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Controlled Plasma Generation for Beam Driven Plasma Wakefield Accelerators

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Plasma-based accelerators offer the chance of dramatically shrinking the size and cost of future particle accelerators and free-electron lasers. In the FLASHForward project a high-power laser creates a plasma inside which an electron bunch from the FLASH linac drives large amplitude wakefields. Disentangling the processes of ionisation and excitation of wakefields enables improved control over the radial and longitudinal plasma density profile and hence the structure of the wakefields. The disentanglement facilitates the preservation of beam quality during the acceleration. Simulations have shown that using hollow-core plasma channels allow for control of the beam transport and acceleration separately by decoupling transverse and longitudinal fields. To model the plasma density distribution across the target we compute over-barrier, strong-field ionisation rates for a measured laser-intensity. We benchmark the calculated ionisation and dissociation behaviour against measurements using plasma interferometry. These studies provide for an optimisation of the focusing geometry and laser-power-profile to obtain specific plasma profiles. Moreover, comprehension of the underlying processes of laser induced plasma generation allows a better estimation of additional plasma properties. As a proof of concept we create plasma channels with tailored shapes and lengths of approximately 25 centimeters experimentally.

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