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Possibility of high performance quantum computation by superluminal evanescent photons in living systems

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ABSTRACT

Penrose and Hameroff have suggested that microtubules in living systems function as quantum computers by utilizing evanescent photons. On the basis of the theorem that the evanescent photon is a superluminal particle, the possibility of high performance computation in living systems has been studied. From the theoretical analysis, it is shown that the biological brain can achieve large quantum bits computation compared with the conventional processors at room temperature.

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1. Introduction

Penrose (1989, 1994, 1999) proposed his idea on the connection between fundamental physics and human consciousness in his books, in which he argued the possibility of quantum computation in human brains, which are superior to conventional computer systems.

Hameroff and Penrose (1996) have constructed a theory, in which human consciousness is the result of quantum gravity effects in microtubules, which they dubbed Orch-OR (orchestrated object reduction) that involves a specific form of quantum computation conducted at the level of synapses among brain neurons. They have suggested that microtubules in brain neurons function as quantum computers with tublin proteins in macrotubles acting as a quantum bits of computation through two-state q-bits formed from tublin monomers. Vitiello (1995) proposed that consciousness mechanisms in the brain was achieved by the condensation of collective modes (called Nambu–Goldstone bosons) in the vacuum.Jibu et al. (1994, 1996, 1997b) and Jibu and Yasue (1997a) also proposed that the conscious process in the brain was related with the macroscopic condensates of massive evanescent photons generated by the Higgs mechanism, i.e. that of general biological cell functioning arising from dynamical effects of electromagnetic interaction among electric dipoles in biological systems, which were studied by Del Giudise et al. (1986). They claimed that human consciousness could be understood as arising from those creation-annihilation dynamics of a finite number of evanescent (tunneling) photons in the brain. They also considered that each microtubule was a coherent optical encoder in a dense microscopic optical computing network in the cytoplasm of each brain cell, acting as a holographic information processor. Faber et al. (2006) proposed the models of the mind based on the idea that neuron microtubules could perform computation and they estimated the favorable condition for storage and information processing, which was found at temperatures close to the human body. However, Tegmark (2000) published a refutation of the Orch OR model in his paper that the time scale of neuron firing and excitations in microtubules was slower than the decoherence time by at least $1/10^{10}$. According to his paper, it is reasonably unlikely that the brain functions as a quantum computer at room temperature. But some researches suggest that the brain requires quantum computing for perception (Bialek and Schweitzer, 1987), which means that the human brain has to work as a quantum processing system. Hameroff (1982) proposed the idea in his paper that the biological information processing could be occurred by computer-like transfer and resonance among subunits of cytoskeletal proteins in microtubules. Subsequently to it, Hameroff and Tuszynski (2004) published a paper that microtubule subunit tublins underwent coherent excitations which led to the automatic sequence, where quantum coherence superposition was emerged in certain tublins, and consciousness was occurred in the brain. In this article, the author studies the possibility of quantum computation in microtubules of the biological brain at room temperature based on the theory that the evanescent (tunneling) photons moves at a superluminal speed as claimed by Recami (2001).

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2. The Possibility of Superluminal Speed in Quantum Region Within Microtubules

The evanescent photon generated in quantum domain satisfies the following Klein–Fock–Gordon equation given by

$$\left(-\frac{1}{c^2}\frac{\partial^2}{\partial t^2}+\nabla^2-\frac{m_*^2c^2}{\hbar^2}\right)A(x,\ t)=0, \tag{1}$$

where c is the light speed, m_* is an absolute value of the proper mass of the evanescent photon and $\hbar$ is the Plank constant divided by 2π.

This equation has the solution for the photon traveling in an evanescent mode given by

$$A(x,\ t)=A_0\ \exp\left[-\frac{Et+px}{\hbar}\right], \tag{2}$$

which corresponds to the elementary particle with an imaginary mass im_* that travels at a superluminal speed satisfying

$$E^2=p^2c^2-m_*^2c^4, \tag{3}$$

where E is the energy and p is the momentum of the superluminal particle given by

$$E=\frac{m_*c^2}{\sqrt{v^2/c^2-1}}, \tag{4}$$

and

$$p=\frac{m_*v}{\sqrt{v^2/c^2-1}}. \tag{5}$$

respectively. From which, it is seen that tunneling photons traveling in an evanescent mode can move at a superluminal speed. By the superluminal property of evanescent photons, the higher capability of computation in living systems can be shown as follows.

