INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211 (Online)

Realization Of Quantum Logical Operations Through Quantization Of Electrodynamics

Ankush Rai
CRIAD Laboratories, Association of Scientific Empowerment & Commerce, Bhilai, Chhattisgarh, India

Abstract:

The difficulty of working on quantum computing is the long-standing unsolved mystery in physics. The study presents the concept of quantization of electron can enable oneself to perform quantum computational operations. It is showed that the co-existence of basic single qubit or quantum bit state can be realized using self-quantized state of electrons in constant electric field & self force region of charge itself. Based upon the present work the first quantum computer is being building up at CRIAD laboratories which will be operational from September, 2013.

Key words: *electrodynamics, qubits, Quantum Computing, Hadamard gate, NOT Gate, Phase-flip Gate.*

1.Introduction

A quantum computer is a computation device that makes use of quantum mechanical phenomena, such as superposition and entanglement, to perform operations on data. Quantum computers are different from digital computers based on transistors. Whereas digital computers require data to be encoded into binary digits (bits), quantum computation uses quantum properties to represent data and perform operations on these data. A theoretical model is the quantum Turing machine, also known as the universal quantum computer. Quantum computers share theoretical similarities with non-deterministic and probabilistic computers, like the ability to be in more than one state simultaneously. The field of quantum computing was first introduced by Richard Feynman in 1982. Both practical and theoretical research continues, and many national government and military funding agencies support quantum computing research to develop quantum computers. Although quantum computing is still in its infancy, experiments have been carried out in which quantum computational operations were executed on a very small number of qubits (quantum bits). An example of an implementation of qubits for a quantum computer could start with the use of particles with two spin states: "down" and "up" (typically written $|\downarrow\rangle$ and $|\uparrow\rangle$, or $|0\rangle$ and $|1\rangle$).

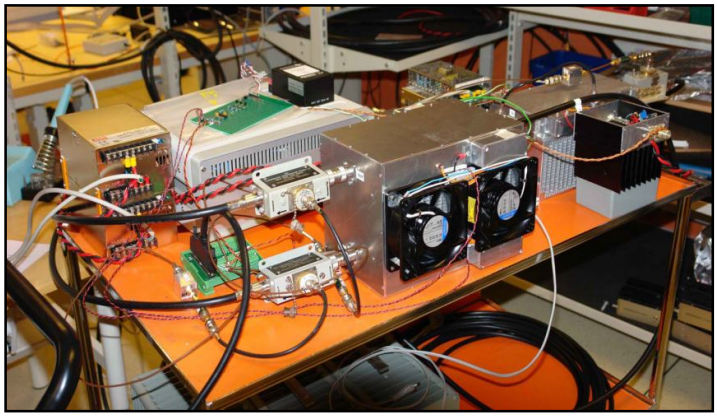

Figure 1: Quantum Computer at its initial stages of development at CRIAD Laboratories

Large-scale quantum computers will be able to solve certain problems much faster than any classical computer by using the best currently known algorithms, like integer factorization using Shor's algorithm or the simulation of quantum many-body systems. Advancing further, researchers at CRIAD Laboratories are successful in successfully utilizing the quantum mechanical property of self-force field of an electron through superposition principle operating in all the manipulations of qubits.

The study discusses the consistent classical theory of the radiation reaction and the self force is discussed which thereupon it is shown to obtain a phenomenological velocity depending Hamiltonian, representing a classical dissipative system, and to proceed to make the usual quantization with this Hamiltonian. Within this approach, one can, additionally, study the mathematical consistence of the Hamiltonian formalism in quantum mechanics[1-2]. In the remainder of the paper we formulate the idea mathematically & draw features of qubit operation with quantized state of electrons. It can give a classical representation of the phenomenon of pair production in sufficiently strong fields. This is of interest because the physical ideas of quantization may possibly be carried to give a clearer understanding of the whole theory of quantum computing.

2.Mathematical Formulation Of Self-Force Region Of Electron

In order to find the relativistic equation of motion of an electron with radiation reaction, we use the generalization rule that the ordinary velocity is replaced by the four velocity, thus V→ v^{σ} & $V.V \rightarrow -v^{\sigma}v_{\sigma}$. The minus sign shows up because for n=1,2,3 $v_n = -v^n$. With this the power scalar from (1) becomes

$$P = m\tau_o \dot{v^{\sigma}} \dot{v_{\sigma}} \quad (3)$$

Now, we generalize the traditional equation
of motion of a charged particle in an electromagnetic field, without radiation reaction, which is
given by $\frac{dp^{\mu}}{d\tau} = \frac{e}{c}F^{\mu\sigma}v_{\sigma}$ where $p^{\mu} = mv^{\mu}$ by adding the yet unknown radiation reaction force f^{μ}as:

$$m\frac{dv^{\mu}}{d\tau} = \frac{e}{c}F^{\mu\sigma}v_{\sigma} + f^{\mu} \quad (4)$$

