2014

OPTICAL CONTROL OF ELECTRON TRAPPING AND ACCELERATION IN PLASMA CHANNELS: APPLICATION TO TUNABLE, PULSED SOURCES OF MULTI-COLOR THOMSON GAMMA-RAYS

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Plasma Sciences (ICOPS) held with 2014 IEEE International Conference on High-Power Particle Beams (BEAMS), 2014 IEEE 41st International Conference on
Year: 2014
Pages: 1 - 1, DOI: 10.1109/PLASMA.2014.7012362

OPTICAL CONTROL OF ELECTRON TRAPPING AND ACCELERATION IN PLASMA CHANNELS: APPLICATION TO TUNABLE, PULSED SOURCES OF MULTI-COLOR THOMSON GAMMA-RAYS*

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Reducing the size of a GeV-scale laser-plasma accelerator to a few millimeters requires maintaining an accelerating gradient as high as 10 GV/cm. This, in turn, dictates acceleration in the blowout regime in high-density plasmas ($n_0 \sim 10^{19}$ cm^{-3}). With current high-power laser technology, these highly dispersive plasmas are poorly suited as accelerating media. They transform the driving pulse into a relativistic optical shock long before electron dephasing, causing the plasma wake bucket (electron density bubble) to constantly expand and trap background electrons, degrading the beam quality [1, 2]. We show that this can be overcome using a high-bandwidth driver, with up to 400 nm initial bandwidth [2-4]. Introducing a large negative chirp (to compensate for the nonlinear frequency red-shift) and propagating the pulse in a plasma channel (to suppress diffraction of its leading edge) delays pulse self-steepening through electron dephasing and extends the dephasing length. As a result, continuous injection is suppressed, and electron energy is boosted to a GeV level [2, 4]. In addition, periodic self-injection in the channel may produce a sequence of background-free, quasi-monoenergetic bunches with a femtosecond-duration, controllable time delay and energy difference. The number of spectral components, their charge, energy, and energy separation can be controlled by varying the channel radius and length, whereas accumulation of the noise (viz. continuously injected charge) is prevented by the proper dispersion control of the driver via the negative chirp [4]. This level of control is hard to achieve with conventional accelerator techniques. Using the newly-developed relativistic 3D nonlinear Thomson scattering code [5], it is demonstrated that these clean, polychromatic beams can drive high-brightness, tunable, multi-color γ-ray sources.

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* This work supported by the U.S. DOE Grant DE-SC0008382, NSF Grant PHY-1104683, and DOD AFOSR Grant FA9550-11-1-0157.