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Carrier-envelope phase control of a kilohertz laser-wakefield accelerator

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The interaction of an ultra-intense single-cycle laser pulse with an underdense plasma in a laser-wakefield accelerator can lead to an asymmetry in the plasma response that depends on the carrier-envelope phase (CEP) of the laser driver[1]. In our experiment, we use near-single cycle pulses with controlled CEP to accelerate electrons in a laser wakefield accelerator. We observe the oscillation of the accelerated electron beam pointing in the laser polarization direction in phase with the CEP. This effect is significant, with an oscillation amplitude as high as 15 mrad. A dependence of the injected charge to the laser CEP is also observed. Particle-in-Cell simulations explain these observations through highly localized, off-axis injection of sub-fs, ultralow emittance electron bunches triggered by the CEP-dependent asymmetry in the plasma wake [2,3,4,5]. These observations imply that we achieve sub-cycle control on the injection and subsequent dynamics of the electron beam through the waveform of the laser.

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[2] J. Kim et al, Phys. Rev. Lett. 127, 164801 (2021)

[3] J. Huijts et al, Physics of Plasmas 28, 043101 (2021)

[4] J. Huijts et al, Phys. Rev. X 12,011036 (2022)

[5] L. Rovige et al, arXiv:2205.08374 (2022)

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