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Self-modulated plasma wakefield accelerators[1]

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A long, relativistic, particle beam propagating in an overdense plasma is subject to the self-modulation instability. This instability modulates the beam radius and density at the plasma wavelength, exciting a large plasma wave that potentially could be used for high-gradient acceleration of particle beams. Self-modulation of proton beams (such as those available at CERN) are actively being considered to drive compact plasma accelerators. The beam self-modulation instability is analyzed in homogeneous and inhomogeneous plasma. While undergoing modulation, the phase velocity of the plasma wave is significantly less than the beam velocity, which severely limits the energy gain of the accelerated electron beam. Tapering (i.e., a plasma density that increases along the direction of beam propagation) offers the possibility to compensate for the slow wave phase velocity, improving the efficiency of the accelerator, and the optimal form of the taper is presented. Small plasma density inhomogeneities may result in decoherence effects that will suppress the instability, making experimental realization challenging. The transverse stability of the drive beam (e.g., the growth of beam hosing) is a critical concern for beam-driven plasma wakefield accelerators, and, in particular, for long beams. Coupling of the beam envelope self-modulation to the beam centroid displacements (hosing) is described. Methods to mitigate hosing by seeding the self-modulation will be presented. Implications for proton-beam-driven plasma accelerator experiments will be discussed.

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