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RESEARCH ARTICLE

An all optical scheme for implementing an integrated Pauli's X, Y and Z quantum gates with optical switches

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Abstract Quantum logic gates have currently drawn the attention of optical community, as the qubits can easily be formed by polarization states of light. Again Pockels materials can take the role of changing the state of polarization of light by biasing the electric field. In this paper the authors propose first time an integrated scheme of Pauli X, Y, and Z quantum logic gates using electro optic Pockels material as an optical switch. This system not only preserves the basic advantages of quantum gates, but also exploits the parallelism of optics towards the increase of the speed of operation.

Keywords Qubit · Quantum logic gate · Pauli's X, Y, Z-gate · Polarization state of light · V_π voltage

Introduction

Quantum bits or qubits are formed by the suitable quantum states of atoms, photons, nuclei, quantum dots etc. [1–9]. Like classical computers, a quantum computer can also store the digital information in its memory in the form of qubits [9–11]. In last few years there are several schemes proposed which used the optical signal for the implementation of the members of quantum logic family [12–16].The universality as well as the reversibility are the two prime features in quantum computing [7, 15]. Some schemes of optical simulations are also proposed in regard of quantum computing [8, 16]. Again it is needless to say that optics can exhibit a great role in information processing, digital computing and data processing [17–20]. As light forms a quantum state easily so in quantum computing and in information processing of qubits, photon can take a very meaningful role [20]. The main advantage of qubit is that it is represented by the superposition of pure (|0> and |1>) states. As a result, the system lies in both the |0> and |1> states jointly at the same time with certain probability ratio. Dirac notation for the general qubit state is $|\Psi \geq C_0|0> + C_1|1>$; where the coefficient $|C_0|^2$ and $|C_1|^2$ denote the normalized probability of the respective orthogonal pure states. Classical computers deal with Boolean logic gates, where as the quantum logic gates serve its logic operations using quantum circuits. A single qubit gate changes its input qubit q to output qubit q′ or |Ψ> to |Ψ′> depending on the necessary logical requirement. Some most important single qubit gates are the Pauli X, Y and Z gates etc. The quantum NOT(X) gate reverses the amplitude coefficients as: $X.q = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}\begin{pmatrix} C_0 \\ C_1 \end{pmatrix} = \begin{pmatrix} C_1 \\ C_0 \end{pmatrix}$.

The quantum Z gate flips 1, while 0 remains unchanged. The matrix representation of Z gate is $\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$. Thus $Z.q=\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}\begin{pmatrix} C_0 \\ C_1 \end{pmatrix}=\begin{pmatrix} C_0 \\ -C_1 \end{pmatrix}$. The matrix representation of Y gate is $\begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}$, which changes the qubit $\begin{pmatrix} C_0 \\ C_1 \end{pmatrix}$ to $\begin{pmatrix} -iC_1 \\ iC_0 \end{pmatrix}$.

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