EMP mitigation for high energy laser experiments

M. BARDON, F. LUBRANO
Commissariat à l'énergie atomique, CEA
Le Barp, 33114, France
matthieu.bardon@cea.fr

V. TIKHONCHUK
Centre lasers intenses et applications, CELIA-University of Bordeaux-CNRS-CEA
Talence, 33405, France

Abstract—Electromagnetic pulses generated in the interaction of a Petawatt laser with a target have been described theoretically and measured in a series of experimental campaigns conducted in various laser facilities. One mitigation method has been identified and tested at high laser energy.

Keywords – EMP, mitigation device, laser experiment.

I. INTRODUCTION

The interaction of a Petawatt laser with a flat target can produce intense electric field [1] which may exceed 1 MV/m. Such a field leads to equipment failures, may damage diagnostics and produce spurious signals in detectors. The PETAL laser is a Petawatt laser with energy up to 3 kJ and 0.5 picosecond pulse duration. This laser has been developed by the CEA, inside the Laser MegaJoule (LMJ) facility in France. As part of the PETAL project, we have studied the EMP generation mechanisms. A 3D, multi-physics, simulation chain has been developed. EMP mitigation devices have also been developed and tested on different campaigns, in different facilities, at low and high energy, in order to prepare the first PETAL experiments.

II. EMP GENERATION MECHANISM AND DEVELOPMENT OF A 3D SIMULATION CHAIN

A mechanism of the EMP generation has been identified [2]. An intense laser pulse focused on the target surface creates a group of energetic electrons that partially escape and leave a positive charge on the target. A discharge current is provided by the target holder after the end of the laser pulse. Then the holder acts as an antenna creating a strong electromagnetic signal. The proof of concept of this scheme is a major scientific breakthrough which allowed us to develop a multi-physics simulation chain.

The simulation is performed in four subsequent steps with a suite of numerical codes. First, the effect of the laser pre-pulse on the solid target is simulated with a hydrodynamic code developed at CEA/DIF. Second, the main laser-plasma interaction is simulated with particle-in-cell (PIC) code developed at CEA/DIF. The electrons are propagated inside the target by a Monte-Carlo code. Finally the escape of electrons from the target and their propagation to the laser chamber is simulated by another PIC code developed at CEA/CESTA.

This simulation chain has been validated on different experimental campaigns. Magnetic field measurements (B-dot probes) have been compared to numerical results. Simulations have allowed us to design new target holders with integrated EMP mitigation devices.

III. EMP MITIGATION DEVICES AND EXPERIMENTAL VALIDATION

The new target holders are composed of a glass capillary with inside resistive gel. One end of this capillary is fixed to the target and the other end is fixed on a conducting cylinder surrounded by a magnetic material which operates as an inductance. The goal of this new holder is to mitigate the discharge current produced and to limit the generation of the electromagnetic radiation. These devices have been tested, first, at low laser energy (0.1 J), and lately, at higher energy (80 J) on the POPCORN campaign at the LULI2000 facility. Fig 1 shows the magnetic field measured during the POPCORN campaign with and without the EMP mitigation devices. This result validates the EMP mitigation devices at high energy. The last qualification step for these new target holders was the first PETAL campaigns at the end of 2017. Results are still in progress.

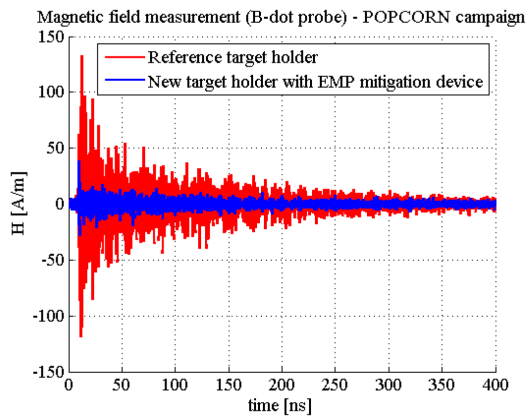

Figure 1. Validation of the new target holder at high laser energy.

REFERENCES

[1] C. J. Brown et al., "Analysis of electromagnetic pulse (EMP) measurements in the National Ignition Facility's target bay and chamber", *EPJ Web of Conf.*, **59**, 08012, (2013).

[2] A. Poyé et al., "Physics of giant electromagnetic pulse generation in short-pulse laser experiments", *Phys. Rev. E*, **91**, 043106, (2015).