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Accélération de particules et instabilités dans les plasmas

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This talk will present an overview of the latest results and on-going projects at the Laboratoire d'Optique Appliquée (LOA) in the field of particle beam-plasma interaction. Two main aspects of the beam-plasma interaction will be covered: beam-driven plasma wakefield acceleration and beam-plasma instabilities.

The beam-driven plasma wakefield acceleration (PWFA) has proven to be an efficient process to transfer the energy from a "drive"particle beam to a second "witness"particle beam, making this acceleration technique a promising candidate for future particle colliders. Yet, one of the next major experimental milestones of the field is the preservation of the quality of the accelerated beam, and in particular its transverse emittance. To assess potential emittance growth in a PWFA stage, we have proposed a new diagnostic based on betatron radiation [P. San Miguel *et al.*, PTRSA 377, 20180173 (2019)], which has been installed and commissioned in the upgraded accelerator facility FACET-II at SLAC. Another important challenge in the field of PWFA is the acceleration of positrons for which there is not yet clear optimal acceleration scheme, while it is crucial for an application of plasma acceleration to particle colliders. We have shown, via theory and simulations, that there exists a trade-off between the accelerated beam charge, energy efficiency and beam quality [C. Hue *et al.*, PRR 3, 043063 (2021)] for positrons, in contrast to electron acceleration that can achieve simultaneously high efficiency and quality. Furthermore, a novel area of research has been explored in our group, the so-called hybrid wakefield acceleration. In this scheme, an electron beam produced in a laser-driven plasma accelerator is used to drive a beam-driven wakefield accelerator in a second stage. Recent experimental results, e.g. the direct optical visualisation of beam-driven plasma waves and ion motion [M.F. Gilljohann *et al.*, PRX 9, 011046 (2019)], and the injection and acceleration of "witness"electron beams in the PWFA stage [T. Kurz *et al.*, Nat. Comm. 12, 2895 (2021), J. P. Couperus Cabadag *et al.*, PRR 3, L042005 (2021)] with improved stability and quality, will be presented. They open the way towards a new generation of high-brightness ultralow-emittance electron sources, with a quality exceeding significantly the current state-of-the-art.

In the second part of this talk, I will report on recent developments in the field of beam- plasma instabilities, which play an important role in several astrophysical environments. We have studied these instabilities in two different experimental scenarios. On the one hand, we have used the laser system of the Salle Jaune at LOA to excite the instabilities by focusing the high intensity, ~ 30 fs laser pulse onto a thin solid target, probing the unstable fields via electron radiography [G. Raj *et al.*, PRR 2, 023123 (2020)]. On the other hand, we are planning to use the high-peak-current 10 GeV electron beams produced at FACET-II to explore the ultra-relativistic regime of these instabilities. For the latter, we have developed a novel spatiotemporal theory to account for the finite spatial extent of the electron beam [P. San Miguel Claveria *et al.*, accepted in PRR]. This spatiotemporal model predicts, in good agreement with PIC simulations, an important slow-down of the instability compared to the purely temporal evolution of the unbounded system. Furthermore, the interplay between the self-focusing dynamics of a finite electron beam and the instability is analysed.

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