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Spin effects in strong laser fields and plasma wakefields

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A charged particle with non-zero spin interacts with the external field via the Lorentz equation and the Stern-Gerlach force, where the particle of different spin states can be deflected by the gradient of the magnetic field. For an ultra-relativistic electron in strong fields, when the field strength in its rest frame approaches the Schwinger limit, γ-photon emission and its dependence on the electron's spin state as well as the consequent spin-dependent radiation-reaction come into play and alter the electron dynamics. On the other hand, the spin vector evolves according to the Thomas-Bargmann-Michel-Telegdi (T-BMT) equation. The photon emission in strong fields can also lead to substantial radiative polarization. Here we will show how spin evolves in plasma wakefield in the classical regime and reveal the coupling effects between the spin-dependent radiation-reaction and radiative polarization in extreme laser fields. The work presented is aiming at producing polarized electron sources based on wakefield acceleration [1, 2] and developing a self-consistent theory of spin dynamics in the strong-field QED regime [3, 4].

In plasma wakefield acceleration, electron spins suffer from precession in the magnetic field associated with the injected beam. This can cause significant depolarization for accelerated electrons. Here we propose to two methods to generate high flux polarized electron beams: a) vortex laser-driven wakefield which preserve the spin orientations by lowering down the current density (see in Fig. 1) and b) a spin filter to enhance the polarization purity by filtering out the low polarization population (see in Fig. 2).

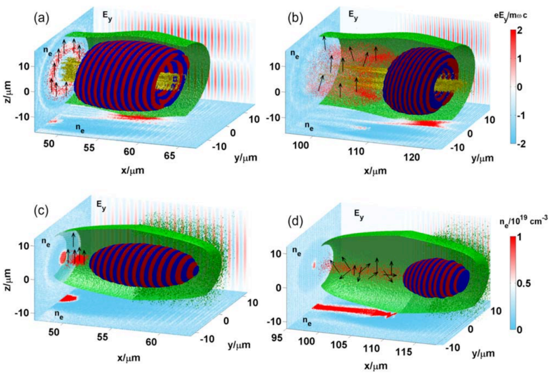

Figure 1. Spin orientations are well preserved in vortex-laser driven wakefield (a) and (b), but severely disturbed in ordinary gaussian laser-driven wakefield (c) and (d).

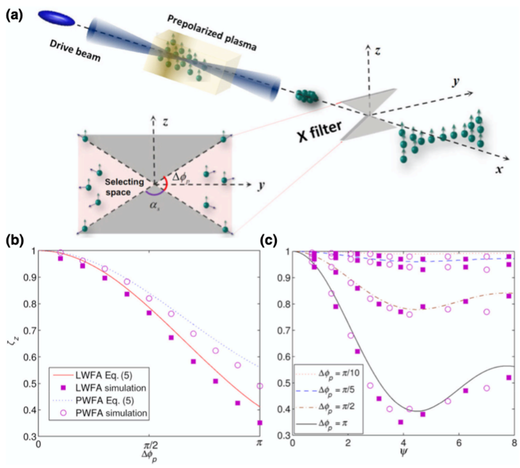

Figure 2. The proposed X-filter increases the electron polarization from 35% to >80% by filtering out the low polarization population.

Highly polarized electrons colliding with ultra-intense lasers provides an efficient approach to study the spin-dependent strong-field QED physics. We found that electrons of different spin states can be deflected when coupling the spin effect to the radiation-reaction force [3]. This is about 4 orders of magnitudes stronger than the well-known Stern-Gerlach force. In addition, a consistent numerical model is developed to fully account for the spin information along all directions. This is accomplished by considering the polarization rather than individual spins during photon emission.

References

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Note: Abstract should be in 1 page.