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Relation between chirality imbalance and fermion pair-production under the parallel electromagnetic field

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There has been recently an increasing interest for study of the chirality imbalance n_5, which is the difference between right- and left-handed fermions. The chirality imbalance is expected to be arised from the axial anomaly and plays a key role to understand anomalous transport phenomena in the hot/dense quark matter or the Dirac/Weyl semimetals under the magnetic field. One of interesting transport phenomena in the presence of chirality imbalance is the chiral magnetic effect(CME), appearance of electric current in direction of the external magnetic field. However, the electric field gives a crucial contribution to the emergence of the chirality imbalance in addition to the magnetic field. In the previous work, we have studied the chirality imbalance and the CME using the analytical solution of the Dirac equation in the constant magnetic and Sauter-type pulsed electric fields, and found that the time-dependence of the gauge field is essentially important for the production of n_5. Here, we try to extend our study to the general time-dependent electric field, and discuss a relation between n_5 and the fermion pair-production from the vacuum. In this talk, we study the time evolution of the chirality imbalance and the electric current under spatially-uniform and parallel electromagnetic field in the vacuum of massive fermion. For the time-dependence, we assume the constant magnetic field, but do not impose any specific form for the electric field with boundary conditions $E(t \to \pm\infty) \to 0$. We solve the Dirac equation and calculate vacuum expectation values of the currents with the gauge invariant regularization. In particular, we find that n_5 and CME at $t \to \infty$ are solely determined by the probability distributions of the fermion created non-perturbatively by the electric field. As a result, asymptotic forms of n_5 and CME consists of a constant part and an oscillating part independent of details of intermediate time-dependence of the gauge potential. The non-zero constant term is proportional to a relativistic velocity and the momentum distribution of the created particle, and understood as a classical analogue of the electric current. We discuss how the chirality imbalance arises and roles of the electromagnetic fields in detail.

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