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Scalable laser-plasma acceleration using Traveling-Wave Electron Acceleration

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While laser-plasma accelerators provide multi-GeV electron beams today, the acceleration to higher energies is limited. The sub-luminal group-velocity of plasma waves let electrons outrun the accelerating field. We present Traveling-Wave Electron Acceleration, a novel compact laser-plasma accelerator scheme which circumvents the LWFA constraints of electron beam dephasing, laser pulse diffraction and depletion.

For controlling the speed of the accelerating plasma cavity, TWEAC utilizes two pulse-front tilted lasers whose propagation directions enclose a configurable angle. The accelerating cavity is created along their overlap region in the plasma and can move at the vacuum speed of light. Such guiding-structure-free, lateral coupling of lasers into the plasma allows the field within this overlap region to be continuously replenished by the successive parts of the laser pulse. Supported by 3D particle-in-cell simulations, we show that this leads to quasi-stationary acceleration conditions for electron bunches along the total acceleration length, such that TWEAC is in principle scalable to arbitrarily long acceleration stages.

We discuss scaling laws and detail experimental design considerations. We find that for low-angle TWEAC setups, it is possible to accelerate nanocoulomb-class bunches with laser to electron beam energy efficiencies close to 50%, thus exceeding energy efficiencies typically attained with LWFA.

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