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Vacuum laser acceleration via laser-foil transparency

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Intense lasers can accelerate electrons to very high energy over a short distance. Such compact accelerators have several potential applications including fast ignition, high energy physics, and radiography. Among the various schemes of laser-based electron acceleration, vacuum laser acceleration has the merits of super-high acceleration gradient and great simplicity. Yet its realization has been difficult because injecting free electrons into the fast-oscillating laser field is not trivial. Here we experimentally and numerically demonstrate free-electron injection and subsequent vacuum laser acceleration of electrons up to 20 MeV using the relativistic transparency effect. The key physics are identified through multi-dimensional particle-in-cell simulations and test-particle simulations. When a high-contrast intense laser drives a thin solid foil, electrons from the dense opaque plasma are first accelerated to near-light speed by the standing laser wave in front of the solid foil and subsequently injected into the transmitted laser field as the opaque plasma becomes relativistically transparent. It is possible to further optimize the electron injection/acceleration by manipulating the laser polarization, incident angle, and temporal pulse shaping. Our result also sheds light on the fundamental relativistic transparency process, crucial for producing secondary particle and light sources.

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