1 - 17 FFLO State with Angle Dependent Gap in Asymmetric Nuclear Matter

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In asymmetric nuclear matter, the FFLO[1,2] state and DFS (deformed Fermi surfaces)[3] state are studied in Refs.[4,5]. Both these two phases imply an anisotropic quasiparticle spectrum in the ground state. On the other hand, the previous studies of FFLO sate[4] and DFS state[5] adopt the angle-averaging procedure which has been proved to be a quite good approximation in symmetry nuclear matter[6] by considering the gap as isotopic one. In fact, our previous work indicates that the angle dependence of the gap should be taken into account when calculate the pairing gap for asymmetric nuclear matter at low temperature. In the previous work, we propose an axi-symmetric angle dependent gap (ADG) state which correspond to the axi-symmetric deformation of the neutron and proton Fermi spheres. In the ADG state, the rotational symmetry is broken spontaneously and there is a symmetry breaking axis. While in the FFLO configuration, both the rotational symmetry and translational symmetry are spontaneously broken and the axis of the symmetry breaking is along the direction of the total Cooper pair momentum. To determinate the true ground state structure for bulk isospin asymmetric nuclear matter we should consider the FFLO and ADG state together within the same model.

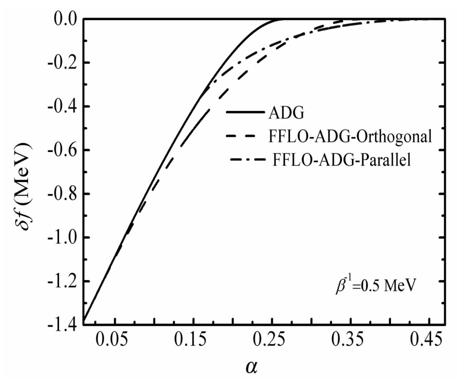

Fig. 1 The differences of the free energy between the superconducting and normal states. The solid, dashed and dash-dotted lines correspond to the ADG state with pair momentum $Q=0$, FFLO-ADG-Orthogonal state and FFLO-ADG-Parallel state respectively.

As the stepped of our previous work we combined the FFLO phase and the axi-symmetric angle dependent gap (ADG) phase within the same model for iso-spin asymmetric nuclear matter. And the arbitrary angles between the two symmetry breaking axes are considered to determine the favored angle for the ground state. In the calculations we take the $^3SD_1$ partial-wave channel, which dominate the pairing interaction at low density, into account only.

The essential quantity to describe the thermodynamics of the system is free energy. We calculate the differences between the superconducting and normal states for different cases with the temperature $\beta^{-1}=0.5$ MeV in Fig. 1. The solid line is related to the ADG state with zero pair momentum. The dashed line corresponds to case the pair momentum perpendicular to the rotational symmetry breaking axis of axi-symmetric ADG state which is favored when asymmetry is relative small. The dash-dotted line related to the case the the pair momentum parallel to the rotational symmetry breaking axis of axi-symmetric ADG state which becomes the ground state near the superconducting-normal transition. Moreover, the transition from ADG state to FFLO-ADG-Orthogonal state is of second order, while the ADG-(FFLO-ADG-Parallel) is of first order. All the transitions from the three superconducting states to normal state are of second order.

References

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