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Experimental demonstration of Hydrodynamic Optical-Field-Ionized plasma channels at kHz repetition rate

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Many potential applications of plasma accelerators - such as light sources and future particle colliders - require the stable generation of multi-GeV electron bunches at high (>kHz) repetition rate. A consequent goal for current research into laser-driven plasma accelerators involves the development of waveguides capable of operating at densities of ~10¹⁷ cm⁻³, over lengths of several centimetres or more, guiding laser pulses at kHz repetition rate. Whilst guiding structures such as capillaries are not well suited to this repetition rate due to laser damage and heating, plasma waveguides formed from hydrodynamic optical-field-ionized (HOFI) channels can potentially meet the requirements. Guiding of high intensity laser pulses in HOFI channels has been demonstrated previously at on-axis densities of $1 \times$ 10¹⁷ cm⁻³ over lengths of >10 cm, whilst in this work we demonstrate experimentally that HOFI channels can be generated at kHz-scale repetition rates for an extended period of time. Using a pump-probe arrangement, we show via transverse interferometry that the properties of two HOFI channels generated 1 ms apart are essentially the same, and that HOFI channels can be generated at a mean repetition rate of 0.4 kHz for a period of 6.5 hours without degradation of the channel properties. The results suggest that HOFI channels are ideal for future high-repetition rate, multi-GeV laser-plasma accelerator stages.

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