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Optimisation strategies for proton acceleration from thin foils with petawatt ultrashort pulse lasers

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Laser-driven plasma accelerators can produce pulsed multi-MeV ion beams with high peak currents by irradiating solid materials with ultra-intense laser pulses. This innovative concept attracts much attention for various multidisciplinary applications as a compact and energy-efficient alternative to conventional accelerators. The maturation of plasma accelerators from complex physics experiments to turnkey particle sources for practical applications requires breakthroughs in the generated beam parameters, their robustness and scalability.

In this work, new benchmarks for accelerator performance and understanding of the underlying interaction physics were achieved through combining innovative laser diagnostics, advanced measurement techniques and hybrid simulation approaches. This enabled precise tuning of interaction conditions for optimized performance in established acceleration regimes and facilitated the exploration of relativistically transparent targets. The results from this advanced regime far exceeded previous records, demonstrating the immense potential of this technology. The strategies outlined provide a roadmap for advancing and integrating plasma accelerators into scientific, industrial, and medical fields.

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