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Phase Structure of Holographic Superconductors with Spontaneous Scalarization

Holographic superconductor phase transition and spontaneous scalarization are triggered by the instability of the underlying vacuum black hole spacetime. Although both hairy black hole solutions are closely associated with the tachyonic instability of the scalar degree of freedom, they are understood to be driven by distinct causes. It is, therefore, interesting to explore the interplay between the two phenomena in the context of a scenario where both mechanisms are present. To this end, we investigate the Einstein-scalar-Gauss-Bonnet theory in asymptotically anti-de Sitter spacetime with the presence of a Maxwell field. Even though different origins for the tachyonic mass behave independently and can be recognized by the distinctive natures of their effective potentials, it is shown that near the transition curve, the holographic superconductor and spontaneous scalarization are found to be largely indistinguishable. This raises the question of whether the hairy black holes triggered by different mechanisms are smoothly joined by a phase transition or whether these are actually identical solutions. To assess the transition more closely, we evaluate the phase diagram in terms of temperature and chemical potential and discover a smooth but first-order transition between the two hairy solutions by explicitly evaluating Gibbs free energy and its derivatives. In particular, one can elaborate a thermodynamic process through which a superconducting black hole transits into a scalarized one by raising or decreasing the temperature. Exhausting the underlying phase space, we analyze the properties and the interplay between the two hairy solutions.

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