Chiral Symmetry Breaking in 2D Materials: A Generalized QED Approach

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Dynamical mass generation is a phenomenon where massless Dirac fermions acquire a finite mass through interactions. We investigate this effect for electrons in two-dimensional materials, where the Coulomb interaction is strongly screened by a large dielectric constant — a effect observed in Fermi velocity renormalization experiments. To model this screened interaction, we employ an extension of quantum electrodynamics (QED) known as Generalized QED (GQED). Originally proposed by Podolsky in (3+1)D, GQED introduces a higher-order derivative term characterized by a parameter a, which renders the theory finite at high energies and yields an effective potential that interpolates between the standard 1/r Coulomb potential ($a \to 0$) and a severely screened (Yukawa-like) interaction. We formulate the (2+1)D version of this theory and study chiral symmetry breaking using a non-perturbative approach. By deriving the gap equation for the mass function, we demonstrate that a quantum phase transition occurs, leading to dynamical mass generation for a finite Podolsky parameter $a > 0$. We establish the critical conditions for this transition in terms of the coupling constant and the Podolsky parameter. Furthermore, we analyze the role of the material's Fermi velocity in facilitating mass generation.

Keywords: Generalized QED, Higher-order derivative theory, 2D materials.