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Self-modulation of long particle beams in plasma wakefield accelerators

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The self-modulation instability (SMI) is the key effect that makes possible the usage of presently available high-energy proton beams as drivers for plasma wakefield acceleration. The seeded SMI first transforms the long beam into a bunch train and then partly destroys these bunches. Both effects occur because of particle defocusing by the plasma wakefield. Development of the instability is always accompanied with a flow of beam particles through potential wells of the plasma wave.
The character of beam evolution changes favorably by a small increase of the plasma density at the linear stage of SMI growth. The optimum magnitude of the increase is such that to make the beam one wavelength longer if measured in local plasma wavelengths. As a result, well separated bunches are formed, and these bunches quickly come to equilibrium with the wave and excite the strong wakefield over a long propagation distance.
The final stage of beam evolution in both the uniform and increasing density plasmas strongly depends on the initial beam emittance. The established wakefield amplitude drops down approximately linearly with the emittance growth.

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