& set about finding f^{μ}. If we generalize the force in the non-relativistic equation of motion with the radiation reaction effects given by:
$ma = F_e + m\tau_o\ddot{V}$, as $m\tau_o\ddot{V} \rightarrow m\tau_o\ddot{v^{\mu}}$, we obtain,

$$m\frac{dv^{\mu}}{d\tau} = \frac{e}{c}F^{\mu\sigma}v_{\sigma} + \tau_o\ddot{v^{\mu}} \quad (5)$$

Unfortunately this cannot be correct. This is because the four velocity satisfies the constraint $v^\sigma v_\sigma = c^2$. By differentiating this we find $\dot{v}^\sigma v_\sigma = 0$. This result states that the four acceleration is orthogonal to the four velocity, a result that will be used below. Differentiating this result, we find that $\dot{v}^\sigma \dot{v}_\sigma = -v^\sigma \ddot{v}_\sigma$, another result to be used below. Now we multiply (5) by v_μ(& sum over μ) & note that left side vanishes. Also, $F^{\mu v} v_\mu v_v$ vanishes because $F^{\mu v}$ is antisymmetric while $v_\mu v_v$ is symmetric in μ & v. But $v^\sigma \ddot{v}_\sigma$ does not vanishes, so the equation is inconsistent. To resolve that we simply add another term to make the equation consistent. This is valid as long as it disappears in the low velocity limit. It is easy to check that the added term should be $\tau_o v^\mu \dot{v}^\sigma \dot{v}_\sigma / c^2$ so the equation becomes

$$\frac{dv^\mu}{d\tau} = \frac{e}{mc} F^{\mu\sigma} v_\sigma + \tau_o \left(\ddot{v}^\mu + \frac{\ddot{v}^\mu}{c^2} \dot{v}^\sigma \dot{v}_\sigma \right) \quad (6)$$

A formal procedure to derive this may be viewed as follows. We generalize the work done, $\int F.V\, dt$ to $-\int f^\sigma v_\sigma d\tau$ (the trouble here is the breakup of the space part and the time part, the latter carrying information about power, but we assume that in the non relativistic limit the interpretation is correct), then, as before, we assume that "the negative of the work done on the electron is equal to the energy radiated," so that

$$\int f^\sigma v_\sigma d\tau = -\int P\, dt \quad (7)$$

Integrating by parts this may be written

$$\int v_\sigma d\tau \, (f^\sigma - m\tau_o v_\sigma \ddot{v}^\sigma) = \left| -m\tau_o v_\sigma \dot{v}^\sigma \right|_{\tau_1}^{\tau_2} \quad (8)$$

Since, $v_\sigma \dot{v}^\sigma$ vanishes we can read out f^σ from (8), so that 95) becomes (6). Which we can write as:

$$\frac{dv^\mu}{d\tau} = \frac{e}{mc} F^{\mu\sigma} v_\sigma + \mathcal{G}^\mu \quad (9)$$

3.Quantizing Stationary State Of Electrons In Its Self-Force Field

From equation (9)

$$\frac{dv^\mu}{d\tau} = a + \frac{\alpha\, \mathcal{G}^\mu}{m}$$

Where, $a = \frac{e}{mc} F^{\mu\sigma} v_\sigma$.

A constant of motion for this system is a function $K = K(x, \mathcal{G}^\mu)$ such that $\frac{dK}{d\tau} = 0$.

i.e. $\mathcal{G}^{\mu}\frac{\partial K}{\partial x}+\left(a+\frac{\alpha\,\mathcal{G}^{\mu}}{m}\right)\frac{\partial K}{\partial \mathcal{G}^{\mu}}=0$

The general solution is given by

$$K_{\alpha}(x,\mathcal{G}^{\mu})=G\big(C(x,\mathcal{G}^{\mu})\big)$$

Where, G is an arbitrary function of the characteristic curve $C(x,\mathcal{G}^{\mu})$ which can be given in following ways:

$$C_1=\frac{m\,a}{\alpha}\ln\left(1+\frac{\alpha\,\mathcal{G}^{\mu}}{m\,a}\right)+ax$$

