Interlayer coherence and entanglement in bilayer quantum Hall states at filling factor ν = 2/λ

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Abstract

Quantum Hall Effect (QHE) keeps catching researchers' attention owing to its peculiar features mainly related to quantum coherence and the emergence of a new class of particles called "composite fermions", due to collective behaviour shared with superconductivity and Bose-Einstein condensation phenomena. In fact, the physics of the bilayer quantum Hall (BLQH) systems, made by trapping electrons in two thin layers, *a* and *b,* at the interface of semiconductors, is quite rich owing to unique effects originating in the intralayer and interlayer coherence developed by the interplay between the spin and the layer (pseudospin) degrees of freedom. For example, the presence of interlayer coherence in bilayer quantum Hall states has been examined by magnetotransport experiments [1], where electrons are transferable between the two layers by applying bias voltages and the interlayer phase difference is tuned by tilting the sample. Also, anomalous (Josephson-like) tunneling current between the two layers at zero bias voltage were predicted in Refs. [2–4], whose first experimental indication was obtained in Ref. [5]. Other original studies on spontaneous interlayer coherence in BLQH systems are [6, 7].

Spin and pseudospin quantum degrees of freedom are correlated in BLQH systems and entanglement properties have also been studied in, for example, Refs. [8-10], mainly at filling factor ν = 1. An appropriate description of quantum correlations is of great relevance in quantum computation and information theory, a field which has also attracted a huge degree of attention. Actually, one can find quantum computation proposals using BLQH systems in, for example, [11-13].

In References [14,15] we have studied coherence and entanglement properties of the state space of a composite bi-fermion (two electrons pierced by λ magnetic flux lines) at one Landau site of a bilayer quantum Hall system. In particular, interlayer imbalance and entanglement (and its fluctuations) are analyzed for a set of $U(4)$ coherent (*quasiclassical*) states generalizing the standard pseudospin $U(2)$ coherent states for the spin-frozen case. The interplay between spin and pseudospin degrees of freedom opens new possibilities with regard to the spin-frozen case. Actually, spin degrees of freedom make interlayer entanglement more effective and robust under perturbations than in the spin-frozen situation, mainly for a large number of flux quanta λ. Interlayer entanglement of an equilibrium thermal state and its dependence with temperature and bias voltage is also studied for a pseudo-Zeeman interaction.

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