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Twisted Waves in Plasmas: Topology and Applications

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The topic of twisted waves in plasmas received considerable attention in recent years. It is mainly related with the potential use of twisted laser pulses to accelerate particle beams (electrons and positrons) in laser-plasma interaction experiments [1, 2]. Other relevant aspects are those of stimulated Raman and Brillouin scattering, high-harmonic generation and radiation processes [3].

Our presentation will focus on the topology of waves in plasmas, and applications of laser beams with orbital angular momentum (OAM) and on the corresponding plasma wakefields. They are usually described by a superposition of Laguerre-Gauss (LG) modes.

We discuss the field configurations of single and multiple LG modes, for both photons and plasmons, as well as spin-orbit coupling. These configurations include donut wakes, light springs, and self-torque pulses. They allow to generalize the well-known concepts of wakefield and beat-wave acceleration.

Possible applications to real experiments will be exemplified with numerical simulations [4]. Different types of electron plasma waves produced by laser beams with one of more LG modes with the same or different frequencies, are shown in Figure 1. They correspond to (A) donut waves, that generalize the laser wakefield concept of Gaussian beams, (B) self-torque wakes, produced by the superposition of two laser LG modes with the same frequency, and (C) light-spring wakes, produced by the superposition of two laser LG modes with different frequencies. It should be noticed that, in this last case, when the frequency difference is nearly equal to the electron plasma frequency, this configuration generalizes the well-known beat-wave acceleration scheme.

Of particular interest is the behaviour of light springs near a plasma cutoff, where they act as a mechanical spring, which contracts and expands upon reflection [5].

Another interesting aspect of twisted wave configurations is related with the quantum electron states, usually called Volkov states, that can be defined [6]. Compton scattering of both twisted electrostatic and electromagnetic waves will then be established in the nonlinear regime [7].

References

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Figure 1 - Examples of laser wakefields.