Laser-Driven Electromagnetic Pulses for the Manipulation of Charged Beams

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Abstract: The interaction of high-intensity laser pulses with matter generates a wide range of physical phenomena, including particle acceleration and emission of pulsed electromagnetic radiation ranging from ionizing (γ, X, UV) to non-ionizing frequencies. Among these emissions, Electromagnetic Pulses (EMPs) extend from the MHz to the THz range [1] and can reach field strengths of several MV/m at distances of about one meter from the interaction point. While such intense transient fields have traditionally raised concerns regarding electronic equipment integrity and personnel safety in experimental facilities, increasing attention is now being devoted to their use for innovative applications.

A recently-patented scheme developed at ENEA - Centro Ricerche Frascati enables the generation of large-intensity (MV/m and beyond) transient electric fields over large volumes with specific spatial distributions [2]. These configurations open the way for a broad spectrum of applications in areas including particle acceleration and beam manipulation, medicine, biology, electromagnetic compatibility, materials science, aerospace, electronics and sensor.

We present here considerations regarding the patented ENEA EMP-based scheme for the conditioning of charged particle beams, either laser-driven or conventionally accelerated, with a focus on temporal/spatial beam chopping and energy selection of broadband beams. The study integrates analytical models of single-particle dynamics with dedicated numerical computations of particle bunches. The results show that EMP-driven devices offer a promising route to compact, high-performance beam manipulation systems, providing high field strengths, ultrafast rise times, and compact setups compared to conventional techniques. This innovative method shows performances far beyond the current state-of-the-art of existing particle-beam-chopping devices used in conventional particle accelerators, and allows for effective energy selection of beams accelerated by high intensity laser-matter interaction, such as TNSA (Target Normal Sheath Acceleration) scheme.

[1] F. Consoli, et al. High Power Laser Science and Engineering, 8, e22 (2020).

[2] F. Consoli et al, Patent PCT/IB2020/057464, WO2021/024226

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