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Superconductivity in confining models

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Content

For cold, ultra-dense matter, color superconductivity is characterized by the formation of Cooper pairs of quarks through gluon exchange, yielding a frequency-dependent superconducting gap on the order of 100 MeV. Conversely, the phenomenon of confinement is characterized by the fundamental particles confined within hadrons at low to intermediate energies. In this regime, lattice QCD has shown that gluon two-point correlation functions in Landau gauge display a finite zero-momentum value, suggesting the dynamical generation of an infrared mass scale for the gluon and a nontrivial spectral structure.

In this work, we investigate how an infrared massive gluon might affect color superconductivity and use this phenomenon as a testing ground for confining models. In particular, we analyze superconductivity using a Yukawa model in which we replace the conventional bosonic propagator of the mediator with a confining propagator. This propagator has a structure similar to those found in Gribov-Zwanziger (GZ), Refined Gribov-Zwanziger (RGZ), and Curci-Ferrari models. In these models, the gluon includes an explicit mass parameter linked to nonperturbative effects and may exhibit nonstandard analytical structures, such as complex-conjugated poles. Considering low temperature and high chemical potentials, we derive the superconducting gap with frequency dependence. Our results reveal two phases in the system concerning the mass parameter: one phase exhibits superconductivity with a low-frequency peak, consistent with literature on color superconductivity (low-mass regime), while the other phase without superconductivity, displaying a "plateau" characteristic of BCS superconductivity in the point-like approximation (high-mass regime). Solving the integral gap equation we further observe a reduction in the superconducting gap across all confining models as the mass parameter increases. We also obtain results with renormalization group improvement in an infrared-safe scheme specifically for a massive Curci-Ferrari version of the gluon. Finally, we discuss the extension of this analysis to the gauge theory case to appear.

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