Linear and Non-linear phases of an SF-QED cascade from exponential growth to the background field absorption

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In plasmas exposed to ultra-intense electromagnetic fields, radiation of high-energy photons and pair creation can significantly impact the background field. This is especially true in the context of the SF-QED cascades created by intense lasers, where the exponentially growing density will eventually reach a value so high that the background field amplitude may be partially or completely depleted inside the pair plasma [1-2].

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In this work, we study the linear and the non-linear phase of an SF-QED cascade in the special case of a purely rotating field. We show that it is possible to integrate the Boltzmann equation and extract perturbatively exact solutions for the growth rate and the steady-state distribution function. Inspired by the method used to solve the non-linear phase of plasma instabilities [3], we address the response of the pair plasma to the background field, where the effect of radiation is treated as a classical friction on the pairs.

Starting from Ampère's equation and the equations of motion of charges, we obtain a differential equation for the total electric field, which takes the form of a forced non-linear time-varying damped oscillator. This equation can be solved exactly under certain limits and provides the necessary conditions for significant screening of a high-intensity oscillating external field, which is consistent with previous numerical works [1, 2]. These results show that the proposed model is promising for the study of the QED plasma response in ultra-intense fields.

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