Cuprate superconductor qubits simulation

Hiroyasu Koizumi

Center for Computational Sciences, University of Tsukuba

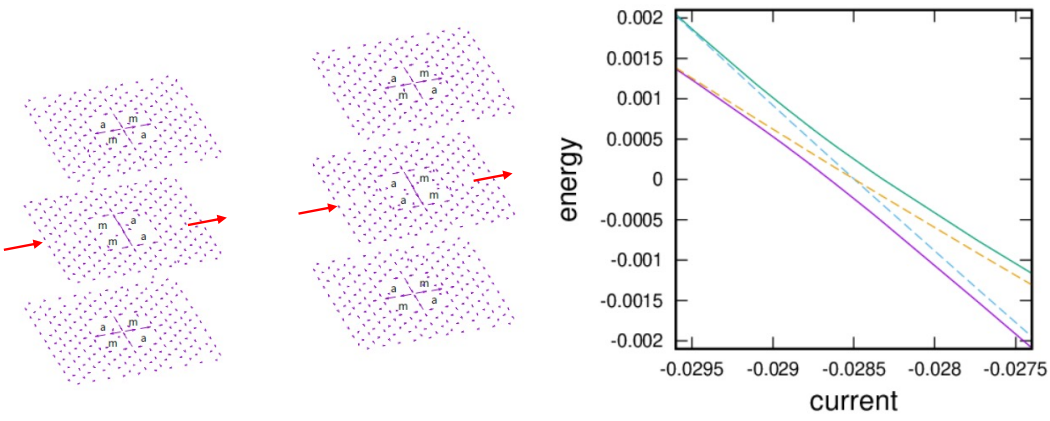
1. Project Purpose

Development of theory for realizing quantum computers using nano-sized superconducting loop currents predicted to exist in cuprate superconductors as qubits; construction of computer codes based on it; and performing computer simulations using the codes.

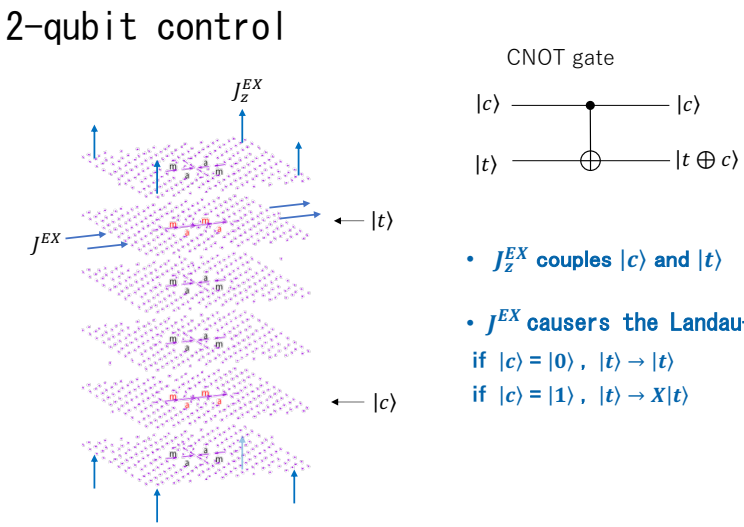
2. Results

We formulated a theory using the loop currents predicted to exist in cuprate superconductors (Spin-vortex-induced loop currents) as qubits, which are controlled by external current. We constructed computer programs based on it. The single-qubit control is achieved by the Landau-Zener type transition as shown in the figure below. 2-qubit gate is also achieved by the Landau-Zener type transition by feeding external current that turns-on the coupling between the two qubits.

Qubit control by external current



Left : Three-layer model. 2nd layer is used as a qubit layer.
right: Two states with different loop current patters are used as a quibt. They are controlled by the Landau-Zener transition using current as a parameter.



3. Roles of the MCRP and its significance

The present calculation requires a large amount of memories and computational time since it deals with nano-sized system involving atoms explicitly, including superconducting current that adds an extra computational complexities compared to the ordinary electronic state calculations. In this respect, supercomputers available through MCRP is highly helpful.

4. Future plan

We include readouts and error-corrections to our formalism and simulations.

5. Publications and conference presentations

(1) Journal papers: in preparation.

(2) Presentations: A. Ishikawa and H. Koizumi, "Spin-vortex-induced loop current qubits: Simulation for gate control by external current", The 76th annual meeting of Japanese Physical Society, March 12-15 2021, online.

(3) Others: none

Supercomputer	Use	Allocated resources*	
		Initial resources	Additional resources
Cygnus	No		
Oakforest-PACS	Yes	30000	0
*in units of node-hour product			