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Optical probing of laser-driven electron acceleration with synchronized few cycle pulses

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Experiments on laser wake field acceleration rely heavily on numerical simulations to explain observed phenomena. This is mainly attributed to the unique properties of the acceleration structure, the plasma wave: The spatial extension in the order of a few micrometers and its propagation with nearly the speed of light have so far defied a direct observation. Even pulses with durations as short as 25fs, as commonly available at most of the high power laser facilities worldwide, only result in blurred images due to temporal averaging. To overcome this challenge, a few cycle probe beam was developed for the JETI laser system operated at the Institute of Optics and Quantum Electronics in Jena, Germany. This probe pulse was used to track the evolution of the plasma wave with unprecedented spatial and temporal resolution. The transition from the non relativistic oscillation of the electrons inside the plasma wave to a highly relativistic regime with spatial features so far only seen in PIC simulations was observed. Essential characteristics for the laser plasma interaction could be derived by characterizing the transformation of the plasma wave during wave breaking and subsequent electron injection, which form the basis for a future optimization of the acceleration process.

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