Design of a High Energy Ti:Sapphire Amplifier for the Extreme Photonics Applications Centre

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Abstract: *Details of a high energy Ti:Sapphire amplifier capable of delivering up to 50 J broadband pulses at 10 Hz for a state-of-the-art petawatt laser-driver at the Extreme Photonics Applications Centre are presented.*

1. Introduction

The Extreme Photonics Application Centre (EPAC) is a new state-of-the-art laser facility being built at the Central Laser Facility (CLF) to study applications of laser-driven sources in industry, medicine, and security [1]. The first laser system to be built in the facility is a petawatt laser delivering 30 J, 30 fs pulses at 10 Hz pulse rate that will be used to drive plasma accelerators. It consists of an all-OPCPA frontend delivering stretched ns-pulses that will be amplified in a high energy Ti:Sa amplifier stage, before being compressed and propagated to one of two experimental areas. A new radiologically shielded building to house the laser systems and experimental areas was completed in April 2022 and installation has now commenced. In this paper we will provide details of the design of the final Ti:Sa amplifier stage and an update on the progress of laser development at EPAC.

2. High energy Ti:Sa amplifier stage

The Ti:Sa amplifier design for EPAC is based on the helium gas-cooled multi-slab architecture developed for the CLF family of DiPOLE high energy, high pulse rate pump lasers. A pair of Ti:Sa crystals (100 mm clear aperture, 20 mm thick) will be housed in a pressure vessel and face cooled by a high velocity flow of helium gas at near room temperature.

In the first phase of development, the amplifier will be pumped from both sides by a pair of 515 nm beams (total energy 70 J) generated by wavelength conversion and shaping of the output from a single DiPOLE100 laser [2], delivering 120 J, 15 ns pulses at 10 Hz, in a 75 mm aperture LBO crystal. The circular super-Gaussian output beam from the frontend (20 mm diameter, 4 ns, broadband 740 to 850 nm pulses with up to 1.5 J) will be expanded to 52 mm before injection into the amplifier. Stored energy will be extracted using a conventional 4-pass asymmetric bow-tie geometry, similar to that used on the CLF Gemini laser [3], with three achromatic 1:1 telescopes, made using custom refractive air-spaced doublets, providing relay imaging through the system.

A 3D drawing of the layout of the Ti:Sa amplifier system is shown in Figure 1. A CLF-made adaptive optic mirror will be positioned at the output for wavefront correction, and a rotating wedge compensator will be included at the input to correct for pulse front tilt errors.

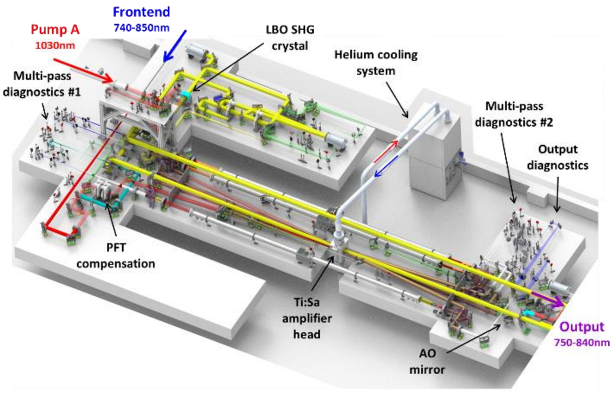

Fig. 1. Layout of EPAC high energy Ti:Sa amplifier highlighting key system components.

Diagnostic camera systems will be installed on each pass of the amplifier to ensure alignment is maintained and to monitor system performance. Off-axis dark-field Schlieren imaging systems will continuously monitor the integrity of the LBO crystal and Ti:Sa amplifier during operations.

The target output from the Ti:Sa amplifier stage after the first phase is 30 J, with a bandwidth greater than 75 nm FWHM, increasing to 50 J in the second phase with the addition of a second pumping beamline and expansion of the frontend beam to 72 mm diameter. Installation in the EPAC building is scheduled to start in April 2023, with commissioning of the Ti:Sa amplifier stage commencing at the end of the year.

References

[1] Extreme Photonics Applications Centre https://www.clf.stfc.ac.uk/Pages/EPAC-introduction-page.aspx.

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[3] C. J. Hooker *et al*, "The Astra Gemini Petawatt Ti:Sapphire Laser," The Review of Laser Engineering 37 (6), 443-448 (2009).