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Dirac materials in parallel non-uniform electromagnetic fields generated by SUSY: a chiral Planar Hall Effect

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Abstract

Within a Supersymmetric Quantum Mechanics (SUSY-QM) framework, the (3+1) Dirac equation describing a Dirac material in the presence of external parallel electric and magnetic fields is solved. Considering static but non-uniform electric and magnetic profiles with translational symmetry along the y-direction, the Dirac equation is transformed into two decoupled pairs of Schrödinger equations, one for each chirality of the fermion fields. Taking trigonometric and hyperbolic profiles for the vector and scalar potentials, respectively, we arrive at SUSY partner Pöschl-Teller-like quantum potentials. Restricting to the conditions of the potentials that support an analytic zero-mode solution, we obtain a nontrivial current density perpendicular to the electric and magnetic fields, thus, defining a plane where these three vectors become coplanar, indicating the possibility of realizing the Planar Hall Effect. Furthermore, this non-vanishing current density is the sum of current densities for the left- and right-chiralities, suggesting that the net current is a consequence of chiral symmetry. Possible application in current steering of solitonic nature through a Type-I Weyl semimetal is discussed.

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