Or

$$C_2=\left(1+\frac{\alpha\,\mathcal{G}^{\mu}}{m\,a}\right)e^{-ax/m}$$

Therefore,

$$K_{\alpha}{}^{(1)}(x,\mathcal{G}^{\mu})=\frac{m^2a}{\alpha}\ln\left(1+\frac{\alpha\,\mathcal{G}^{\mu}}{m\,a}\right)+ax$$

$$K_{\alpha}{}^{(2)}(x,\mathcal{G}^{\mu})=\frac{m^2}{\alpha}\left(a+\frac{\alpha\,\mathcal{G}^{\mu}}{m}\right)e^{-\frac{ax}{m}}+\frac{m^2a}{\alpha}$$

Thus, the associated Hamiltonian, $H(x,p)=K\big(x,v(x,p)\big)$, can be determined as

$$H_{\alpha}{}^{(1)}(x,p)=\frac{m^2a}{\alpha}\ln\left(1+\tan\left(\sqrt{\frac{\alpha}{ma}}\frac{p}{m}\right)\right)+max$$

$$H_{\alpha}{}^{(2)}(x,p)=\frac{p^2}{2m}\alpha\left(\frac{x\,p^2}{m^2}+ax^2\right)+max$$

The evolution of the quantum system characterized by the Hamiltonian $\widehat{H}^{(i)}$, being initially in the state $|\psi(0)\rangle$, is given by $|\psi(t)\rangle=U_i(t)\big||\psi(0)\rangle$, where U_i is the unitary evolution operator, $U_i(t)=e^{-it\widehat{H}^{(i)}/h}$. Thus,

$$\widehat{H}^{(i)}|n_i\rangle=E_{n_i}|n_i\rangle.$$

Given the initial state, the evolution is then written as

$$|\psi(t)\rangle=\textstyle\sum_{n_i}c_{n_i}\,e^{-\frac{iE_{n_i}t}{h}}\,|n_i\rangle,\quad\text{with}\quad c_{n_i}=\langle n_i|\psi(0)\rangle,$$

$i=1,2$.

The above derived Hamiltonian equation can be written as the following Hermitian operators

$$\widehat{H}^{(i)}(x,p)=\widehat{H}_o(x,p)+\widehat{W}^{(i)}(x,p)$$

Where, $\widehat{H}_o$ represents the non dissipative part of Hamiltonian,

$$\widehat{H}_o(x,p)=\frac{\widehat{p^2}}{2\,m}+max$$

& $\widehat{W}^{(i)}$ represents the contribution of the dissipation at first order in α,

$$\widehat{W}^{(1)}(x,p) = \frac{\alpha\,\hat{p}^4}{12\,a\,m^4}$$

& $$\widehat{W}^{(2)}(x,p) = \alpha\left[\frac{1}{3\,m^2}(x\hat{p}^2 + x\hat{p}^2 + \hat{p}x\hat{p})\right]$$

Therefore,

$$\widehat{H}_o(\hat{x},\hat{p})\psi_n^{(0)}(x) = E_n^{(0)}\psi_n^{(0)}(x)$$

Where the eigen value is given as:

$$\psi_n^{(0)}(x) = \frac{Ai(z-z_n)}{|Ai'(-z_n)|}$$

$$\& \; E_n^{(0)} = mal_a z_n$$

Where, $\psi_n^{(0)}(x) = \langle x|n\rangle$ is the zero order solution($\alpha = 0$). The function Ai & Ai' is the airy function & its differentiation with respect to z. The variable z is defined as $z = x/l_a$, where l_a is given by $l_a = \left(\frac{\hbar^2}{2m^2a}\right)^{1/3}$, & z_n is the nth-zero of airy function (Ai(-z_n)=0). At first order in perturbation theory is

$$\langle n|\widehat{W}^{(2)}|n\rangle = \alpha\frac{4a{l_a}^2{z_n}^2}{15}$$

Using, $\langle n|d^4/dz^4|n\rangle = {z_n}^2/5$

$$\langle n|\widehat{W}^{(1)}|n\rangle = -\alpha\frac{\hbar^4{z_n}^2}{60\,a\,m^4\,{l_a}^4}$$

Therefore, for the same classical dynamical system we have two different associated quantum systems which have completely different quantum dynamics, which is shown through the eigen values

$$E_n^{(1)} = E_n^{(0)} + \alpha\frac{4a{l_a}^2{z_n}^2}{15}$$

&

$$E_n^{(2)} = E_n^{(0)} - \alpha\frac{\hbar^4{z_n}^2}{60\,a\,m^4\,{l_a}^4}$$

4.Determination of qubit gates from rotation operations

Gate, an abstraction that represents information processing is a unitary operator in quantum computing. In this section we construct single qubit operations in quantum computing. Three main single qubit gates implemented here are NOT gate, Phase-flip gate and Hadamard gate.

