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GeV electron bunches in low-density plasma channels by all-optical density transition injection

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Hydrodynamic [1,2] and conditioned hydrodynamic [3,4] optical-field-ionised plasma channels are promising candidates to support low-density, high repetition-rate multi-GeV laser wakefield accelerator (LWFA) stages. They are generated by focusing an ultrashort pulse into neutral gas, forming a hot column of plasma via optical field ionization, which expands hydrodynamically to form a plasma channel. Because they are freestanding, they can be operated at high repetition-rate [5]. An advantage of optically generated channels is the potential to sculpt the plasma density along the LWFA stage, for example to promote injection. Here we explore the use of a density down-ramp generated between neutral gas immediately prior to the channel and the channel itself to trap electrons. We present results of a recent experiment at the Gemini TA3 laser (RAL) in which ~ 1 GeV bunches, with percent-level energy spread, were generated by sub-100 TW laser pulses. The effect of the longitudinal and transverse position of the drive pulse focus on the generated electron bunches was investigated. These results, and particle-in-cell simulations, demonstrate that the channel entrance down-ramp is responsible for electron injection.

[1] Shalloo, RJ, et al, (2018). PRE, 97(5)
[2] Shalloo, RJ, et al, (2019). PRAB, 22(4)
[3] Picksley, A, et al, (2020). PRE, 102(5)
[4] Feder, L, et al, (2020). PRR, 2(4)
[5] Alejo, A, et al, (2022), PRAB, 25(1)

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