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Hybrid Laser-Plasma Wakefield Acceleration: Harnessing the Best of Both Worlds

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Both, lasers and particle beams can drive plasma waves for particle acceleration and radiation production, historically known as "Laser Wakefield Acceleration" (LWFA) and "Plasma Wakefield Acceleration" (PWFA). Today, LWFA is routinely realized with compact, commercially available high-power-laser systems. In contrast, PWFA requires high-current particle beams and was, until recently, the exclusive domain of large-scale accelerators such as SLAC, CERN, DESY, BNL or INFN. However, LWFA and PWFA have complementary advantages with regard to plasma wave excitation, acceleration mechanisms, and electron injection strategies. Hybrid laser-plasma Wakefield acceleration is an approach strategically developed to harness the best of both worlds [1-7]. For example, electron beams produced with compact LWFA are excellent femtosecond, multi-kiloampere drivers for realization of dephasing-free strong-field PWFA in a subsequent plasma accelerator stage [1-3,7]. With features such as resonant high-plasma density operation and accelerating gradients of the order of 100 GV/m [1-3], and inherently synchronized laser pulses for preionization, interaction probing [2,3,7] and beam injection [3,7], hybrid LWFA →PWFA democratizes PWFA, and provides capabilities previously thought unattainable. In particular, plasma photocathodes [4-8] promise dark-current-free, tunable production of beams with superior emittance and brightness. These could enable applications such as ultrahigh-gain, hard X-Ray Free-Electron-Lasers operating near the cold-beam limit [9,10].
This invited presentation will discuss physics, progress and prospects of these developments, including the first experimental realization of a plasma photocathode in a hybrid plasma accelerator [7] as recent culmination of hybridization of concepts.

References

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