Hikaru Wakaura
University of Tsukuba
Quantum Error Correction using spin-vortex induced loop currents as qubits

A theory for copper oxides (cuprates) high temperature superconductivity predicts the existence of spin-vortex-induced loop currents (SVILCs). The SVILCs are nano-sized persistent loop currents exists in the CuO_2 plane of the cuprates. In this theory, holes lose their mobility since they form small polarons due to strong hole-lattice interaction at temperatures below the superconducting transition temperature. An exchange interaction exists between nearest neighbor copper $d_{x^2-y^2}$ electrons, and in addition to it, a superexchange interaction occurs between copper $d_{x^2-y^2}$ electrons across the small polaron holes. By these interaction, itinerant electrons move around holes with twisting their spins. As a consequence, spin-vortices are formed around each hole and circulating motion of itinerant electrons generates the SVILCs [1]. The goal of the present study is a physical realization of quantum computers using spin-vortex induced loop currents as qubits [2]. The single qubit is represented by a quantum state with a particular current pattern created by a single SVILC or a collection of SVILCs. Merits of the SVILC qubit are

1, By cooling each qubit from psudogap temperature, the state of each qubit drops to its bottom level[3].
2, By measuring magnetic field emerged by SVILCs themselves, the states of each qubit are easily identified.
3, By splitting the energy levels of each state by external static vertical magnetic field and irradiating laser equivalent to energy difference between two given states, rapid universal gate operation is affordable.
4, Each state of SVILCs is determined by topological winding number of χ on each spin-vortices. So, the states of SVILCs are certainly robust against environmental noise.
5, By allocating each qubit separately and coupling given neighboring qubits, the system with large number of qubits can be fabricated in microscale region.

Hence, the SVILC qubit is a very promising candidate for making practical quantum computers. In the present work, we will present the result of numerical simulations for bit-flip detections using a 3-qubit system of SVILCs, which 3 qubits are allocated in a row with keeping C2 symmetry on $100a \times 10a$ sized CuO_2 plane. Then, $a=0.4$nm is the lattice constant of CuO_2 plane. And, all the states are split by parabolic vertical static magnetic field. In addition, dipole moments between two states are significant. Hence, gate operations are very swift. Coupling neighboring two qubits can be realized deliberately and selectively.

[1] H. Koizumi, R. Hidekata A. Okazaki and M. Tachiki, J. Supercond. Nov. Magn., 27, 121-132(2014)
[2] Hikaru Wakaura and Hiroyasu Koizumi, Physica. C., 55-66, 521-522(2016)
[3] A. Okazaki, H. Wakaura and H. Koizumi, J. Supercond. Nov. Magn. ,28, 3221-3233(2015)