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Quantitative reconstruction of wakefield electron density distribution

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Few-cycle shadowgraphy is a common tool to qualitatively investigate the longitudinal and transverse structure of laser generated wakefields. However the measured intensity distribution provides hardly any information about the wake amplitude since the wakefield itself is a pure phase object and the measured intensity distribution is a function of the imaging plane. Commonly this plane is not precisely known due to the pointing jitter of the driver laser. One possible approach to investigate the phase object constituted by the electron distribution inside the wake is to image multiple planes around the wakefield. From these multiple intensity distributions it is possible to reconstruct the phase that defines the propagation between the imaged planes and therefore represents the original phase object.
We report on the successful reconstruction of the phase accumulated by the probe beam and subsequent extraction of the plasma refractive index. From that the electron density distribution of the wakefield is calculated. We experimentally observe wakefields in He-gasjets driven by a 100TW-class laser. The gas density is in the range of $5 \cdot 10^{18} cm^{-3}$. We find linear and quasi-linear plasma wakes with a modulation depth comparable to that expected from theory and simulations.

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