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Modeling of axion and electromagnetic fields interaction in particle-in-cell simulations

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Axion, a theoretically well-motivated particle, has been searched extensively worldwide via its hypothetical interaction with ordinary matter and fields. Recently, a new axion detection approach has been considered utilizing the ultra-intense electromagnetic (EM) fields produced by laser-plasma interactions. However, a detailed simulation tool is missing in current studies to understand the axion-coupled laser-plasma interactions in such a complex environment. In this paper, we report a custom-developed particle-in-cell (PIC) simulation to incorporate the axion field, the electromagnetic fields, and their interactions. The axion field equation and modified Maxwell's equations are numerically solved, where the axion-induced modulation to the electromagnetic field is treated as the first-order perturbations in order to handle the huge orders of magnitude difference between the two type fields. The simulation has been benchmarked with well-studied effects such as the axion-photon conversion and the propagation of an extremely weak laser pulse in a magnetized plasma. Such an extended PIC simulation provides a powerful tool to study axions under ultra-intense electromagnetic fields in the laboratory or astrophysical processes.

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