RELATIVISTIC BRIGHT SOLITON FORMATION IN LASER MAGNETIZED PLASMA INTERACTIONS

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Intense laser plasma interactions have always been a hot research area in high energy density physics, compact laser accelerator, new radiation sources, and especially in laser fusion. Recently, the progress in generating kilo-tesla magnetic field makes it possible to study the nonlinear dynamics in strong magnetized plasma, such as relativistic electron transport, nonlinear wave propagation and ion acceleration. Among these nonlinear dynamics, one important topic is the soliton formation. In laser plasma interactions, solitons are finite size, self-trapped electromagnetic waves. They are usually generated in the wake of laser pulse with strong plasma depletion. Inside the solitons, the nonlinearities are balanced by the dispersion effects due to the finite electron inertia. Solitons are observed in experiments by a proton imaging technique as well as in particle-in-cell simulations, where people find up to 40% of the laser energy can convert into soliton or soliton-like structures[1], thus solitons plays an important role in laser plasma interactions. While most of the existing investigation of solitons are on unmagnetized plasma, it is natural to incorporate the magnetic effects.

Here, we present the particle-in-cell simulation and analytic results of relativistic bright soliton generation in strong magnetized plasma. The nonlinear wave propagation and heating with different magnetic field and laser intensities are investigated. Generally speaking, the plasma absorption rate increases with magnetic field as long as the electron cyclotron mode is not excited. However, solitons can be generated under some suitable conditions and they help to increase the absorption rate a lot.

The Maxwell-fluid model[2] is adopted to describe the soliton and density envelop, where two second-ordinary differential equations for vector potential A and scale potential φ coupled by the nonlinear terms due to the density perturbation and relativistic effects are obtained. Mathematically, solving this set of equation systems is equal to find the homoclinic or heteroclinic orbits of a four-dimensional reversible autonomous Hamiltonian system[3]. We succeed to find the Hamiltonian of this system and each of the equilibrium points is identified. The parametric dependence of the existence of solitons on magnetic field amplitude is obtained and we find the lower limit of soliton frequency decreases compared to Farina's results[4], when ion motion is taken into consideration. The soliton can reach rather low frequency, when external magnetic field is negative. The finite temperature effects on soliton amplitude are also discussed.

References.
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