Fast Polarization Manipulation

Ismail Nassar

Research Proposal

Under the supervision of

Prof. David Gershoni

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Contents

1 The Proposal

1.1 Problem Definition and Solution Approach.

The presence of the splitting in the lowest excitonic state is an unwanted effect in QDs that causes a degradation in the degree of entanglement between the two photons in the biexciton-exciton radiative cascade by lifting the degeneracy of the levels[1]. This is due several causes but mainly due to the asymmetry of the QD.

Several methods where investigated to control such as inducing strain and magnetic and electrics fields, but the problem continue to persist. A more straightforward approach is to ignore the causes for the splitting and assume that

1.2 Theoretical formulation (exciton).

The state of photon emitted from exciton excitation is described as:

$$|\Psi(t)\rangle = \alpha\,|H_X\rangle \cdot e^{\frac{-iE_H t}{\hbar}} + \beta\,|V_X\rangle \cdot e^{\frac{-iE_V t}{\hbar}} \tag{1}$$

Here $E_{H,V}$ are the energy levels,H_X and V_X are the horizontal and vertical respectively, and α,β are coefficients such that $\alpha^2 + \beta^2 = 1$.This can be rewritten as:

$$|\Psi(t)\rangle = \alpha\,|H_X\rangle + \beta\,|V_X\rangle \cdot e^{\frac{-i\triangle Et}{\hbar}} \tag{2}$$

Where $\triangle E = E_H - E_V$. This can we further simplified by rewriting $\frac{\triangle E}{\hbar}$ with ω:

$$|\Psi(t)\rangle = \alpha\,|H_X\rangle + \beta\,|V_X\rangle \cdot e^{-i\omega t} \tag{3}$$

1.3 Theoretical formulation (biexciton-exciton)

$$|\Psi(t)\rangle = \alpha(|H_{XX} \otimes H_X\rangle \cdot e^{\frac{-iE_H t}{\hbar}} + |V_{XX} \otimes V_X\rangle \cdot e^{\frac{-iE_V t}{\hbar}}) \tag{4}$$

$$|\Psi(t)\rangle = \alpha(|H_{XX} \otimes H_X\rangle + |V_{XX} \otimes V_X\rangle \cdot e^{\frac{-i(\triangle Et)}{\hbar}}) \tag{5}$$

1.4 Rotation of the exciton's polarization.

1.5 Restoring the entanglement of the photons in the biexciton-exciton radiative cascade.

If we construct two interferometers that allow us to induce phase shift to both the biexciton and exciton polarizations, then we can write the time-dependent phase relations as:

$$\begin{aligned}
\Phi_{H_{XX}}(t, t_{prop}) &= k_{H_{XX}} \cdot (t - t_{prop}) + \Phi^0_{H_{XX}} \\
\Phi_{V_{XX}}(t, t_{prop}) &= k_{V_{XX}} \cdot (t - t_{prop}) + \Phi^0_{V_{XX}} \\
\Phi_{H_X}(t, t_{prop}) &= k_{H_X} \cdot (t - t_{prop}) + \Phi^0_{H_X} \\
\Phi_{V_X}(t, t_{prop}) &= k_{V_X} \cdot (t - t_{prop}) + \Phi^0_{V_X}
\end{aligned} \tag{6}$$

Here the K's are the different slopes that introduce the shift to the photons' polarizations, and Φ^0's are the initial phase of the photons at the time of emission. t_{prop} is the propagation times of the photons from the quantum dot to the device. Since it's constant time we can simplify the function by including it in the constant phase Φ^0. By taking the starting time of our system as the biexciton excitation time, we can write the state using the t_x and t_{xx} (where t_{xx} and t_x are the random emission times of the biexciton and exciton respectively), as follows:

$$|\Psi(t)\rangle = \alpha(|H_{XX}\rangle \cdot e^{i*\Phi_{H_{XX}}(t_{XX}-t^{xx}_{start})} \otimes |H_X\rangle \cdot e^{i\Phi_{H_X}(t_X-t^{x}_{start})} + \\ |V_{XX}\rangle \cdot e^{i\Phi_{V_{XX}}(t_{XX}-t^{xx}_{start})} \otimes |V_X\rangle \cdot e^{i\Phi_{V_X}(t_X-t^{x}_{start})} \cdot e^{-i(\triangle Et)/\hbar}) \tag{7}$$

next, plug it in

$$\Psi(t) = |H_{xx}H_x\rangle + e^{i\Phi}|V_{xx}V_x\rangle \tag{8}$$

where $\Phi(t)$:

$$\Phi(t) = (K_{V_{XX}} - K_{H_{XX}} + K_{V_X} - K_{H_X}) \cdot t_{xx} + (K_{V_X} - K_{H_X} + \triangle E/\hbar) * t_x + \\ (K_{V_{XX}} - K_{H_{XX}}) \cdot -t^{XX}_{Start} + (K_{V_X} - K_{H_X}) \cdot -t^{X}_{Start} + \\ (\Phi^0_{V_{XX}} - \Phi^0_{H_{XX}} + \Phi^0_{V_X} - \Phi^0_{H_X}). \tag{9}$$

Conditions:

$$K_{V_X} - K_{H_X} = -\triangle E/\hbar \tag{10}$$

$$(K_{V_{XX}} - K_{H_{XX}}) = -(K_{V_X} - K_{H_X}) \tag{11}$$

1.6 Additional proposed advances

1.6.1 Combining the radiative cascade into the knitting machine.

1.6.2 Using the experimental system for feed-forward operations in 1D cluster states.

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Appendices

Appendix I

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Appendix 2

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