Propagation of Hard Photons in Plasmas: from the Formation of Wakes to Fireballs

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The description of plasmas as a dielectric media breaks down at scales where the notion of averaged fields loses its meaning – this scale being typically the inter-particle distance. Photons with a wavelength smaller than the plasma inter-particle distance are not dressed and only interact with the electrons of the plasma through incoherent quantum processes such as Compton scattering. A photon burst/beam can exert a Compton force on the electron/positron of plasma and then trigger the collective plasma phenomenon. We investigate analytically in this work the effect of the propagation of a photon beam in a plasma. The analytical findings are in very good agreement with the simulations performed with the particle-in-cell code OSIRIS coupled to a Compton scattering module [1].

A short burst and low frequency (less than the electron mass) can lead to plasma wakes [2]. For low photon energy densities, the amplitude of the wakes remains linear, and one observes the generation of Langmuir and extraordinary modes. For extreme photon energy densities, the amplitude of the wake becomes non-linear and becomes analogous to the blowout of the regime observed with intense lasers. We have also studied the typical mechanisms that eventually limit electron acceleration in these wakes, such as phase velocity of the wake, dephasing, driver collimation, and driver depletion. We then focus on the self-consistent interaction of an intense gamma-ray source with a background pair plasma. We prove that an intense flash of gamma rays travelling in a pair of plasma can create a fireball [3]. The latter is self-sustained by the incident gamma-rays and continuously filaments, self-consistently generating a small-scale B field over the depletion length of the beam.

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References

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