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Progress towards high-repetition-rate GeV-scale plasma-modulated plasma accelerators

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We describe recent results from our programme to develop high-repetition-rate, GeV-scale plasma-modulated plasma accelerators (P-MoPAs).
This programme seeks to take advantage of advanced thin-disk lasers (TDLs) that can deliver joule-scale pulses, at kHz repetition rates, but with a pulse duration that is too long ($\sim 1\,\mathrm{ps}$) to drive a wakefield directly at the densities of interest. The P-MoPA concept circumvents this by modulating a single TDL pulse to form a train of short pulses that can resonantly excite a plasma wave.
A P-MoPA has three stages: (i) a modulator, in which a TDL pulse is guided in a hydrodynamic optical-field-ionized (HOFI) plasma channel and is spectrally modulated by the wake driven by a short, low-energy pulse; (ii) a compressor, which converts the spectrally-modulated drive pulse to a train of short pulses; and (iii) a resonantly-driven accelerator stage, also based on a HOFI channel.
We will present the results of simulations that establish the operating regime of P-MoPAs and demonstrate acceleration to $\sim 2.5\,\mathrm{GeV}$ with a $5\,\mathrm{J}$ drive pulse. This analysis shows that a P-MoPA can drive larger amplitude wakefields than a plasma beat-wave accelerator with the same total laser energy.
We also present the results of experiments that demonstrate resonant wakefield excitation by a train of ~ 10 pulses, of total energy $\sim 1\,\mathrm{J}$, in a $110\,\mathrm{mm}$ long HOFI channel. Measurements of the spectral shift of the pulse train suggest a wake amplitude in the range 3–$10\,\mathrm{GV\,m^{-1}}$, corresponding to an accelerator stage energy gain of order $1\,\mathrm{GeV}$.

Working group

WG1 : Laser-driven plasma wakefield acceleration

Primary author: HOOKER, Simon (University of Oxford)

Co-authors: Dr ROSS, Aimee (University of Oxford); PICKSLEY, Alex (Lawrence Berkeley National Lab); Mr MUENZER, Andreas (Ludwig-Maximilians-University); Mr CHAN, Darren (University of Oxford); Dr EMERSON, David (STFC Daresbury Laboratory); Mr MCMAHON, David (University of Oxford); Dr ARCHER, Emily (University of Oxford); Dr JONES, Harry (DESY); Dr CHAPPELL, James (University of Oxford); Mr COWLEY, James (University of Oxford); Mr VAN DE WETERING, Johannes (University of Oxford); CORNER, Laura (Cockcroft Institute, University of Liverpool); Dr REID, Lewis (University of Liverpool); Dr FEDER, Linus (University of Oxford); Dr KRÜGER, Mathias (Ludwig-Maximilians-University); BOURGEOIS, Nicolas (Central Laser Facility, STFC); Mr JAKOBSSON, Oscar (University of Oxford); Prof. WALCZAK, Roman (University of Oxford); Mr KALOS, Sebastian (University of Oxford); KARSCH, Stefan (Ludwig-Maximilians-Universität München, Munich, Germany); Mr WANG, Wei-Ting (University of Oxford); Dr GU, X. J. (STFC Daresbury Laboratory)

Presenter: HOOKER, Simon (University of Oxford)

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