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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), which seeks to take advantage of advanced thin-disk lasers (TDLs) that can deliver joule-scale, picosecond-duration pulses, at kHz repetition rates.

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.

We present simulations that establish the operating regime of P-MoPAs and demonstrate acceleration to $\sim 2.5\,\mathrm{GeV}$ with a 5 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 ~ 1 J, in a 110 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 $1\,\mathrm{GeV}$.

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