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Leptons Based Quantum Computing

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Abstract

The transformation of digital computers from large installations to portable systems has been enabled by advanced processing technologies that allow ultrahigh integration of devices with atomic- scale dimensions increasingly possess properties that are dominated by quantum physics. The leptons: the electron (e), the muon (μ), and the tauon (τ) are the good candidates to be quantum information particles (qubits); after all they have an associated anti-particle, which has the same mass but opposite charge.

Keywords: Digital Computers; Electron; Leptons

Introduction

If we consider the universal introduction of quantum computing as one of the last remarkable achievements of the end of twentieth century, we should recognize the development of quantum information technologies as the most important achievement of the first decades of the twenty-first century. Now, in the quantum era, the most interesting prospect is the creation and use of quantum computers and their networks. As the Moore law gradually loses its effect, conventional charge-based electronics will come to the end in the near future. Developing alternative high speed and low energy consuming information technology is urgently needed. Up to now, many new methodologies have been proposed, such as molecular electronics, nanoelectronics, spintronics, quantum information techniques, etc. Modern Electronics (Micro Nano Spin Electronics) and its development. In parallel, quantum information science has emerged as an alternative to conventional transistor technology, promising new paradigms in computation, communication and sensing.

Discussion

The convergence between quantum materials properties and prototype quantum devices is especially apparent in the field of 2D materials, which offer a broad range of material's properties, high flexibility in fabrication pathways and the ability to form artificial states of quantum matter. Along with the quantum properties and potential of 2D materials as solid- state platforms for quantum- dot qubits, single- photon emitters, superconducting qubits and topological quantum computing elements it is necessary to select the best method of preparation spinqubit nanosystems.

Based on difference from conventional electronics e electron's which uses the electron's charge degree of freedom for information processing, spintronics is devoted to incorporating the electron's spin degree of freedom. In an ideal situation, there will be purely spin current and no charge current in the spintronic circuit, thus practically no heat will be created and wasted. Meanwhile, information will be transmitted at a high speed owing to the spin coherence effect. Despite its great potential advantages, spintronics now faces a number of challenges, such as generation of fully spin-polarized carriers (pure spins) and injection of spin into devices, long distance spin transport, and manipulation and detection of carriers' spin orientation. The solutions to these issues rely on the development of device fabrication and designing new spintronics materials with specific properties. As with spin manipulation and detection, there are some methods based on the coupling effects between spin and light, magnetic field, electric field, According to their electronic and magnetic properties, spintronics materials can be classified as magnetic metals, topological insulators, and magnetic semiconductors. In a spintronic device, magnetic metals and topological insulators, serve as spin sources and drains, while magnetic semiconductors constitute the central region of the device. In the three components, spin manipulation detection can be performed separately based on the coupling effects between spin and light, magnetic field or electric field.

Despite of the fact that photon is a boson with spin 1, which is a typical boson spin, it is also a good candidate to be an quantum information particle (qubit). A qubit itself is a symmetrical quantum system and it could be representing by two optical modes, mainly spatial or polarization ones. Using the single photon with two optical modes of internal polarization degree of freedom we are coming to term “polarization qubit” which together with so called “dual-rail” qubits is the main engine for organization of nonlinear quantum computing.

In linear optical quantum computing the basic building blocks are beam splitters, half- and quarter-wave plates, phase shifters, etc. Important optical component is the single-mode phase shift, which changes the phase of the electromagnetic waves by using the of transparent material covers with an index of refraction different from the outside space. Physically, it consists of a semi-reflective mirror: when light falls on this mirror, part will be reflected and part will be transmitted. The main characteristic of photonic computing process is the effect of nonlinearity of computation. Design of photonic computers was inspired by the theoretical Ising model is based on lasers, mirrors, and other optical components commonly found on an optical table.

Basic features for possible realization of quantum optical computer using quantum photonic treatment is based on corpuscular nature of light. Photons refraction phenomenon when travel through the interface between two different transparent solids is simulated, and photons, as signal carriers are tracked by controlling Short Range Interatomic Forces.

Leptons are fermions - particles with ½ and they are an important part of the Standard Model. Following the spin-statistics (spin-communication theorem) theorem which states that one fermion can exist in a given quantum state and no two leptons of the same species can be in the same state at the same time. Following this a lepton can have only two possible spin states - up or down. The charged lepton is the electron; the next lepton to be observed was the muon, which was classified as a meson at the time. After investigation, it was realized that the muon has not the expected properties of a meson, but rather behaved like an electron, but with higher mass. Another lepton the first neutrino, the electron neutrino, was proposed in order to explain certain characteristics of beta decay. The muon and the tau neutrinos were discovered were discovered later up to end of 20th century.

An important property of Leptons is chirality, which in turn is closely related to a more easily visualized property called helicity. The helicity of a particle is the direction of its spin depending of its momentum; particles with spin in the same direction as their momentum are called right-handed and particles with different direction spins called left-handed. In quantum field theory (quantum electrodynamics and quantum chromodynamics) left- and right-handed fermions are identical. However, the Standard Model’s Weak interaction treats left-handed and right-handed fermions as asymmetrical: Only left-handed fermions (and right-handed anti-fermions) participate in the weak interaction. Right-handed neutrinos and left-handed anti-neutrinos have no possible interaction with other particles.

Today usage of electron spins as quantum bits for quantum information processing in so called quantum computers, were a qubit exists in more than one state simultaneously (until its state is measured), is clear. Qubits in this state display a degree of correlations impossible in classical physics. This phenomenon is called entanglement and is crucial property of quantum computing. It is also possible to create qubits as the up/down and spin-states of electrons on quantum dots. In this case it is impossible to control the state of a single electron well enough to perform calculations using them. According the known properties of neutrinos that: each neutrino flavor state is a linear combination of the three discrete mass eigenstates, the flavor eigenstates (creation and annihilation combinations) are not the same as the neutrino mass eigenstates and they are in associated specific quantum superposition. Following this it is possible to consider this family as a good candidate to be the qubit for quantum information systems.

Conclusions

Finally, when we are choosing the particles for quantum computing we should consider that the candidate for a qubit generally needs to have the quantum properties of superposition and entanglement. There a are also the main technical requirements of quantum computation which are: scalable physical systems with well characterized qubits (Zeeman Splitting); long decoherence time higher than gate operation one; existence of qubits at the ground state; set of quantum gates; measurement capabilities, etc. Leptons – fermions (electrons, protons, neutrons, muons, tauon and even neutrinos) as we know have that kind of properties. Concerning the photons – bosons particles with frequency-dependent energy collecting into the same energy state (Bose-Einstein condensation), they also could acting as a qubits because of polarization effects they characterized. The usefulness the other boson particles as quantum information carriers is the very interesting task current and future research works.

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