Triple-density-product and loop-current orders in multi-component Boson, Fermion, and spin systems

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Internal degrees of freedom often lead to qualitatively novel phenomena. It is widely known that the electron spin degree of freedom induce a number of physical phenomena and states, especially, in solid-state physics. In the field of ultra-cold atoms, internal degrees of freedom can be easily controlled by using optical techniques, compared to those of solid. As a result, some ultra-cold gas systems made from the atoms with large internal degrees of freedom have been already realized. Spin-1 and spin-2 Bose-Einstein condensates [1,2] and nearly SU(6)-symmetric fermion atomic gases [3] are typical examples.

In this study, as a simple realistic system with large internal degrees of freedom, we mainly focus on three-component interacting Bose gases trapped in one-dimensional elongated potential. By using the field theory approach, we show [4] that when the inter-component repulsion (hopping) is relevant in the sense of the renormalization-group theory, the triple-density-product order defined by a product of three density operators (a loop current flowing among different components) emerges. The same orders are also realized in N-component Bose gases and N-leg antiferromagnetic spin tubes [5] when N (>2) is odd. Furthermore, the triple-density-product order can also appear in N-component Fermi gases with odd N (>2). Remarkably, as far as we know, the triple-density-product order has never been considered so far in many-body physics.

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