Revolutionary Implications of Nuclear Waste Disposals by Quantum Entanglement: Prospective Frontier of Nuclear Engineering by the U.S. National Quantum Computing Initiative

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1. Introduction

President Donald J. Trump proposed for the National Quantum Computing Initiative Act in the United Sates [1]. The quantum mechanics is applied to our lives from the invisible subatomic world to the information and knowledge in the real-life of humans where the theoretical implications could be the consequences as the communications and simulations purposing job creations and industrial promotions. The abundant goals in the quantum regions would be manipulated including the tiny nuclei which can be informed by the quantum computation. The basic feature is in Fig. 1 in which the interest of quantum is extended to the level of the Quark. Until the initiative, there are quantum applications as semiconductor manufacturing, photonics, global positioning systems, magnetic resonances, and more areas to our society. This act could give the potential future with aggressively and beneficially to our lives.

Quantum computing is based on the quantum computer which has the abilities of faster calculations as well as the encryptions [2]. There are two characteristics of the quantum computing as superposition and entanglement in the quantum manipulations. Fig. 2 shows the description of quantum computing. The superposition is described by the Qubit which is positioned 0 or 1 quantum state. The conventional bit exists only as 0 or 1 state individually. By the way, the Qubit could be in simultaneously as well as separately. The entanglement can be expressed by the quantum spin which is one of particular quantum numbers. The quantum state in superposition produces a new kind of quantum state where the Qubits can be in a superposition of both the basis states $|0\rangle$ and $|1\rangle$ and then *n* Qubits could give the 2^{nd} states. Otherwise, a pair or group of particles can be entangled when the quantum states of each particle give the different quantum states in dependent situation [3].

In the applications, there are academic studies on the nuclear industry where an efficient fuel arrangement with the quantum annealing, a Qubit based computing, reactor reload matters, and the nuclear security by quantum cryptography have been investigated in Fig. 3 [4-7].

2. Methods

Table 1 is the list of selected physical implementations in quantum [8] where there is quantum information as the spin, charge, or polarization with the quantum descriptions. For the graphical feature, Fig. 4 shows the Bloch sphere for Qubit [8] in which the quantum numbers are described by the Bloch sphere. The states are described by the spin of the quantum which could be applicable to the designed purposes such as information transfer. In the particular characteristics of quantum mechanics, the meaning of quantum entanglement is one who has already observed one quantum state, then the observer can observe the other, which is described in Fig. 5. Schrödinger's cat experiment shows it is impossible to know the cat's death by poison leaked out of the bottle that could be broken by the radioactive timer [9].

In this work, the nuclear waste repository is modelled for the application entanglement in the quantum computing. Fig. 6 shows the configuration of high-level nuclear waste repository. For description of the quantum computing applications, Fig. 7 is the transportations of quantum entanglement in the repository site. The proposed 'Quantum Separation Transmitter' can produce a sampled quantum which is decayed following the time based decay chain from the uranium of the high-level nuclear fuel waste. The decayed quantum is emitted to another proposed 'Quantum Separation Receiver' in out side of the repository. There is the basic principle of the entanglement of quantum computing. For the mathematical form, the linear notion of a single Qubit is [8],

$$|\psi\rangle = \alpha\,|0\rangle + \beta\,|1\rangle \quad (1)$$

There is the constraint as,

$$|\alpha|^2 + |\beta|^2 = 1 \quad (2)$$

There are the presentations of Bloch sphere in Fig. 4 [10]. There are the descriptions of quantum entanglement. Two entanglement qubits in the $|\Phi^+\rangle$ Bell state as,

$$\frac{1}{\sqrt{2}}(\,|00\rangle + |11\rangle\,) \quad (3)$$

So, the basis states are as,

$$|00\rangle \mapsto |00\rangle \quad (4)$$

$$|01\rangle \mapsto |01\rangle \quad (5)$$

$$|10\rangle \mapsto |11\rangle \quad (6)$$

$$|11\rangle \mapsto |10\rangle \quad (7)$$

The spins are shown [8] in Table 2 which is the list of selected physical implementations in quantum [11]. Table 3 is the list of the quantum states [12]. In the normal state, most molecules are in a singlet state. Fig. 8 is the proposed mapping of the quantum entanglement system in nuclear waste repository. Outside of the repository, 'Central Quantum Entangle Receiver System (CQERS)' would be constructed, which is in Fig. 9. This is the principle of the nuclear magnetic resonance imaging (MRI) system where the electromagnet and coil system can produce the high frequency wave and then the spin could be arranged linearly. So, the direction of spin of each proton is formed after disconnecting of the high frequency wave. Then, one can find the atomic number of inside atom of repository. Fig. 10 has the simplified decay chain of the uranium nuclear waste form where the uranium is the initial atom of 92 protons in the decay chain [13].