3. Uncertainty Principle for the Superluminal Elementary Particle

From relativistic equations of energy and momentum of the moving particle, shown as

$$E=\frac{m_0c^2}{\sqrt{1-v^2/c^2}}, \tag{6}$$

and

$$p=\frac{m_0v}{\sqrt{1-v^2/c^2}}, \tag{7}$$

we have the relation shown by $p/v=E/c^2$.From which, we have

$$\frac{v\ \Delta p-p\,\Delta v}{v^2}=\frac{\Delta E}{c^2}. \tag{8}$$

Supposing that $\Delta v/v^2\approx 0$, Eq. (8) can be simplified to

$$\Delta p\approx\frac{v}{c^2}\Delta E. \tag{9}$$

It can be shown that this relation is also valid for the superluminal particle (Musha, 2005, 2006), where its energy and momentum are given by Eqs. (4) and (5), respectively.

According to Park and Park (1996), the uncertainty relation for the superluminal particle can be given by

$$\Delta p\cdot\Delta t\approx\frac{\hbar}{v-v'}, \tag{10}$$

where v' and v are the velocities of a superluminal particle before and after the measurement.

By using Eq. (9), Eq. (10) can be rewritten as

$$\Delta E\cdot\Delta t\approx\frac{\hbar}{\beta(\beta-1)}, \tag{11}$$

when we let $v'=c$ and $\beta=v/c$.

4. Energy Cost for the Quantum Tunneling Photon Computation

Feynman (1986) discussed the possibility of a quantum computer by taking an example of reversible computing and showed that computational energy cost versus speed was limited by energy dissipation during computation. Benioff (1982) showed that the computational speed was close to the limit by the time-energy uncertainty principle. Margolus and Levitin (1998) also have shown that the number of elementary operations that a physical system can perform per second is limited by $2E/\pi\hbar$, where E is an averaged energy to perform computation.

From which, the minimum energy to perform computation satisfy the relation $E_0\approx\Delta E$, where E_0 is a minimum averaged energy required to perform computation and ΔE is an uncertainty of energy to perform computation.

Then we have

$$E_0\approx\frac{\hbar}{\Delta t}, \tag{12}$$

where Δt is a operational time of an elementary logical operation.

Instead of a logical gate utilizing particles moving at subluminal speeds including photons, energy required for the logical gate utilizing superluminal tunneling photons becomes

$$E_0'\approx\frac{\hbar}{\beta(\beta-1)\Delta t}. \tag{13}$$

As an uncertainty in the momentum of tunneling photons moving at the superluminal speed can be given by

$$\Delta p=\frac{m_*v}{\sqrt{v^2/c^2-1}}-\frac{\hbar\omega}{c}, \tag{14}$$

where ω is an angular frequency of the photon, the velocity of the tunneling photon can be estimated as (Musha, 2005, 2006)

$$v\approx c\left(1+\frac{1}{\sqrt{\omega\ \Delta t}}\right). \tag{15}$$

Then the time for a photon tunneling through the barrier with the distance of d can be roughly estimated as by $\Delta t=d/v$. Thus the velocity of the tunneling photon becomes

$$v\approx c\left(1+\frac{c}{2\omega d}+\sqrt{\frac{c}{\omega d}+\frac{c^2}{4\omega^2d^2}}\right). \tag{16}$$

If we let T is the relaxation time of a single qubit and Δt is the operation time of a single logical gate, the figure of merit for computation can be defined as $R=T/\Delta t$ (Haroche and Raimond, 1996), which is on the order of the number of qubits times the number of gate operations. As a superposition state of the L-qubits system would cause decoherence approximately 2^L times faster than a superposition state of one qubit (Gea-Banacloche, 2005), then the relaxation time of the L-qubits system can be roughly estimated to be 2^{-L} times the relaxation time of a single qubit computation. Thus the minimum energy required to perform quantum computation for the L-qubits system can be given from Eq. (12) as

$$E_0\approx\frac{\hbar v_G L}{T}2^L, \tag{17}$$

where v_G is the number of gate operations.

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