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Generating VHEE Beams from a Laser-Plasma Accelerator and Characterizing their Stability for Medical Applications

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Laser-driven Plasma Accelerators (LPAs) have emerged as compact (sub-)picosecond sources of Very High Energy Electron (VHEE, energy ≥ 50 MeV) beams. VHEE beams are of great interest to the medical physics community for their applications in radiotherapy in the Ultra-High Dose-Rate (UHDR) domain. Our experiments focus on optimizing VHEE beam stability and reproducibility from an LPA.

Using different gas mixtures with varying N_2 concentrations (1%, 2%, and 5% N_2 in He), experimental results show stable electron beams consistently peaking around 50 MeV, with high charge-per-shot (~450 pC/shot) and minimal charge fluctuations (≤10%). Such beam stability and consistent peak energy directly contribute to improved dose accuracy and reliability, essential for clinical radiotherapy applications. Real-time diagnostics, including online spectrometry, beam profiling, and charge measurements, were developed and enabled precise control & monitoring, significantly advancing our capability to optimize beam parameters.

Plasma density profiles and laser focus measurements provided necessary inputs for complementary Particle-in-Cell (PIC) simulations to investigate the underlying physical mechanisms. These advancements establish a solid foundation for active-feedback stabilization strategies and higher repetition-rate operations, essential steps toward practical medical applications. Moving forward, integrating these beam stability improvements into clinical setups and exploring robust feedback control methods remain exciting challenges.

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