Laser-driven plasma acceleration in a regime of strong mismatch between the incident laser envelope and the nonlinear plasma response

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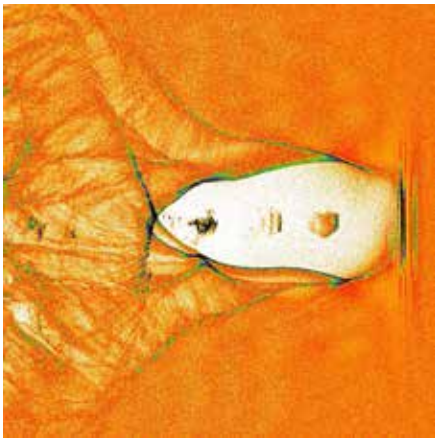
Laser-driven plasma wakefield acceleration of electrons in a strongly mismatched regime is explored and shown to have several advantages over the matched regime. Experimentally, larger laser focal spots of a high quality are much easier to produce and thus allow the plasma waves in this regime to have a high-quality transverse profile. An adjusted a0 model is presented to unravel the underlying laser-plasma dynamics while predicting the experiments more accurately. The injection events in this regime correspond to the formation of an optical shock. Its unbalanced radial and longitudinal ponderomotive force results in an elongated bubble that injects electrons with ultra-low emittance and high charge. Since laser slicing and bubble elongation are only activated over a small density range, the mismatched regime is useful only over a small density range. The triggering of optical shock also results in plasma fields as high as a TV/m, enabling multi-GeV electron beams in less than a centimetre.



A laser-driven plasma wakefield with an elongating bubble structure in the strongly mismatched regime driven in response to the unbalanced ponderomotive forces of the laser pulse driving it. The laser pulse enters an optical shock state triggered by its slicing due to the radial envelope oscillations changing the wake structure interacting with the head of the pulse. As the longitudinal ponderomotive force in the optical shock state is much higher than the radial force an asymmetry is induced in the electron trajectories, this results in the injection of an electron bunch with ultra-low emittance and high charge in the back of the bubble. This bunch gets accelerated to nearly 2.25GeV.

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Use of Raman Forward Scatter for seeding a Plasma Amplifier

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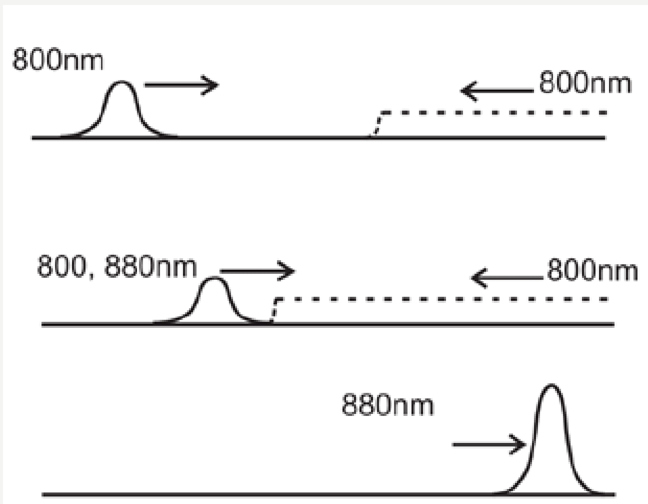
Raman plasma amplifiers offer a promising new route to compress laser pulses to frontier powers, possibly into the UV range. Progress has been hampered by the requirement for a short, powerful seed pulse with a wavelength approximately 10% longer than the counter-propagating pump pulse. Here we investigate the generation of an effective seed pulse using Raman forward scatter in a pre-amplifier stage. The subsequent light was well characterised and had many desirable properties for a seed, once the remaining fundamental light has been spectrally filtered out. Furthermore, this technique allows a single laser system to generate both pulses. The feasibility is also assessed using a particle-in-cell simulation.



Schematic of the backwards Raman amplifier scheme, with seeding from forward scatter of a short pulse in an under-dense plasma.

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