A Study of Radiation Reaction Effects in Superintense Laser-Plasma Interaction

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Abstract: Radiation Reaction is expected to play an important role in superintense laser-plasma interaction where it can both enhance the bulk plasma motion and cool the electrons. In the present work we investigate the Radiation Reaction effects in the Radiation Pressure Acceleration regime by particle-in-cell simulations both for linear and circular polarization. In particular we check the Radiation Reaction ability to reduce the electron heating which is responsible of the broadening of both the electron and ion spectrum.

1. Introduction

At the extremely high laser intensities expected in next-generation experiments, electrons can become ultrarelativistic within a fraction of wave period experiencing superstrong accelerations. At these intensities radiation reaction (RR) effects become more and more important as RR can be the dominant force acting on electrons [1]. It may be then necessary to include RR effects to describe the foreseen laser-plasma interaction regimes at such extreme intensities. One prominent example is Radiation Pressure Acceleration (RPA) in the “radiation-dominated” or “Laser Piston” (LP) regime [2] where relativistic ion energies may be obtained. In fact, early particle-in-cell (PIC) simulations [3] showed that RR effects can become important even at laser intensities of $5\text{x}10^{22}$ W/cm^2 and increase quadratically with the intensity I. First theoretical studies [4] suggested that the RR force cools the plasma and enhances the bulk plasma motion as found in recent PIC simulations which showed that RR plays an important role in RPA both in the “Hole Boring” (HB) [5,6] and “Light Sail” [7] regimes. In the present contribution we present our first PIC simulations and a preliminary study of the RR effects in the RPA regime both for linear and circular polarizations and for different plasma thickness and densities.

2. The Radiation Reaction force

The RR basically describes the back-action on a particle by its self-generated electromagnetic fields. The RR force is mostly a friction force and its inclusion in the dynamics of a plasma may account for radiative losses due to incoherent radiation of frequency higher than the plasma frequency. Our approach is based on the Landau-Lifshitz (LL) equation of motion [1] for electrons which is free from known problems of other approaches such as, e.g., runaway solutions. The exact solution for the motion of an electron in a plane wave [8] has been used as a benchmark and reference case. The numerical algorithm and consistent approximations to the LL force will be described. Our approach has been tested for a range of intensities from $5\text{x}10^{22}$ W/cm^2 up to 10^{24} W/cm^2 with good agreement between analytical and numerical predictions.

3. Radiation Reaction effects on Radiation Pressure Acceleration

We analyze RR effects in RPA of both thick and thin targets comparing with [5, 7]. Our preliminary results for circularly polarized (CP) pulses show that in thin targets RR effects are small unless the pulse is intense enough to be transmitted through the foil, i.e. in conditions that are not optimal for ion acceleration. A comparison with the case of linearly polarized pulses is also made.

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