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Holographic vector superconductor in Gauss–Bonnet gravity

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Abstract

In the probe limit, we numerically study the holographic p-wave superconductor phase transitions in the higher curvature theory. Concretely, we study the influences of Gauss–Bonnet parameter α on the Maxwell complex vector model (MCV) in the five-dimensional Gauss–Bonnet–AdS black hole and soliton backgrounds, respectively. In the two backgrounds, the improving Gauss–Bonnet parameter α and dimension of the vector operator Δ inhibit the vector condensate. In the black hole, the condensate quickly saturates a stable value at lower temperature. Moreover, both the stable value of condensate and the ratio ω_g/T_c increase with α. In the soliton, the location of the second pole of the imaginary part increases with α, which implies that the energy of the quasiparticle excitation increases with the improving higher curvature correction. In addition, the influences of the Gauss–Bonnet correction on the MCV model are similar to the ones on the SU(2) p-wave model, which confirms that the MCV model is a generalization of the SU(2) Yang–Mills model even without the applied magnetic field to some extent.
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1. Introduction

The gauge/gravity duality [1,2] shows that a $(d + 1)$-dimensional weak gravity system corresponds to a d-dimensional strongly coupled conformal field theory on its boundary, which thus provides us a feasible and efficient approach for studying the system involving the strong interaction, especially the high temperature superconductors.

In Ref. [3], the first holographic s-wave superconductor model was numerically realized in the four-dimensional Schwarzschild anti-de Sitter (AdS) black hole coupled to the Maxwell complex scalar field. The results showed that below a critical temperature, the scalar "hair" appears outside the horizon, which spontaneously breaks the U(1) gauge symmetry of the system. This corresponds to the spontaneous breaking of the global U(1) symmetry from the holographic dictionary, and thus models the s-wave superconductor phase transition. Thereafter, Refs. [4,5] constructed holographic p-wave and d-wave superconductors, respectively. Except the numerical approach, that the Sturm–Liouville (SL) eigenvalue approach [6] as well as the matching method [7] are showed to be efficient for the critical behavior of the superconductor phase transition. It should be noted that all above works based on the probe limit, away from which the holographic model was further investigated in Ref. [8]. Considering that there exists a mass gap in the insulator, the authors of Ref. [9] modeled the insulator/superconductor phase transition in the five-dimensional AdS soliton. Moreover, the holographic superconductor models were studied in the system involving the magnetic field [10,11]. Because the Mermin–Wagner (or Coleman) theorem forbids continuous symmetry to be spontaneously broken in three-dimensional spacetimes at finite temperature, the study of the higher curvature theory to construct holographic superconductors attracted a lot of attention, especially the five-dimensional Gauss–Bonnet gravity with high curvature correction, see, for example, [12–28], where the results showed that the increasing Gauss–Bonnet correction inhibits the phase transition.

On the other hand, similar to the construction of the s-wave superconductor [3,29–31], a holographic p-wave superconductor model was proposed in the four-dimensional Schwarzschild AdS black hole coupled to a Maxwell complex vector (MCV) field in the probe limit [32]. It was showed that, for the lowest Landau level, the applied magnetic field can induce the vector condensate, which is reminiscent of the QCD vacuum phase transition [33–35], while for the excited Landau level, the magnetic field effect on the MCV superconductor is similar to the ordinary superconductors [10,11]. In Ref. [36], the holographic insulator/superconductor phase transition induced by the magnetic field was studied in the five-dimensional AdS soliton coupled to such a MCV field and the SU(2) Yang–Mills (YM) field, respectively. It was shown that the MCV model is a generalization of the SU(2) model with general mass, charge. Subsequently, Refs. [37,38] studied respectively the Lifshitz and Gauss–Bonnet effects on the MCV superconductor model induced by the magnetic field, and found that the increasing Gauss–Bonnet parameter always hinders the vector condensate. Considering the backreaction of the MCV field on the AdS gravity spacetime, Refs. [39–43] further studied the holographic vector condensate and its related complete phase diagrams as well as entanglement entropy, and obtained the rich phase structures, especially the "retrograde condensate". Then, the coexistence and competition of ferromagnetism and MCV superconductivity were studied in Ref. [44], which showed that the results depend partly on the self-interaction of magnetic moment of the complex vector field. The authors of Ref. [45] investigated the MCV model in the four-dimensional Einstein–Born–Infeld AdS theory away from the probe limit, and obtained the rich and varied phase structure depending on the mass parameter m, the backreaction parameter κ as well as the Born–Infeld parameter γ. In the probe limit, the authors of Ref. [46] numerically and analytically studied the effect of the

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