Ponderomotive Recoil for Electromagnetic Waves

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When waves damp or amplify on resonant particles in a plasma, the resonant particles absorb momentum and energy from the interaction. At the same time, the nonresonant particles must experience a recoil force that conserves the total momentum between the particles and electromagnetic fields. This recoil is important to understand, as it can completely negate current drive [1, 2] and rotation drive [3] mechanisms, such as those due to alpha channeling, that are predicted on the basis of only the resonant particles. Here, the existing electrostatic theory [4, 5, 6] of this recoil force is extended to electromagnetic waves [7]. While the result bears close similarity to historical fluid theories of laser-plasma interactions, it now incorporates both resonant and nonresonant particles, allowing momentum conservation to be self-consistently proven. Furthermore, the result is shown to be generally valid for kinetic plasmas, which is verified through single-particle hot-plasma simulations. The new form of the force provides physical insight into the nature of the generalized Minkowski (plasmon) momentum of geometrical optics [8], which is shown to correspond to the momentum gained by the field and nonresonant particles as the wave is self-consistently ramped up from vanishing amplitude. This work was supported by Grant Nos. DOE DE-SC0016072 and and DOE DE-FG02–97ER25308.

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