3. Results

The simulations are done by the 'Quantum Separation Transmitter' where the protons in fermion are transmitted as the singlet spin. Then the atomic states of the transmitted are found. Fig. 11 shows the proton numbers in the interested region where the 92 is in the initial time during 1000 years. Then the singlet state in the CQERS is in the initial state. As time goes on, the graph would be changed to lower proton numbered atom.

4. Conclusions

The $|\Phi^{+}\rangle$ Bell state forms part of the setup of the superdense coding, quantum teleportation, and entangled quantum cryptography algorithms [8]. Following the application of the high-level nuclear wastes, the quantum computing usages could be extended in the nuclear industry. Furthermore, the reactor analysis in the aspect of the complex calculations of the neutron transportations can be applied using quantum computing as the aspect of the quantum characteristics. In addition, it is imaginable to change the concept of conventional cross section, the basic and most important factor in the nuclear science and technology, is from the probability to spin's erections, which is in Fig. 12.

It is needed to develop the CQERS with 'Quantum Separation Transmitter'. Although the CQERS is similar to the conventional MRI theory, the 'Quantum Separation Transmitter' should be developed for the very long term operation, that is needed inside of the repository. This could be applicable to the other kind of industrial apparition for the geological feature in the deep position below ground to find out the integrity of the seismic state. In addition, the neutron and nuclear fuel state in the operating reactor could be detected in the real-time. There could be imaginable for much more applications in the entanglement as well as superposing of quantum computing. Fig. 13 shows the possible future of the nuclear science and technology by quantum computing.

Acknowledgements

This study was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea Ministry of Science and ICT (NRF2020M2B5A1110908 11).

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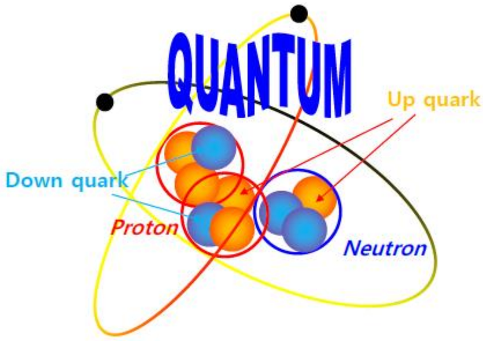

Fig. 1. Feature of quantum.

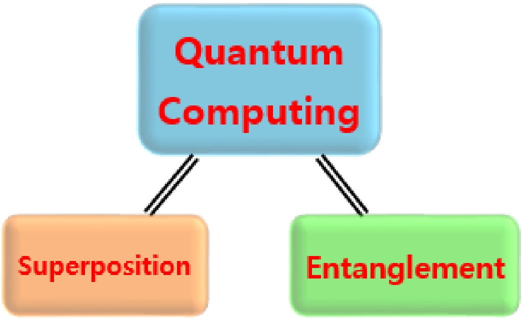

Fig. 2. Description of quantum computing.

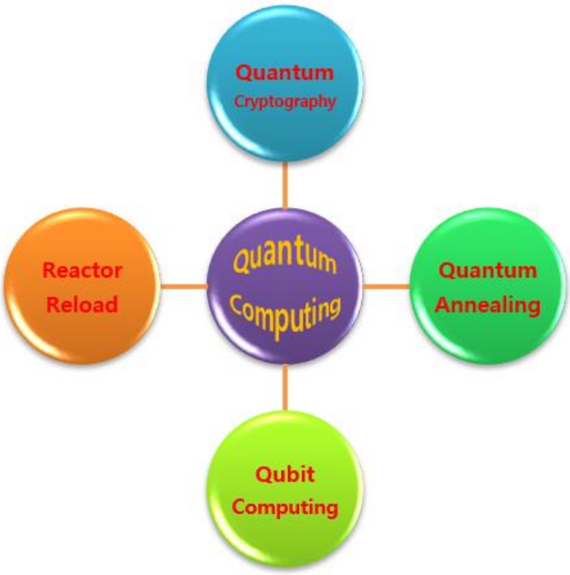

Fig. 3. Quantum computing in nuclear industry.

