Spin Polarization Rotations of Electron and Photon Beams in Strong Fields

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An all-optical method of ultrafast spin rotation is put forward to precisely manipulate the polarization of relativistic charged particle beams of leptons or ions. In particular, laser-driven dense ultrashort beams are manipulated via single-shot interaction with a co-propagating moderate temporally asymmetric (frequency-chirped or subcycle THz) laser pulse. Using semi-classical numerical simulations, we find that in a temporally asymmetrical laser field, the spin rotation of a particle can be determined from the flexibly controllable phase retardation between its spin precession and momentum oscillation. Initial polarization of a proton beam can be rotated to any desired orientation (*e.g.*, from the common transverse to the more useful longitudinal polarization) with extraordinary precision (better than 1%) in tens of femtoseconds using a feasible frequency-chirped laser pulse. Moreover, the beam qualities, in terms of energy and angular divergence, can be significantly improved in the rotation process. This method has potential applications in various areas involving ultrafast spin manipulation, like laser-plasma, laser-nuclear and high-energy particle physics.

Moreover, we also would like to introduce one of our other works on vacuum birefringence (VB), which is a key phenomenon predicted by quantum electrodynamics (QED). However, due to the smallness of the signal, conventional magnet-based and extremely intense laser-driven detection methods are still very challenging. This is because in the first case, the interaction length is large, but the field is limited, and vice versa in the second case. We put forward a method to generate and detect the subtle VB signal in a plasma bubble wakefield, which combines both advantages of providing large fields along large interaction lengths. A polarized γ-photon beam is considered to probe the wakefield along a propagation distance of millimeters to centimeters in the plasma bubble, in which the main source of noise from plasma electrons is mitigated by choice of the probe γ-photon polarization and by proper modulation of the plasma density. We find via plasma particle-in-cell simulations that the VB signal in terms of Stokes parameters can reach about 10^{-5} (10^{-3}-10^{-2}) for tens of MeV (GeV) probe photons with moderately intense lasers (10^{20}-10^{21} W/cm^2). Our method provides a feasible alternative for the experimental observation of VB with existing laser technique via laser-plasma interaction and offers high potential for numerous applications, such as searching for new physics beyond the standard model.