Plasma lensing of a laser wakefield accelerated electron bunch

S. Kuschel[1,2], T. Heinemann[3], O. Karger[3], M. Schwab[1], C. Rodel¨[1,2,5], D. Ullmann[1], A. Knetsch[3], D. Hollatz[1], M. Yeung[2], M. Leier[2], A. Savert¨[2], M. C. Kaluza[2], B. Hidding[3,4], and M. Zepf[1,2]

[1]Institute for Optics and Quantumelectronics, University of Jena, Max-Wien-Platz 1, 07743 Jena, Germany; [2]Helmholtz Institute Jena, Frobelstieg¨ 3, 07743 Jena, Germany;
[3]Institute for Experimental Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany;
[4]SUPA, Department of Physics, University of Strathclyde, G4 0NG Glasgow, UK; [5]SLAC National Accelerator Laboratory, 2575 Sand Hill Road, 94025 Menlo Park CA, United States

We report on the first all-optical demonstration of plasma lensing using laser wakefield accelerated elec-trons in a two-stage setup. The LWFA electron bunch was focused by a second plasma stage without any ex-ternal fields applied.

Plasma wakefields can provide electrical fields in the or-der of hundreds of GV/m und thus allow to build compact particle accelerators. However, transportation, shaping and focusing of accelerated particle beams still requires con-ventional structures which will be much larger than the ac-celerator itself. As a plasma is used for the acceleration process, it has been shown, that a plasma can be used for focusing the particle bunch as well due to transversal fields inside the plasma wave[1, 2].

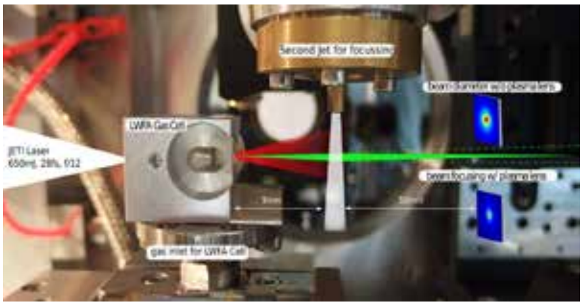

Figure 1: Illustrated photo of experimental setup: the laser pulse, incident from the left, drives an LWFA stage in a mixed-species gas cell, and the generated electron beam expands in vacuum according to its obtained divergence. If the second gas jet is turned on, the remnant and diverged laser pulse preionizes the H_2 gas and the trailing electron beam experiences plasma lensing, which reduces the diver-gence substantially as observed on a Lanex (Fig 2).

The experiment presented here was conducted at the 40 TW ”JETI” Ti:sapphire laser system at the University of Jena, delivering = 28 fs pulses at a central wavelength $_0$ = 800 nm with E = 650 mJ on target. The laser pulses were focused by an f/12 off-axis parabolic mirror to a spot size w_0^2 120 m^2 (FWHM), resulting in a vacuum peak normalized amplitude of a_0 2:2. The laser focus was aligned to the entrance aperture of a z_C = 2:5 mm long gas cell (acceleration stage) as seen in figure 1. The gas in the gas cell was composed of a 95% He, 5% N_2 mixture in order to make use of higher-level laser ionization injection [3, 4]. The LWFA stage produced electron bunches up to E_{max} = 130 MeV with a large energy energy spread and a total charge of up to 10 pC.

As soon as the focusing stage is turned on, the solid an-gle covered by the electron beam on the Lanex scintillator screen reduces from 16 mrad^2 to 6 mrad^2 (figure 2) while the total charge of the bunch decreases to 75% of its inital value only (not shown). Thus not only a decrease of the electron divergence but also an increase in electron inten-sity on the Lanex (a net focusing effect) was measured.

The measured focusing matches the results from particle-in-cell simulations with the EPOCH Code (not shown here).

a) without second stage b) with second stage

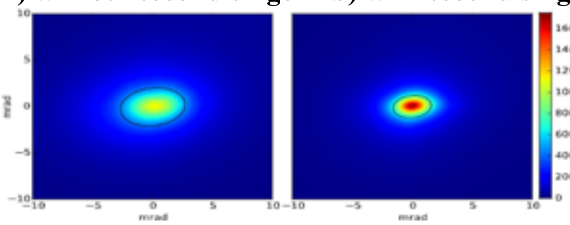

Figure 2: Averaged and center aligned (pointing corrected) beam profile as seen on the Lanex: a) 227 reference shots with the acceleration stage only. b) 175 shots with the sec-ond lensing stage. In both pictures the ellipse encloses the standard deviation of a best fit 2D gaussian function to the beam profile. The ellipse reduces its area from 16 mrad^2 (left) to 6 mrad^2 (right) when the focusing stage is turned on.

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