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Acceleration-Induced Self-Interactions of Ultra-Short Electron Bunches

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We present a theoretical description of the radiative and space-charge intra-bunch interaction of a compact charged bunch undergoing high-field acceleration relevant to LWFA, PWFA conditions. The effects during the process of acceleration are considered specifically, in contrast to previous work that assumes an instantaneous change in energy and examines the post-acceleration interaction with radiated fields.

For compact bunches (i.e. volume is < O(1)um^3) there is a significant modification to the space-charge and radiation field interactions within the bunch in the presence of high gradient acceleration, with the fields being asymmetric with respect to the centroid of the bunch. We find these effects to be significant for acceleration fields of order GV/m and charges exceeding 10pC, with potential to provide a mean energy loss on the order of 0.1-1% of the energy gained, and a head-tail energy difference of similar magnitude.

The model points to an inherent vacuum beam-loading process within compact bunches that is exacerbated rather than compensated by higher gradient acceleration fields.

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