Spin Supercurrent in the Canted Antiferromagnetic Phase

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Physics of the bilayer quantum Hall (QH) system is enormously rich owing to the intralayer and interlayer phase coherence controlled by the interplay between the spin and the layer (pseudospin) degrees of freedom. At the filling factor $\nu = 1$ there arises a unique phase, the spin-ferromagnet and pseudospin-ferromagnet phase, showing the intriguing phenomena such as the anomalous behavior of the Hall resistance reported in counterflow and drag experiments [1]. They are triggered by the supercurrent within each layer [2], which are played by the Goldstone mode describing a pseudospin wave.

On the other hand, at $\nu = 2$ the bilayer QH system has three phases, the spin-ferromagnet and pseudospin-singlet phase, the spin-singlet and pseudospin ferromagnet phase, and a canted antiferromagnetic phase (abridged as the CAF phase) [3], depending on the relative strength between the Zeeman gap and tunneling gap.

We have recently analyzed the full details of these Goldstone modes in each phase [4]. The CAF phase is most interesting, where one of the Goldstone modes become gapless, having a linear dispersion relation as the tunneling gap vanishes. It is an urgent and intriguing problem what kind of phase coherence this Goldstone mode develops.

In this research, we show that it is the entangled spin pseudospin phase coherence, and explore the associated phase coherent phenomena. We show that the supercurrent flows within the layer when there is inhomogeneity in the phase field. The Hall resistance is predicted to become anomalous precisely as in the $\nu = 1$ bilayer system in the counterflow and drag experiments. Furthermore, it is shown that the total current flowing the bilayer system is a supercurrent carrying pure spins in the counterflow geometry (Figure 1). All these phenomena occur only in imbalanced bilayer systems [4].

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