DPP17-2017-001141

Abstract for an Invited Paper
for the DPP17 Meeting of
the American Physical Society

Particle acceleration and exotic light emission in structured plasma wakefields[1]

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Twisted Laguerre Gaussian lasers, with orbital angular momentum (OAM), are characterised by twisted wavefronts and doughnut intensity profiles. These lasers provide a transformative set of research directions in a growing range of fields, particularly at intensities below damage thresholds. Here, we explore how the interaction between ultra-intense twisted light and matter could enhance plasma accelerators and light sources. We support our findings with theory and massively parallel three-dimensional particle-in-cell Osiris simulations [R.A. Fonseca et al, PPCF, 55 124011 (2013)]. Providing a solution to a long-lasting challenge in plasma acceleration, we show that twisted light can excite a nonlinear doughnut blowout suitable for electron and positron focusing and acceleration [J. Vieira et al PRL 112 215001 (2014)]. This is a new type of wakefield that contrasts with the nonlinear spherical blowout, characterised by positron defocusing forces. Despite being driven by an OAM laser, doughnut plasma waves contain no OAM. This picture changes dramatically, when the laser driver contain multiple OAM levels characterised by distinct frequencies. The corresponding beating pattern results in a spiralling laser intensity profile, known as a light spring [G. Pariente et al Optics Lett. 40, 2037 (2015)], which can excite a twisted plasma wave with OAM. The twisted wakefields accelerate particles both longitudinally and azimuthally. This feature can be exploited towards the generation of relativistic bunches with similar longitudinal and transverse momenta, which changes radiation emission processes. Structured lasers have been produced in the laboratory, using conventional spiral phase plates and plasma based holograms [A. Denoeud et al PRL 118 033902 (2017)]. Here, we demonstrate how to create and amplify ultra-intense OAM lasers in the plasma, through stimulated Raman backscattering [J. Vieira et al Nat. Comms. 7 10371 (2016); J. Vieira et al. PRL 117, 265001 (2016)].

[1]Work supported by FCT (Portugal) Grant No. SFRH/IF/01635/2015