

## **Multi-scale theory and simulations for Texas Petawatt experiments on laser wakefield acceleration**

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The Texas Petawatt (TPW), the only operating petawatt laser in the United States, offers the ability to demonstrate laser wake field acceleration (LWFA) in a unique regime with pulse duration ( $\sim 150$  fs) shorter than other petawatt-scale systems currently in operation or under development. By focusing the 1.25 PW, 200 J, 150 fs pulses to peak intensity  $\sim 10^{19}$  W/cm<sup>2</sup>, multi-GeV electron bunches can be produced from a few centimeter long low-density He gas cell.

Guiding properties of the plasma wave together with the nonlinear effects of relativistic self-focusing, phase self-modulation and subsequent temporal selfcompression enable the PW laser pulse to self-guide without the use of a preformed plasma channel [1]. These properties, as well as the beam stability against relativistic filamentation, are studied in fine detail by means of reduced 3D particle-in-cell (PIC) simulations using the code WAKE [3]. WAKE is the time averaged (over laser period) PIC code describing the plasma response in the quasi-static approximation, and the laser beam dynamics in the extended paraxial approximation. These assumptions speed up the simulations by a factor of  $>100$  against conventional 2D PIC codes and thus allow for a quick optimization study. Details of the electron injection process are captured by the PIC simulations using the fully relativistic 3D code Virtual Laser Plasma Lab (VLPL) [3]. Various injection schemes are numerically optimized for the conditions of planned TPW-LWFA experiment. Quasi-monoenergetic acceleration up to 3-5 GeV electron energy is predicted.

[1] W. Lu *et al.*, “Generating multi-GeV electron bunches using single stage laser wakefield acceleration in a 3D nonlinear regime,” *Phys. Rev. ST Accel. Beams* **10**, 061301 (2007).

[2] P. Mora and T. M. Antonsen, Jr., “Kinetic modeling of intense short laser pulses propagating in tenuous plasmas,” *Phys. Plasmas* **4**, 217-229 (1997).

[3] A. Pukhov, “Three-dimensional electromagnetic relativistic particle-in-cell code VLPL (Virtual Laser Plasma Lab),” *J. Plasma Physics* **61**, 425 (1999).