Electro-optical probing for electromagnetic pulses measurements in laser-matter interaction

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Abstract

When a high-intensity laser interacts with matter, it generates strong electromagnetic pulses (EMPs). These EMPs propagate into the surrounding space from the interaction point and can reach peak electric-field amplitudes in the order of MV/m over a broad frequency range, from MHz to THz, even at large distances from the source. These radiations can be harmful to surrounding diagnostics/devices and compromise the measurements of many detectors. Investigating these electromagnetic pulses has therefore become a major concern for the laser–plasma scientific community over the past several years. EMPs can also be useful in many different field of applications such as defense, medicine or aerospace.

Dedicated conductive antennas, such as the D-DOT antenna, have been widely used to measure EMPs in laser-plasma experiments. However, these antennas can interact with the emitted particles and ionizing radiation, compromising their functioning. Moreover, they provide the time derivative of the electric field, making the retrieval of the actual amplitude of the electric field non-trivial. EMP detection using conductive probes remains challenging under the harsh conditions of laser–matter interaction [1,2]. An alternative consists of probes based on the electro-optical effect [3], which directly measure one component of the electric field vector and are much less sensitive to spurious radiation thanks to their nonconductive materials. These probes are often protected by a sheath made of an optically absorbent plastic, known to provide effective shielding [4]. In general, electro-optical probes have a complex setup, including the probe itself with a fiber connected to an optoelectronic converter, that need to be correctly calibrated and shielded.

In this study, we present the calibration, characterization, and optimization of an electro-optical probe for EMP measurements in laser–matter interaction experiments. Several experimental investigations were carried out to assess the probe performance under representative operating conditions. In particular, the Ertalon sheath was characterized through measurements of its electromagnetic properties over a broad frequency range, while the probe response was investigated in the vicinity of dielectric materials to evaluate their influence on the measurements. These experimental results were systematically compared with 2D electrostatic simulations to improve the understanding of the probe response and validate the observed behaviourFinally, we present results obtained with the probe at PALS (Prague Asterix Laser System, capable of delivering 600 J pulses in 350 ps) and compare them with measurements performed using conductive probes placed at different locations, providing a characterization of the emitted EMPs in both the time and frequency domains.

References

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