quantum beam science

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Editorial

Novel Quantum Beams from Integrated Laser-Driven Accelerator Systems

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Received: 13 June 2018; Accepted: 14 June 2018; Published: 15 June 2018

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Welcome to the Special Issue of *Quantum Beam Science* that features Laser-Driven Quantum Beams. Much progress has been made during the past two decades enhancing our understanding of the rapid and intense laser–plasma interaction as a useful source of energetic particles and photons. Our aim for this Special Issue has been to address the many relevant scientific and technical issues for using a high power laser driver as a basis for new accelerator systems of energetic electrons, protons and other ions, as well as for systems delivering neutrons, X-rays and γ-rays associated with particle acceleration. That an extreme laser-induced plasma is capable of synchronously generating an assortment of energetic particles and/or photons is a uniquely powerful feature that can inspire new ideas for the design of laser-driven accelerator 'machines' and therefore novel applications.

Due to the need to better understand basic physics issues and capabilities for single pulse laser–plasma interactions and the repetition-rate limitations of very high power lasers (notably at ~petawatt peak power levels), much research to date has been conducted at the single pulse or so-called 'single shot' level. These are mainly 'source' studies for which targetry, as the microscopic sight for energy conversion, is a critical source component. For clarity, we define the laser-driven 'source' to be: the driving laser, the target and the laser-induced plasma. Source development is therefore intrinsically coupled to high power laser technology.

At the 'system' level, we invoke the stable controlled beam picture (similar to what we have come to expect from conventional accelerators that are not laser-driven); the implied image being well-directed, repetition-rated delivery of energetic particle bunches (or photon pulses) of well-defined energy spectra and purity. This Special Issue addresses the development of such 'integrated laser-driven accelerator systems'. For clarity, we therefore define the laser-driven 'system' to be: the source (as defined above), essential instrumentation (for all diagnostics, metrology and control) and beam line optics for delivery to applications. The development of these quantum beams for meaningful use is clearly a multidisciplinary endeavor that mandates a broad range of scientific and technological subject matter (from high power lasers and targetry at the source end to innovative instrumentation, tailored beam line optics and beam line architecture that can also include post-acceleration schemes). Understandably, realizing the integrated laser-driven accelerator system as a machine resource is also a global effort and we highlight here examples of progress.

Included in this Special Issue are some reported examples of the science and technology essential to laser-driven accelerator system development. Associated with laser-driven electron acceleration are X-ray sources from fundamental processes such as coherent high order harmonic generation [1] and reflection of coherent infrared probe pulses from flying relativistic plasma mirrors [2]. The report of 'Focusing Plasma Mirrors' [3] presents an innovative example for combining intensity contrast enhancement with focusing of intense laser pulses that will be critical for optimizing emergent particle yield from targets. The latter work clarifies that, for a focused laser pulse, high power and high intensity alone are not enough and incremental finesse is essential. The application of rapid electro-optic detection of ultrashort electron bunches [4] demonstrates the obvious need for ultrafast instrumentation in which the laser environment can intrinsically enable and usher new methodologies. Finally, Margarone et al. describe the ELIMAIA program aimed at establishing a laser-driven accelerator beam line that will be dedicated to applications at the ELI-Beamlines facility (Dolní Břežany, Czech Republic) [5].

It is clear that the integrated laser-driven system of particles and/or photons embraces a new machine concept with a character that is determined to a great extent by the ubiquitous nature of the laser itself. Developing scientifically meaningful and otherwise impactful applications will be key to motivating, enabling and guiding continued advancement of the laser-driven accelerator system to higher technical maturity. Further, the uniqueness of the laser-driven system can be exploited by judiciously chosen applications. In the future, we can anticipate that researchers will avail themselves of novel laser-driven machine options that can augment choices with conventional accelerators. Much exciting new development is yet to happen in this special field that is aimed at generating novel quantum beams in unique configurations for new opportunities. We hope you enjoy reading the sample of incremental progress that we present in this Laser-Driven Quantum Beams Special Issue.

Conflicts of Interest: The author declares no conflict of interest.

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