High fidelity quantum gates in quantum dots under several control pulse

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I. INTRODUCTION

We write two level system of quantum dots under driving pulse as[1]

$$H(t) = \Delta\sigma_z + \frac{\hbar}{\tau}X(t)\sigma_x \tag{1}$$

where Δ is anticrossing width in QDs, $\hbar$ is the reduced planck's constant, τ is the electron relaxation time between singlet triplet state and X(t) is a driving pulse. We chose several form of driving pulse to realize high fidelity quantum gates in III-V semiconductor quantum dots. More precisely, we write the symmetric and anti-symmetric driving pulse as:[2]

$$X(t) = \frac{\theta}{2} + \left(a - \frac{\theta}{2}\right)\cos\left(\frac{2\pi t}{\tau}\right) - a\cos\left(\frac{4\pi t}{\tau}\right), \tag{2}$$

$$X(t) = \frac{\theta}{2} + \left(a - \frac{\theta}{2}\right)\cos\left(\frac{2\pi t}{\tau}\right) - a\cos\left(\frac{4\pi t}{\tau}\right) + b\sin\left(\frac{2\pi t}{\tau}\right) - \frac{b}{2}\sin\left(\frac{4\pi t}{\tau}\right), \tag{3}$$

where θ is either π or $\pi/2$, a and b are constants. The time dependent Schrodinger Eq. 1 can be written in terms of two coupled first order differential equation as:

$$\dot{\chi}_+(t) = \frac{1}{i\hbar}\left(\Delta\chi_+(t) + \frac{\hbar}{\tau}X(t)\chi_-(t)\right), \tag{4}$$

$$\dot{\chi}_-(t) = \frac{1}{i\hbar}\left(\frac{\hbar}{\tau}X(t)\chi_+(t) - \Delta\chi_-(t)\right), \tag{5}$$

where we consider $|\chi(t)>= (\chi_+(t) \;\; \chi_-(t))^T$.

At $\theta = \pi$, from (1) we construct two orthogonal spinors as:

$$\chi_+(0) = \frac{1}{\sqrt{(\hbar X_\pi)^2 + (\delta - \Delta)^2}}\begin{pmatrix} \hbar X_\pi \\ (\delta - \Delta)\,\tau \end{pmatrix}, \tag{6}$$

$$\chi_-(0) = \frac{1}{\sqrt{(\hbar X_\pi)^2 + (\delta - \Delta)^2}}\begin{pmatrix} (\delta - \Delta)\,\tau \\ -\hbar X_\pi \end{pmatrix}, \tag{7}$$

where $\delta = \sqrt{\Delta^2 + (\hbar/\tau)^2 X_\pi^2}$. In our simulation, we assuming $\theta = \omega t$ and $\omega = 100GHz$ and find X_π from (2).

Please play with equations (2) and (3) and try to reproduce Figs(5), (6) and (7) of Ref.2

Then please solve coupled Eqs. 4 and 5 by considering the symmetric and antisymmetric pulses of the form (2) and (3).

Then please plot fidelity $F = | < \chi(t)|\chi_+(0) > |$ which is just the absolute value of the square root of the probability.

Later, we together will design experimental device and will find Δ and τ for realistic quantum dots system, similar to Wisconsin group.

[1] E. Barnes and S. Das Sarma, Phys. Rev. Lett. **109**, 060401 (2012).
[2] S. Pasini, P. Karbach, C. Raas, and G. S. Uhrig, Phys. Rev. A **80**, 022328 (2009).