser pulses allows the optimization of the output parameters of an experiment by tuning the shape of the input laser. More specifically D. Symes (STFC) reported about the optimization of soft X-rays emission from electrons generated via LWFA thanks to the optimization of the laser shape by changing the dazzler settings of the 5 Hz Gemini laser. This approach clearly showed, possibly for the first time, that spatio-temporal laser stability plays a major role in the stability of the acceleration process and active control of these features will finally enable a major improvement on the quality of the accelerated electron bunches.

Characterization of the Contrast and Wavefront Control. The transverse properties of the laser beam have a strong impact on the properties of the wake-field generated in the plasma. Moreover the lack of control of the laser wavefront can potentially damage the plasma capillary. A research carried out at LUX, a collaboration between ELI-beamlines, the University of Hamburg and DESY investigates effects of laser beam propagation. The laser wavefront is controlled via a closed loop including a deformable mirror and a wavefront sensor. V. Leroux presented the status of the investigations concerning the laser wavefront at the target position, showing detailed characterization of actual laser specs at interaction point and a first investigations of effects of rep-rated operation on transport line.

At LMU in Munich a new concept has been developed for the measurement of the 2D spatial and temporal intensity distribution of

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an high power laser at the focus. M. Speicher reported about the working principle of the method, that relies on optical probing of the dynamically generated plasma at a mm-thin foil. Experimental data were also presented that demonstrate the possibility to extract details of laser pulse temporal evolution on target.

Extended propagation in Plasmas. In the AWAKE experiment at CERN the laser is used to ionize a rubidium vapor source along a 10 m distance. J. Moody has reported about how the depletion of the laser in the plasma chamber can be controlled by using pulses with sufficient energy and intensity, thus allowing achieving sufficiently homogeneous ionization of the vapor along the complete chamber length. This is also an excellent example of the use of fiber pump laser technology at the multi-TW level to achieve laser stability, both shot-by-shot and on a long term operation.

Increasing Laser Brightness. Laser beam Circulators are used to potentially increase the laser brightness. K. Cassou presented the status of the realization and alignment of a laser beam circulator [3] used in the ELI-Nuclear Physics Project. The laser brightness needs to be increased right before the interaction point of the laser with the ELI electron beam aimed to produce X-rays. The construction of such a system is especially challenging because of the very precise surface manufacture requirement of the mirrors and high precision of their parallelism. Among the highlights of the presentation we mention the progress of the collaboration towards a successful implementation of self-alignment algorithms for alignment at interaction point.

Effects of Laser Properties in Plasmas and LWFA Experiments. The laser pulse propagating in the plasma experiences many changes in the longitudinal energy distribution such as e.g. laser depletion. M. Streeter reported about how the experimental characterization of the Gemini laser at the Central Laser Facility has enabled the understanding of the mechanisms influencing laser evolution in the plasma. A model well representing this phenomenon has been included in simulations and a good fit of the experimental data has been achieved. This is an example of investigation in which the role of laser and plasma properties on LWFA is clearly identified.

At SPARC-LAB the FLAME laser is being used for a variety of experiments such as LWFA, TNSA (i.e. proton acceleration by thin metal target), Compton Scattering etc. M.P. Anania presented an overview of the current status of the different experiments, ranging from high intensity, high density plasmas for generation of energetic ions to extended propagation in gases for LWFA. A. Curcio focused on recent SPARC-LAB experimental results concerning phase-space reconstruction [4] of low emittance electron beams in the plasma by measuring simultaneously the electron beam and the betatron radiation spectra. This novel single-shot measurement proves to be able to provide useful limits for the estimation of the electron bunch emittance in plasmas and may be considered as a method for *on-line* monitoring of shot-by-shot variations of LWFA performance.

Perspectives for High Power and High Repetition rate Lasers On this topic an overview of the US developments was given by W. Leemans (LBNL) who reported on a recent workshop *Laser Technology for k-BELLA and Beyond* [5] held at LBNL in May 2017, focused on the identification of the key technologies for achieving, in the next decades, high (PW) peak power and high (kW and beyond) repetition rates, for applications in advanced accelerators concepts. Six technical approaches were presented based on Ti:sapphire lasers, TM:YLF lasers and fiber lasers. The issues connected to the longevity of the materials, such as heat load and carbon deposition on gratings or non-linear crystals and mirrors were also addressed. In general, this was one of the key subjects of the Working Group 7 that generated significant discussion during the whole workshop.

3. Conclusions

We have summarized the topics and the emerging issues that have been discussed during the WG7 sessions of the workshop concerning development of laser power sources and their control in laser-driven acceleration.

Presentations clearly show that a major effort is ongoing in many laboratories world-wide to address the issues connected to the laser control for application in novel acceleration techniques. Also the strategy for fulfilling the requirements for stable acceleration in short and medium term has been addressed and discussed. Significant progress has been achieved in this direction in the most recent years and we believe that these topics will attract significantly higher attention in the near future. It is therefore extremely important for the future editions of the EAAC workshop to encourage participation of key contributors in these fields, from high average power lasers development to laser characterization and control, from laser–plasma interactions to beam diagnostics.

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