4.1.NOT Operation

Applying NOT operator to a state vector, exchanges the probabilities of between the two states. NOT operator is physically implemented by lowering the potential barriers $E_n^{(1)}$& applying work function $\widehat{W}^{(1)}$ for a time period $\Delta t = \frac{\varphi}{|\vec{\Gamma}|} = \frac{\hbar}{2\gamma}\pi$. In coherence vector space, this event is represented by rotation of the coherence vector ($\vec{\lambda}$) by an angle π around the x-axis. The rotation operator for a NOT-Operation is obtained by substituting $\varphi = \pi$

$$\widehat{U}_{not} = \hat{R}_{-x,\varphi=\pi} = e^{i\sigma_x\left(\frac{\pi}{2}\right)} = \cos\left(\frac{\pi}{2}\right) I - i\sin\left(\frac{\pi}{2}\right)\widehat{\sigma_x} = \begin{pmatrix} 0 & i \\ i & 0 \end{pmatrix} = i\sigma_x$$

4.2.Hadamard Operation

Hadamard gate creates superposition states in quantum algorithms. When it is applied to a qubit, interference between the basis states occurs.

$$\widehat{U}_H|\Psi\rangle = \left(\frac{\alpha+\beta}{\sqrt{2}}\right)|0\rangle + \left(\frac{\alpha-\beta}{\sqrt{2}}\right)|1\rangle$$

There are several ways of implementing a Hadamard gate in a Bloch sphere. One way of implementation is by rotating λ about the Y-axis followed by reflection in the X-Y plane. Operator for Hadamard gate is

$$\widehat{U}_H = \hat{R}_{x,\frac{\pi}{2}}\ \hat{R}_{y,\frac{\pi}{2}} = \frac{-i}{\sqrt{2}}\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix} = i\sigma_x$$

4.3.Phase Flip Operation

The Phase flip gate takes the qubit $|\Psi\rangle = \alpha|0\rangle + \beta|1\rangle$ to the state $|\Psi\rangle = \alpha|0\rangle - \beta|1\rangle$. In Bloch sphere it is represented by rotation of λ around Z-axis by an angle π. Physically this is implemented by raising the potential barrier $\gamma << E_n^{(2)}$ and applying higher bias $\widehat{W}^{(2)}$ as input condition. The operator represents the phase flip operation.

$$\hat{R}_{-z,\varphi=\pi} = \begin{pmatrix} e^{-i\left(\frac{\pi}{2}\right)} & 0 \\ 0 & e^{i\left(\frac{\pi}{2}\right)} \end{pmatrix} = -i\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$$

The phase flip state obtained at the output cannot be physically distinguished from the input because the probability of the output state is same as that of the input state.

However when this state interacts with other cells it might affect their states and cause measurable changes.

5.Conclusion

We have shown two constants of motion, two Hamiltonians for a charged particle moving in a media with quadratic velocity dissipative force. These quantities describe the same classical dynamics of the dissipative system. However, it is showed by us that, at first order in the dissipative parameter and at first order in perturbation theory, that their quantization describes two different quantum dynamics which can be realized as the quantum bit or qubit state of an electron. Both quantum Hamiltonians, describes the same quasi-classical dynamics and coincides with the classical electrodynamics within the limit $\hbar \rightarrow 0$ (or $n >> 1$). The parameters that control the environment are given in coherence space representation and quantum operations are performed. The change in parameters is represented as change of angle and phase in the Bloch sphere representation. The three basic single qubit operations namely NOT, Hadamard, and Phase flip are realized using the rotation operators.

6.Reference

1. G. A. Mourou, T. Tajima, and S. V. Bulanov, Rev. Mod. Phys. 78, 309 (2006).
2. For an introduction to this, see P. Vickers, Brit. J. Phil. Sci. 59, 767 (2008).
3. Craig S. Lent, P. Douglas Tougaw, Nanotechnology, 4 (1993) 49-57.
4. David McMahon, Quantum Computing Explained John Wiley & Sons, Inc., Publication, New Jersey (2008).
5. Geza Toth and Craig S. Lent Phy. Rev. A, Vol. 63, 052315
6. Geze Toth, Craig S. Lent, Superlattices Microstruct., Vol-20, No. 4, 1996.
7. G.L. Snider, A.O.Orlov, I. Amlnni, G. H. Bernstein, C. S. Lent, J.L Merz and Q.Porod; Solid-State Electron., Vol-42,7-8.pp.1355-1359 1988.
8. K. Goser, P. Glosekotter, V. Dienstuhl, “Nano Electronics and nano systems”, springer, 2004.
9. R. Bose, H.T. Johnson, Microelectron. Eng., 75 (2004) 43-53.