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Ultra-high acceleration gradient using structured nanomaterials

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Solid-state plasma wakefield acceleration has recently garnered attention as a viable alternative for achieving unprecedented ultra-high acceleration gradients on the order of 1 TV/m or beyond [1, 2]. In this context, recent advancements in nanofabrication techniques [3] have opened up the possibility of creating structured plasmas with inhomogeneous properties. For instance, the utilization of carbon nanotube (CNT) bundles and multi-layer graphene [4] holds great potential for generating stable plasmas with electron densities reaching as high as 10^24 cm^-3, i.e., orders of magnitude higher than conventional gaseous plasmas. As part of a new collaborative effort called NanoAcc (Application of Nanostructures in Accelerator Physics), we have conducted Particle-In-Cell (PIC) simulations to investigate both laser-driven and beam-driven excitation of pre-ionized targets utilizing CNT arrays. Our results confirm the attainment of wakefields at the TV/m scale. Additionally, we have observed phenomena such as self-injection, sub-femtosecond bunch formation, and the acceleration of electrons within micrometre-scale targets, leading to kinetic energies of approximately 10 MeV. These findings open up promising possibilities for manipulating charged particle beams, thereby shaping the future of compact accelerator design and radiation sources. Furthermore, solid-state plasmas offer a high degree of tunability in extracting relevant bunch parameters through effective control over the target structure. In this article, we present an overview of the studies conducted thus far by the NanoAcc collaboration, and discuss future experimental plans as well as potential applications.

References

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