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Teravolt-per-meter plasma wakefields from low-charge, femtosecond electron beams

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Recent initiatives in ultra-short, GeV electron beam generation have been aimed at achieving sub-fs pulses capable of driving X-ray free-electron lasers (FELs) in single-spike mode. This scheme foresees use of very low charge beams, which may allow existing FEL injectors to produce few-100 as pulses, with very high brightness. Towards this end, recent experiments at SLAC have produced ~ 2 fs rms, low transverse emittance, 20 pC electron pulses. Here we examine use of such pulses to excite plasma wakefields exceeding 1 TV/m, permitting a table-top TeV accelerator. We present a scheme for focusing the beam to very small dimensions, where the surface Coulomb fields are also at the TV/m level. These conditions access a new regime for high field for atomic physics, allowing frontier atomic physics experiments, including sub-fs plasma formation for subsequent wake excitation. We examine the use of such ultra-short beams for creating coherent sub-cycle IR radiation at unprecedented high power levels.