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Determination of the Carrier-envelop phase of PW laser pulses and generation of spin-polarization relativistic electron beams via a single-shot ultra-intense laser pulse

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The impact of the carrier-envelope phase (CEP) of an intense multi-cycle laser pulse on the radiation of an electron beam during nonlinear Compton scattering is investigated. We have identified a CEP effect specific to the ultrarelativistic regime. When the electron beam counterpropagates with the laser pulse, pronounced high-energy x-ray double peaks emerge near the backward direction relative to the initial electron motion. This is achieved in the relativistic interaction domain, where both the electron energy is required to be lower than for the electron reflection condition at the laser peak and the stochasticity effects in the photon emission to be weak. The asymmetry parameter of the double peaks in the angular radiation distribution is shown to serve as a sensitive measure for the CEP of up to 10-cycle long laser pulses and can be applied for the characterization of extremely strong laser pulses in present and near future laser facilities [1, 2].

Moreover, Spin-polarization of an ultrarelativistic electron beam head-on colliding with an ultraintense laser pulse is investigated in the quantum radiation-reaction regime. We develop a Monte-Carlo method to model electron radiative spin effects in arbitrary electromagnetic fields by employing spin-resolved radiation probabilities in the local constant field approximation. Due to spin-dependent radiation reaction, the applied elliptically polarized laser pulse polarizes the initially unpolarized electron beam and splits it along the propagation direction into two oppositely transversely polarized parts with a splitting angle of about tens of milliradians. Thus, a dense electron beam with above 70% polarization can be generated in tens of femtoseconds, see the interaction scenario in Fig. 1. The proposed method demonstrates a way for relativistic electron beam polarization with currently achievable laser facilities [3].

Besides, relativistic spin-polarized positron beams are indispensable for future electron-positron colliders to test modern high-energy physics theory with high precision. However, present techniques require very large-scale facilities for those experiments. We put forward a novel efficient way for generating ultrarelativistic polarized positron beams employing currently available laser fields. For this purpose, the generation of polarized positrons via multiphoton Breit-Wheeler pair production and the associated spin dynamics in single-shot interaction of an ultraintense laser pulse with an ultrarelativistic electron beam is investigated in the quantum radiation-dominated regime. A specifically tailored small ellipticity of the laser field is shown to promote splitting of the polarized particles along the minor axis of laser polarization into two oppositely polarized beams. In spite of radiative de-polarization, a dense positron beam with up to about 90% polarization can be generated in tens of femtoseconds. The method may eventually usher high-energy physics studies into smaller-scale laser laboratories [4].

Finally, we demonstrate a way of single-shot determination of polarization for ultrarelativistic electron beams via nonlinear Compton scattering [5].

References
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Figure 1. Scenario of generation of spin-polarized electron beams via nonlinear Compton scattering