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Ion Motion, Hosing Suppression, and Beam Quality Preservation in Plasma-Based Accelerators[1]

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Plasma accelerators can produce extremely large fields, enabling compact accelerators, and application of plasma accelerators to the next generation of colliders has attracted considerable interest. Acceleration of ultra-low emittance beams with high efficiency is critical to realizing this application. Low emittance beams are strongly focused and pinched in the plasma reaching beam densities sufficiently high to move background ions, inducing beam emittance growth. High efficiency requires large longitudinal wakefield excitation by the accelerated beam, and this has an associated large transverse wakefield that will drive the hosing instability (growth in head-to-tail beam centroid misalignment). In this talk, the nonlinear response of the ions to a dense beam will be described, including the coupling to the hosing instability. It is shown that the head-to-tail variation in the average plasma wakefield induced by ion motion results in the suppression of hosing. A class of initial beam distributions are identified that are equilibrium solutions in the plasma wakefield including ion motion. Using these beam distributions enables ion motion without emittance growth. A plasma-based method to generate the matched equilibrium beam distribution is proposed. Hence, it is shown that stable acceleration in plasma-based accelerators is possible and, by proper bunch shaping, both the low emittance may be preserved and the energy spread minimized.

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