The APOLLON laser facility: Current status and scientific outcomes at multi-PW level

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Petawatt (PW) lasers have become, since their first demonstration few decades ago, an essential tool for the study laser-matter and laser-plasma interaction at extreme laser intensities.
The APOLLON research infrastructure, located in the Paris suburban area, aims at providing the community a versatile system, with enough flexibility to carry complicated multi-beam experiments. Using a combination OPCPA architecture for the front end to enhance temporal contrast, and conventional CPA for power amplification, the final parameters to be reached permit the generation of 10PW peak power femtosecond pulses. Separation of a single high energy beam using a set of beam splitters allows the use of 4 beams. The main beam, called F1, is a 40 cm diameter beam, designed to withstand 10 PW peak power. The second beam, called F2, can handle a maximum power of 1 PW at 14 cm beam diameter. The F3 beam corresponds to the uncompressed beam with energy up to 250 Joules and the F4 to a 10 TW probe beam line.

In the current configuration, pulse energy at the end of the amplification reaches 140 J, and measurement at the target chamber center yields 75 J on target. Coupled with a pulse duration of 23 fs, a peak power above 3 PW is available for user experiments. Along with the user experiments, continuous upgrades of the laser system enable pulse temporal contrast improvement, mandatory for nanometric foil target experiments. Another planned upgrade of the system concerns the F2 beam, with the adjunction of a half-waveplate for polarization management.

The laser beam can be sent to two different experimental areas. The Long Focus Area (LFA) uses spherical mirrors and on-axis configuration to obtain long Rayleigh ranges, suitable for LWFA experiments. As of 2025, only the 1 PW beam is available for users, the 10PW line still being under construction. Three different focal lengths are available for the 1 PW line, 3, 6 and 9 m. Measurement of the focal spot using the 6 m focal length, yields a 44µm diameter at 1/e2. Main target used in this area are gaseous, with the possibility to feed 2 gas jets with different backing pressures and gas type. The same configuration for the 10 PW line will be commissioned during October 2026.

The second experimental area is the Short Focus Area (SFA). Unlike LFA, the aim here is to reach the highest intensity possible on target. It relies on parabolas with f/# of 3 for the F2 beam, and 2.5 for the F1 beam. With all the energy sent to the F1 line, and a measured 5µm focal spot diameter at 1/e2, peak intensity above 10^22 W/cm2 can be reached on target.
While solid targets are mostly used in SFA, gas targets can also be used, using a similar system as the one available in LFA. Along the 2-beam configuration that will be available for users, this permits quite elaborated experiments for the plasma physics community.

The first experimental campaign has been realized in 2020 in LFA at the 1 PW level, followed by the detailed commissioning of the 1 PW line in SFA [1]. Since then, multiple experiments have been carried on in both areas, leading to several peer reviewed articles.
In LFA, electron beams with cutoff energy above 1 GeV can be routinely generated. Those electrons can be characterized using a long electron spectrometer, consisting of a 1 m long magnet, able to resolve electrons up to 5 GeV efficiently. Experiments that were awarded beam time aimed at improving the electron beam properties (higher cutoff energy, less energy spread, …) as well as using the laser plasma accelerator for bright gamma photon source production [2].
Since the commissioning of F1 in SFA in 2023, more experiments were awarded beam time thanks to the attractivity of the Apollon multi-PW beam. During commissioning, 2 PW on target were reached, and proton beams with energies above 50 MeV were easily produced, as well as neutrons using nuclear reactions [3]. Since then, after optimization, 3PW on target is available for users. Experiments spanned a broad range of topics, going from generation and characterization of particle sources [4], to topics of interest for astrophysics studies.

References

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