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High-energy electron beams in optically-formed plasma channels

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Future applications of laser-plasma accelerators will require one or more stages providing multi-GeV energy gain. Preformed plasma channels can increase the maximum energy gain of a laser-plasma accelerator. Recently, hydrodynamic optical-field-ionized (HOFI) plasma channels [1-3] have gained attention because i) they produce tightly confined channels at densities required for multi-GeV acceleration, and ii) contain no external structure making them ideal for >kHz operation. In the first half of the talk, we discuss high-quality beam production in HOFI plasma channels. 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 demonstrate generation of 1.2 GeV bunches with percent-level energy spread, using sub-100 TW laser pulses [4]. In the second half of the talk, we discuss experiments to guide PW-scale pulses in 30-cm-long HOFI plasma channels. Understanding how the laser pulse evolves in the spatial and temporal domain during propagation is critical for high energy gain, and maintaining high bunch quality during acceleration. We present experimental results investigating drive laser propagation in HOFI plasma channels at the BELLA PW laser. We demonstrate conditions under which the channel can be tailored to match the drive laser focus at plasma densities suitable for multi-GeV accelerators, and present example electron beams from those experiments.

[1] R. Shalloo et al., Phys. Rev. E (2018)
[2] A. Picksley et al., Phys. Rev. E (2020)
[3] L. Feder et al., Phys. Rev. Research (2020)
[4] A. Picksley et al., Phys. Rev. Lett. (2023)

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