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Title:Experimental validation of a radio frequency photogun as external electron injector for a laser wakefield accelerator

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Abstract: A purpose-built RF-photogun as external electron injector for a laser wakefield accelerator has been thoroughly tested. Different properties of the RF-photogun have been measured such as energy, energy spread and transverse emittance. The focus of this study is the investigation of the smallest possible focus spot and focus stability at the entrance of the plasma channel. For an electron bunch with 10 pC charge and 3.7 MeV kinetic energy, the energy spread was 0.5% with a shot-to-shot stability of 0.05%. After focusing the bunch by a pulsed solenoid lens at 140 mm from the middle of the lens, the focal spot was 40 μm with a shot-to-shot stability of 5 μm. Higher charge leads to higher energy spread and to a larger spot size, due to space charge effects. All properties were found to be close to design values. Given the limited energy of 3.7 MeV, the properties are sufficient for this gun to serve as injector for one particular version of laser wakefield acceleration, i.e., injection ahead of the laser pulse. These measured electron bunch properties were then used as input parameters for simulations of electron bunch injection in a laser wakefield accelerator. The arrival time jitter was deduced from measurements of the energy fluctuation, in combination with earlier measurements using THz coherent transition radiation, and is around 150 fs in the present setup. The bunch length in the focus, simulated using particle tracking, depends on the accelerated charge and goes from 100 fs at 0.1 pC to 1 ps at 50 pC. When simulating the injection of the 3.7 MeV electron bunch of 10 pC in front of a 25 TW laser pulse with a waist of 30 μm in a plasma with a density of 0.7 × 1024 m−3, the maximum accelerated charge was found to be 1.2 pC with a kinetic energy of ~900 MeV and an energy spread of ~5%. The experiments combined with the simulations show the feasibility of external injection and give a prediction of the output parameters that can be expected from a laser wakefield accelerator with external injection of electrons.