Contribution ID: **201** Type: **poster**

Novel method for transverse probing of low-density, hydrodynamic optical-field-ionised plasma channels

Monday, 16 September 2019 19:00 (1 hour)

Guiding high-intensity laser pulses over long distances through low density plasma ($\sim 1 \times 10^{17}\ \mathrm{cm}^{-3}$) is one of the key challenges to create laser plasma accelerators for high energy physics and industrial applications. We recently demonstrated that low density channels suitable for such guiding could be generated by the hydrodynamic expansion of optical-field-ionised plasma columns formed with an axicon lens.
Recently, we generated 16 mm long channels with on axis densities as low as $1.5 \times 10^{17}\ \mathrm{cm}^{-3}$ and demonstrated highly reproducible guiding of high-intensity pulses over 14 Rayleigh ranges [1]. Control of the channel parameters via adjustment of the initial cell pressure or the delay after the arrival of the channel-forming pulse was demonstrated.
Characterising these plasma channels via transverse probing is challenging since the phase shift through low-density plasma is on the order of 20 mrad, and a slight azimuthal asymmetry of the channel was observed. A novel, forward-fitting algorithm is presented, along with statistical fitting used to characterise channels. We present electron density profiles with parameters ideal for laser wakefield accelerators, with matched spot sizes in the range $20 \leq W_M \leq 40\mu\mathrm{m}$.

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

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Session Classification: Cheese and Wine Poster Session 1

Track Classification: WG5 - Plasma devices, plasma and beam diagnostics