Abstract Title

Mulipulse Control of Quantum Information

Symposium Track

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Abstract body

1. Introduction

As one of the applications of nano-structure devices, the schemes of quantum information processing (QIP) have attracted much attention because of its possibility for high-speed computation and secure communication. However, several obstacles are recognized as impeding the realization of QIP[1]. Especially, quantum superposition and entanglement are vulnerable to noisy environments, which thus causes serious problems for quantum computationand quantum teleportation.

In order to reduce errors caused by environmental effects on a single qubit, many methods have been proposed. The requirements of these methods can be roughly divided into three categories:(1) ancillary qubits, (2) measurements with high degree of accuracy, and (3) pulse train application. However, in method (1), the main problem has been to keep the coherence of all the qubits including ancillary bits, and quantum detection efficiency gives a limitation to execution of method (2). In contrast to the former two methods, method (3), the so-called bang-bang control[2], is more feasible to execute. In fact recently, this method has been extended to suppress the decoherence of a spin qubit in fullurene[3]. However, the pulse interval should be much shorter than the characteristic time of the reservoir τ_c to prevent the decoherence of qubit

In this paper, we present an essential physical background in bang-bang control to release the conditions on the pulse interval. This viewpoint means that we should take into account the non-Markovian (memory) effect of decoherence which remains over different pulse intervals[4]. And we show that this viewpoint can release the conditions on the pulse interval: By synchronizing the pulse interval with the characteristic oscillation period of the reservoir, we can efficiently suppress the decoherence of the qubit, a process which we call "synchronized pulse control" (SPC)[5].

2. Methods

Let us consider to suppress the phase relaxation of a qubit (a spin) that is caused by non-linear interaction with boson reservoir.

$$H_{SB} = S_z \sum_k \sum_q h_{k,q} \sqrt{\omega_k \omega_q} \left(b_k^{+} + b_k \right) \left(b_q^{+} + b_q \right) \quad (1)$$

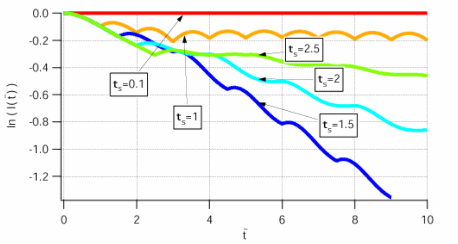
which describes the phase relaxation by simultaneous absorption and emission of bosons from the relevant qubit. In Eq.(1), $h_{k,q}$ represents the coupling strength with the k-th and q-th mode of boson. Assuming that we can apply π pulses instantaneously, we obtained the expression for the time evolution of the absolute value of the transverse component of the qubit under N pulses application by evaluating, $I(t) = \left| Tr_B \langle 1 | \rho(t) | 0 \rangle \right|^2$ where Tr_B means the trace operation over the reservoir and $|0\rangle$ ($|1\rangle$) represents the up (down) state of the qubit.

3.Results and Discussion

We show the time evolution of the quantity $\ln[I(t)]$by assuming that the coupling function

$$h(\omega) = \sum_k \left| h_k \right|^2 \delta(\omega - \omega_k) \qquad (2)$$

is a Gaussian distribution with width γ_p and center frequency ω_p. For a small pulse interval τ_s (=0.1), the decay is well suppressed, which is consistent with the results in the previous studies[5]. However, we found a surprising result with increasing the pulse interval: When we increase the interval to τ_s (=1.5), the degree of the suppression becomes worse, but we can see a significant recovery for τ_s =2 and 2.5. We can see that suppression of pure dephasing becomes more effective when the pulse interval τ_s is near π. Since the time axis is scaled with the center frequency of the coupling function, the pulse interval τ_s corresponds to the oscillation period of the center frequency. The result suggests that we can efficiently suppress the phase relaxation by synchronizing the pulse application with the characteristic oscillation period of the reservoir, which we will call synchronized pulse control (SPC)



In the talk, we will show the formulation can be extended to suppress the decoherence of quantum entanglement which plays an essential role in the scheme of quantum teleportation.

Keywords

pulse control, non-Markovian effect, quantun information

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