10 PW Peak Power Laser at the Extreme Light Infrastructure Nuclear Physics – status updates

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Abstract. We have shown, for the first time in the world, the production of 10 PW peak power laser pulses and their propagation to an experimental area at the Extreme Light Infrastructure - Nuclear Physics (ELI-NP). We are also steadily running the laser system for experimental campaigns, increasing the output power levels delivered for experiments and fine-tuning the parameters of the laser pulses, the operational procedures, and the operational teams. During our presentation, we will show the laser developments at ELI-NP emphasizing the 10 PW peak power demonstrations and the latest results for the HPLS beam delivery.

1. Introduction

Extreme Light Infrastructure – Nuclear Physics (ELI-NP) is a new European Centre for Scientific Research built in Bucharest-Magurele, Romania [1, 2, 3]. One of the scientific tools of ELI-NP is the High-Power Laser System (HPLS) capable of delivering 10 PW laser pulses. The ELI-NP HPLS is a Ti: Sapphire, hybrid CPA, system with six outputs: two 0.1 PW outputs at 10 Hz repetition rate, two 1PW outputs at 1 Hz and two 10 PW outputs at 1 shot per minute. A detailed description of the HPLS is presented in the reference [4].

2. 10 PW peak power laser pulses demonstration at ELI-NP

Laser pulses with peak power above 10 PW were generated for the first time using the Extreme Light Infrastructure – Nuclear Physics HPLS during two demonstration campaigns. The generated 10 PW pulses were transported in vacuum using the Laser Beam Transport System (LBTS) to the 10 PW experimental areas.

The pulses were routed towards different parts of the 10 PW experimental areas during each of the two experimental campaigns.

To qualify the spatial parameters of the laser pulses at the end of the propagation line a dedicated diagnostic bench was deployed.

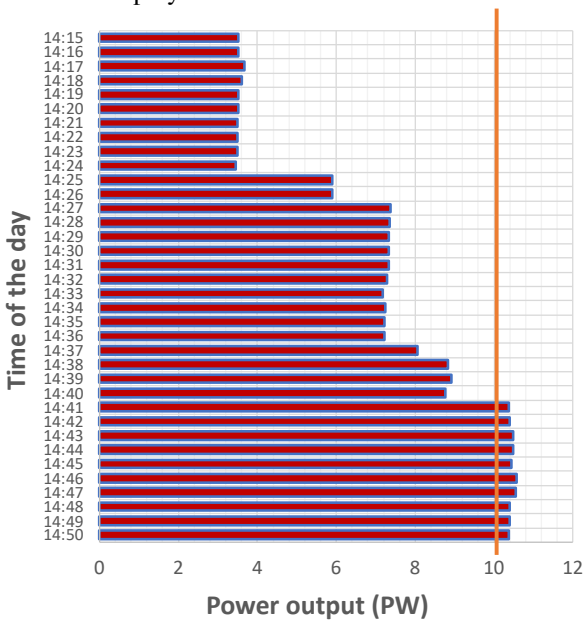

Figure 1. 10 PW shot sequence during one of the demonstrations at ELI-NP, showing the 1 shot per minute repetition rate.

The full aperture pulses are demagnified on this diagnostic bench, and the near field and wavefront are

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measured. The measurement is performed at full HPLS amplification with the energy properly attenuated before the optical compressor. This measurement ensured us that the beam profile and wavefront are proper for the propagation of the high-power pulses. The HPLS diagnostic bench, described in [4], was used for pulse duration measurement and optimisation.

For full-power beam propagation (non-attenuated pulses), a beam dump, produced by Gentec EO, was installed at the end of the LBTS during the firing of the peak power pulses.

Sequences of shots were fired, gradually increasing the pump energy of the last amplifier until reaching the required level for the 10 PW output. Such a sequence of shots can be observed in Figure 1.

After the 10 PW pulse propagation, all the optics were inspected. No damage was observed using visual and computer-aided inspection.

A beam with low wavefront error (74 nm RMS) was propagated to the experimental areas (Figure 2). Based on propagation simulations we estimate that, when tightly focused with the parabolic mirrors that are under implementation, having a focal distance of 1500 mm, this peak power can produce irradiances in the range of 10^{22} – 10^{23} W/cm^2 [5].

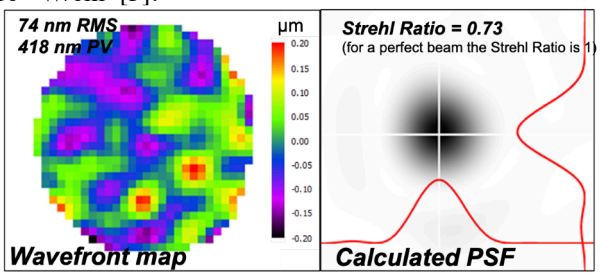

Figure 2. Wavefront map and calculated PSF at the output of the LBTS, in the experimental area, showing a good focusability of the laser pulses, with a calculated Strehl Ratio of 0.73.

3. Beam delivery

The HPLS is used for the Experimental Commissioning Program since January 2020. During this period the laser system and related operational procedure are tuned to deliver the proper parameters on targets and the equipment is prepared to be used for the coming user campaigns.

During the second half of 2021, we delivered 1192 pulses from the 1 PW output on target from which more than 700 had an energy of more than 20 J (Figure 3). A good day on a gas target in the 1 PW experimental area were delivered as shown in Figure 4.

In our presentation, we will include updated statistical data related to the HPLS beam delivery.

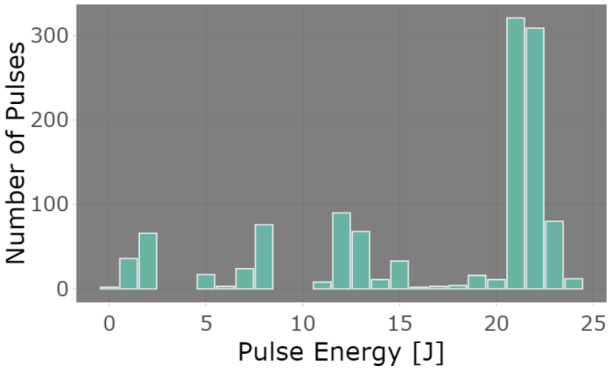

Figure 3. Energy distribution of the pulses delivered in the 1 PW experimental area (reproduction from [6]).

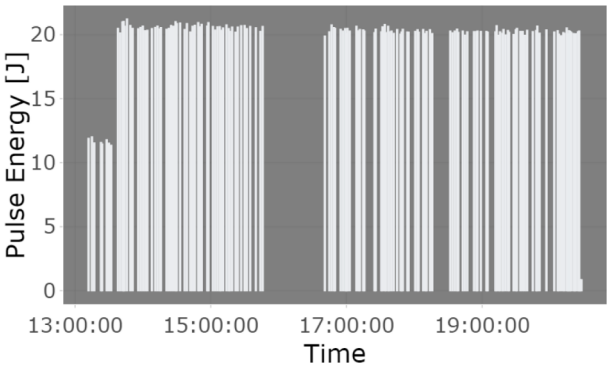

Figure 4. HPLS pulses delivered on a gas target in the 1 PW experimental area (reproduction from [6]).

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