Generating and Measuring High Quality Electron Beams in Plasma-based Accelerators

Fei Li[1], Xinlu Xu[2]*, Chaojie Zhang[2], Yang Wan[1], Yipeng Wu[1], Jianfei Hua[1], Chih-Hao Pai[1], Wei Lu[1,]*, Warren B. Mori[2] and Chan Joshi[2]

[1]Department of Engineering Physics, Tsinghua University, Beijing 100084, China
[2]University of California, Los Angeles, Los Angeles 90095, United States
**weilu@tsinghua.edu.cn*

The plasma-based accelerators (PBA) have experienced tremendous progress in the last decade, which is promising to revolutionize the applications of laser and accelerator technologies. One of the key challenges for PBA is how to controllably generate the high quality electron beams largely exceeding those the state-of-art accelerator techniques can achieve. By understanding the general rules of the injection in PBA, two novel schemes based on the ionization injection and the plasma density modulation injection are proposed and deeply studied. PIC simulations show the schemes can generate high quality electron beams with low slice energy spread (~10 keV to ~1 MeV), ultralow emittance (nm to tens of nm level), high current (~kA to ~20 kA level) and ultrahigh brightness (10^{19} to 10^{22} A m^{-2} rad^{-2}) which is 3 to 6 orders of magnitude higher than the current techniques. Once verified experimentally, it will produce important influence on the development of the future light source and the linear collider technologies. In order to precisely and efficiently simulate the beam dynamics during the injection, a novel PIC algorithm with high parallelization and low noise is proposed and implemented.

The issue of measuring ultralow emittance is deeply discussed. Focusing on the high-gradient permanent magnetic quadrupole (HGPMQ) method, the error and reliability analyses are systematically carried out, confirming its potential for measuring ultralow emittance (<0.1 mm mrad). Experimental system with 50 nm emittance resolution is designed and manufactured, and the measurement of mm mrad level emittance is preliminarily realized, which lays the foundation for the future experiments.