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Density downramp injection in plasma-based acceleration and its applicaitons in XFELs

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Generation of high-quality electron beams in plasma-based acceleration is a critical and active topic in the past decade. By conducting full-scale particle-in-cell simulations, we have shown that electron beams with ultra-high brightness (10ˆ20 ˜10ˆ21 A/mˆ2/radˆ2) and 0.1˜1 MeV energy spread can be produced in density downramp injection in the three-dimensional blowout regime of plasma-based acceleration. Two underlying physical mechanisms that lead to the generation of high-quality electrons are uncovered: transverse deceleration and longitudinal mapping. Recently, we pointed out the injection in a slowly expanding bubble caused by the evolution of a laser pulse driver or an electron beam driver in a uniform plasma shares the same dynamics as downramp injection, thus can indeed produce high quality self-injected electron beams. Furthermore, we proposed to generate a high-quality electron beam with nanometer-scale current modulation in a density modulated downramp. These high-quality beams have many potential applications in X-ray free-electron lasers, such as drive a fully coherent XFEL in a short undulator.

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