Nonadiabatic conditional geometric phase shift with NMR

Wang Xiang-Bin* and Matsumoto Keiji†
Imai Quantum Computation and Information Project,
ERATO, Japan Sci. and Tech. Corp.
Dani Hongo White Bldg. 201, 5-28-3, Hongo Bunkyo, Tokyo 113-0033, Japan

A conditional geometric phase shift gate, which is fault tolerant to certain types of errors due to its geometric nature, was realized recently via nuclear magnetic resonance(NMR) under adiabatic conditions. By the adiabatic requirement, the result is inexact unless the Hamiltonian changes extremely slowly. However, in quantum computation, everything must be completed within the decoherence time. High running speed of every gate in quantum computation is demanded because the power of a quantum computer can be exponentially proportional to the maximum number of logic gate operations that can be made sequentially within the decoherence time. The adiabatic condition makes any fast conditional Berry phase(cyclic adiabatic geometric phase) shift gate impossible. Here we show that by using a newly designed sequence of simple operations with an additional vertical magnetic field, the conditional geometric phase shift gate can be run nonadiabatically. Therefore geometric quantum computation can be done at the same rate as usual quantum computation.

A fault-tolerant quantum logic gate is the central issue in realizing the basic constituents of a quantum information processor. Quantum computation via the controlled geometric phase shift provides a nice scenario to this purpose. Due to its geometric property, a geometric phase shift can be robust with respect to certain types of operational errors. In particular, suppose that the spin(qubit) undergoes a random fluctuation about its path in the evolution. Then the final value of the geometric phase shift will not be affected provided that the random fluctuation does not change the total area.

Recently, it was reported that the conditional Berry phase(adiabatic cyclic geometric phase) shift can be used in quantum computation. In particular, , an experiment was done with NMR under the adiabatic condition.

Demanding on both running speed and precision of every gate in a quantum computer is quite high. It has been reported recently that, due to the requirement of adiabatic condition, faster running speed causes severe distortions to the results. The adiabatic condition makes the fast speed and high precision conflict each other in the conditional Berry phase shift gate. Increasing the running speed of the logic gate can exponentially increase the power of a quantum computation such as quantum factorization. It seems that the geometric phase shift gate will only be practical if it can run at a speed comparable to that of the usual quantum gate. Therefore one is tempted to find an easy way to make the conditional geometrical phase shift through *non*adiabatic state evolution. In this presentation, we present an easy scheme to make the geometric phase shift *non*adiabatically with NMR.

*correspondence author, email: wang@qci.jst.go.jp
†email:keiji@qci.jst.go.jp