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Editorial

Preface for Special Issue: Progress in Laser Accelerator and Future Prospects

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In early 2022, one of the authors (Professor T. Tajima) was invited to edit a Special Issue of the journal *Photonics* under the title of "Progress in Laser Accelerator and Future Prospects". Since this topic is one of the most vigorously pursued and rapidly advanced in the field of photonics, T.T. decided to take up the challenge. T.T. then suggested *Photonics* to invite Professor Pisin Chen as a co-Editor to join the project. Together, we formed the editorship of this Special Issue. We then invited about 15 of the world's authorities on this subject to outline the current status and the future prospect of the field. Nearly all these invited authors accepted our invitations.

As we are motivated to cover theoretical, experimental, and technological advancements from fundamental science to societal applications of Laser Wakefield Accelerator (LWFA), we design the content of this Special Issue as follows.

I. Introduction;
II. Laser Technology;
III. Review of Experimental Status;
IV. Energy Frontier of Laser Wakefield Accelerators;
V. High Density Laser Wakefield Accelerators and Medical Applications;
VI. Fundamental Physics using Wakefields.

Section II consists of two papers, one by Sha et al. [1] and the other by Wheeler et al. [2], where the former reviewed the laser technology of the ultrafast fiber lasers and the fiber delivery of such pulses, and the latter described the thin-film compression technique to increase the pulse intensity in PW-class lasers. These are at the very forefront of state-of-the-art laser technology.

Section III reviews experimental progresses in laser acceleration in Asia, Europe, and the U.S. Li et al. [3] reported on the progress of the Compact Laser Plasma Accelerator (CLAPA) at Peking University, where high quality proton beams have been routinely produced. Hegelich et al. [4] revisited the experimental signatures of the ponderomotive force with fresh insights, while Matys et al. [5] reviewed how high-quality laser-accelerated ion beams can be attained by invoking structured targets where the relativistic instability induced can be utilized to produce highly collimated and quasi-monoenergetic ion beams.

Section IV deals with issues relating to the energy frontier of LWFA. In particular, Hidding et al. [6] reviewed the concept of the Hybrid Laser Plasma Wakefield Accelerator, which attempts to combine the LWFA scheme with that of the charged particle beam-driven Plasma Wakefield Accelerator (PWFA) so as to take advantage of both schemes to address the technical challenge of reaching high energies. Another critical challenge is the production of high-quality electron beams in laser acceleration, whose optimization scheme was nicely examined by Jiang et al. [7].

The next topic in this Issue (Section V) regards the high-density regime of LWFA and its medical applications. Here, we have collected as many as five papers by top experts from both the laser-plasma science and medicine industries. These include the excitation of Wakefields via laser beat-waves in the near-critical regime by Barraza-Valdez et al. [8], the slow phase velocity laser acceleration of ions at the near-critical density by Necas et al. [9], and the investigation of electron acceleration using phase synchronization through nanomaterials density inhomogeneity by Maslov et al. [10]. Roa et al. [11] focused on potential applications of fiber-optic-based laser Wakefield accelerated electron beams for radiotherapy cancer treatment, while Papp et al. [12] introduced the idea of LWFA-driven photoneutron generation aspired by high-impact societal applications. These directions all have a high potential in societal applications.

This Special Issue ends with Section VI that connects LWFA with fundamental physics. The paper by Kando et al. [13] reviewed the theoretical and experimental progress of the relativistic flying mirror (RFM) concept, which is a realization of the relativistic regime of LWFA, for the application to probing the Schwinger critical field limit in strong field science. The other paper, by Chen et al. [14], reports on the concept, design, and status of the AnaBHEL (Analog Black Hole Evaporation via Lasers) experiment. This is an attempt to accelerate ultra-intense LWFA-induced RFM with pre-designed trajectories as analog black holes to investigate the fundamental physics of black hole Hawking radiation.

We see that through the efforts of these world-leading experts and their outstanding coauthors, this Special Issue presents a broad and exciting landscape of the current status and the future prospects of LWFA. It is our sincere hope that this Special Issue provides a timely perspective as well as a future roadmap in the developments of laser Wakefield acceleration not only to the practitioners of this field, especially the younger generation of scientists, but also to those who work in other, albeit related, fields such as high energy physics, black hole physics, high-field science, and medicine. We are very grateful to all authors who contribute to this meaningful endeavor. Our gratuity also goes out to *Photonics* for initiating this Special Issue and the journal's staff for their tireless efforts, without which this Volume would not have been in such a wonderful shape. Last but not least, we deeply appreciate the administrative assistance of Maria Gaytan throughout the preparation of this Special Issue.

Conflicts of Interest: The authors declare no conflict of interest.

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