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Guiding of high-intensity laser pulses through long, low-density hydrodynamic optical-field-ionised (HOFI) plasma channels

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To realise a 10 GeV laser plasma accelerator stage, high-intensity pulses must be guided through low-density ($\sim 1 \times 10^{17}\mathrm{cm}^{-3}$) plasma over distances of order 100s of millimeters.

We recently presented simulations which showed that plasma channels with these parameters could be generated by the hydrodynamic expansion of optical-field-ionised plasma columns formed with an axicon lens [1], and experiments using a spherical lens which demonstrated the generation of short (~ 4 mm long) low-density channels.

Here we report new experiments which demonstrate the formation of 16-mm-long channels with on axis densities as low as $1.5 \times 10^{17} cm^{-3}$ using an axicon lens [2]. Only 0.5 mJ of channel-forming laser energy was required per mm of channel. The hydrodynamic expansion of the plasma column and the properties of the resulting plasma channels are characterized by transverse interferometry. High-quality, highly reproducible guiding of pulses with peak axial intensities exceeding $4 \times 10^{17}\mathrm{Wcm}^{-2}$ through these channels is demonstrated at a repetition rate of 5 Hz.

We also report progress in using reflective axicons to generate HOFI plasma channels with lengths greater than 100 mm.

[1] Shalloo, R. J., et al. (2018) https://doi.org/10.1103/PhysRevE.97.053203

[2] Shalloo R. J., et al. (2019) https://doi.org/10.1103/PhysRevAccelBeams.22.041302

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