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Optimization of Electron Injection and Stable Long-Term Operation of a kHz Laser-Plasma Accelerator

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High-repetition rate laser-plasma accelerators (LPA) have great potential for applications in femtosecond irradiation, X-ray generation and electron diffraction. As relativistic laser intensities are now available at kilohertz, important progress has been achieved in high-repetition rate LPA in the past few years [1] Here, we will review recent experimental results and developments on a kHz LPA. Our laser system is equipped with a post-compression stage which gives us a unique opportunity to tune the spectral bandwidth, thereby generating chirp-free laser pulses ranging from 3.5-fs to 25-fs. This allowed us to study the effect of the number of optical cycles in the acceleration process. In the few cycle regime, we observe a transition from resonant to self-modulated laser wakefield acceleration when the number of cycles N is increased from N=1 to N=3. We observe that the best beam quality is obtained for near single-cycle laser pulses in the resonant regime. In order to further optimize our laser-plasma accelerator, several injection mechanisms were studied as well as their impact on the performance and stability of the accelerator. Density gradient injection was found to yield the most stable electron beams and we demonstrated stable continuous operation for a period of 5 hours [2]. Electron bunches with 2.6 pC charge and 2.5 MeV peak energy were generated via injection and trapping in a downward plasma density ramp. This density transition was produced in a specially designed asymmetric shocked gas jet. The reproducibility of the electron source was also assessed over a period of a week and found to be satisfactory with similar values of the beam charge and energy. Particle in cell simulations confirm the role of the shock and the density transition in the electron injection mechanism. References: [1] D. Guenot et al., Nat. Photonics **11**, 293 (2017). F. Salehi et al., Opt. Lett. **42**, 2015 (2017) [2] L. Rovige et al., ArXiV :2005.06929 (2020)