Laser driven electron acceleration with high repetition rate lasers: from plasma physics to condensed matter applications

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Laser wakefield acceleration is an emerging technique for accelerating electron bunches to relativistic energies in very short distances using ultra-intense laser pulses. It relies on the excitation of an intense plasma wave, or wakefield, that is able to trap and accelerate electrons in a single arch of the wakefield, thereby generating femtosecond relativistic electron bunches. Because of their extremely short duration and natural synchronization with the laser pulse, these electron bunches are of great interest for probing matter on femtosecond time scales via pump-probe experiments, possibly offering unprecedented temporal resolutions for studies in structural dynamics in condensed matter [1]. Such applications require high stability, massive data averaging and would therefore benefit greatly from a high repetition rate electron source.

In this context, our group has started the further miniaturization of laser-plasma accelerators by using small-scale and high-repetition rate lasers. In this talk, we will review the recent development of these kilohertz laser-plasma source [2]. In initial experiments, electrons reached 100 keV energy. The enhanced stability and high repetition rate allowed us to perform ultrafast electron diffraction experiments in which the dynamics of a Silicon lattice could be revealed on the picosecond time scale [3]. In more recent experiments, we have used laser pulses composed of a single optical cycle (3.5-fs duration) in order to drive the plasma wakefield resonantly. This led to an increase of the energy and the charge by two orders of magnitude, and the electron beams now reach 5 MeV energy with >10 pC charge [4]. We will discuss the physics of the laser plasma interaction, the potential of this new source for applications as well as future foreseen developments.

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