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Editorial

Laser-Driven Accelerators, Radiations, and Their Applications

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Particle accelerators and radiation based on radio-frequency (RF) cavities have significantly contributed to the advancement of science and technology in the last century. However, the rising costs and scales for building cutting-edge accelerators form barriers to accessing these particle and radiation sources. Since the introduction of chirped pulse amplification technology [1] in the 1990s, short-pulse, high-power lasers have enabled the realization of laser-driven accelerations and radiation sources. Laser-driven accelerators and radiation sources could be a viable alternative to providing compact and cost-effective particle and photon sources. The accelerating field in a plasma, driven by intense laser pulses, is typically several orders of magnitude greater than that of RF accelerators, while controlling the plasma media and intense laser pulses is highly demanding. Therefore, numerous efforts have been directed toward developing compact, high-quality particle beams and radiation sources based on intense laser-plasma interactions, with the goal of paving the way for these novel sources to be used in a variety of applications.

This Special Issue covers the latest developments in laser-based ion and electron accelerators, laser-plasma radiation sources, advanced targetry and diagnostic systems for laser-driven particle accelerators, particle beam transport solutions for multidisciplinary applications, ionizing radiation dose map determination, and new approaches to laser-plasma nuclear fusion using high-intensity, short laser pulses. This collection of research articles is a complementary set of experimental results, achieved using cutting-edge laser technologies with a broad range of parameters (from 10 TW to 1 PW and from 10 fs to 1 ps) and numerical simulation studies, carried out through particle-in-cell, hydrodynamic, and Monte Carlo advanced modelling.

The versatility of laser-plasma accelerators is demonstrated through an optically switchable, multi-MeV ion/electron accelerator using the same target geometry (thin-foil) [2]. A review of the recent developments, limitations, and perspectives of multi-GeV electron accelerators with PW-class lasers using the laser-wakefield acceleration approach is provided [3]. Advanced spectroscopic investigations of laser-based, far-ultraviolet plasma sources are also presented [4]. Recent progress in the design and development of automated systems to refresh solid targets at a high repetition rate during the interaction with high-intensity laser pulses are presented, along with ion diagnostics and corresponding data collection and real-time analysis methods [5]. Experimental studies on the correlation between the frequency spectrum of the large electro-magnetic pulse generated in the high-intensity laser–target interaction and the distortion of Thomson parabola spectrometer proton tracks are also reported [6]. A dedicated Monte Carlo Study of Imaging Plate Response to Laser-Driven Aluminum Ion Beams is presented [7]. The design, implementation, and characterization of a multi-MeV laser-plasma proton beamline using compact and cost-effective particle beam transport solutions is presented [8]. On the other hand, feasibility studies aimed to perform radiobiological experiments using laser-accelerated proton beams with intermediate-energy (few tens of MeV), properly focused and selected through advanced particle beam transport solutions, are reported [9]. The angular spectral distribution of laser-accelerated particles is assessed for the subsequent modelling of radiation dose maps and a comparison with the experimental results [10]. Finally, the first proof-of-principle experiment to demonstrate the efficient generation of α-particle beams through proton–boron fusion reactions using a PW-class laser in the "in-target" geometry is presented [11].

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