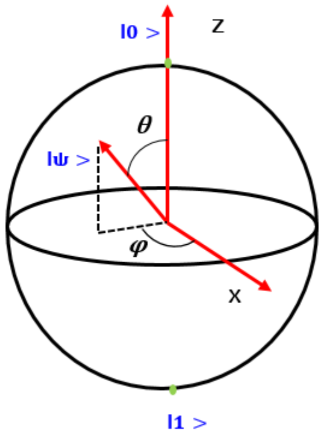

Fig. 4. Bloch sphere for Qubit [9].

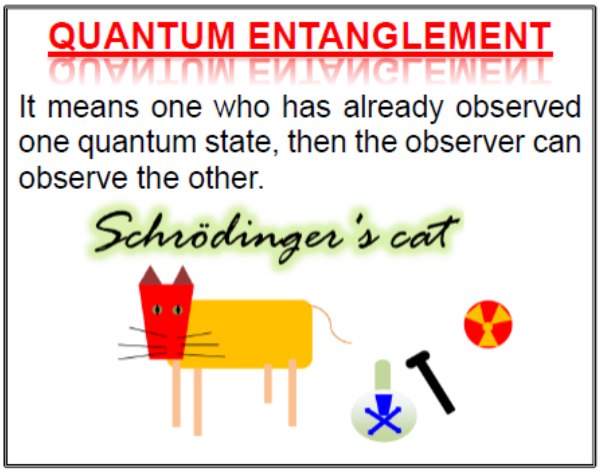

Fig. 5. The meaning of quantum entanglement.

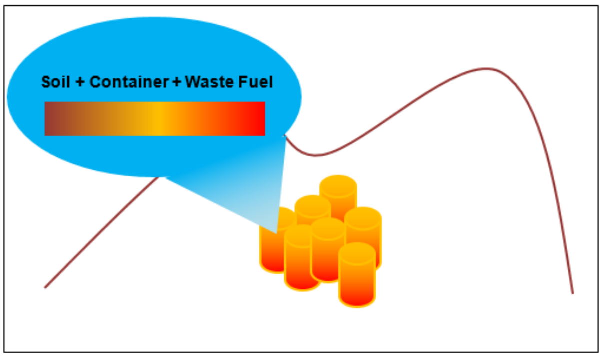

Fig. 6. Configuration of high-level nuclear waste repository.

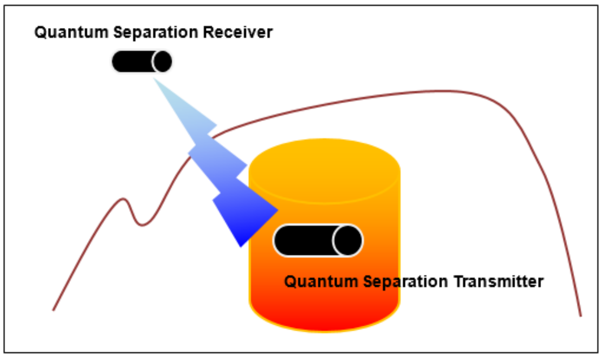

Fig. 7. Transportations of quantum entanglement in the repository site.

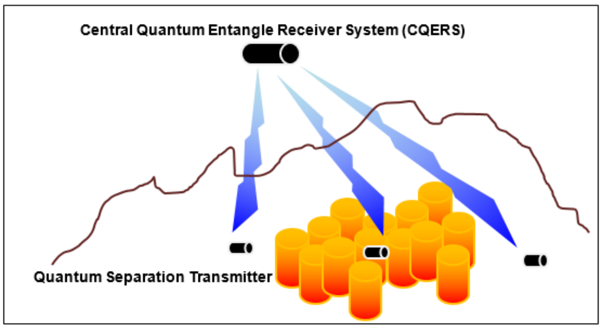

Fig. 8. Proposed mapping of the quantum entanglement system in nuclear waste repository.

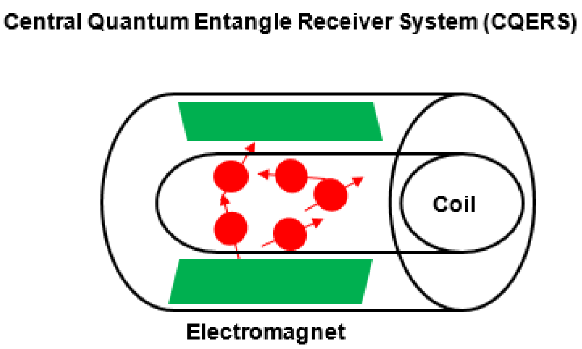

Fig. 9. Proposed Central Quantum Entangle Receiver System (CQERS).

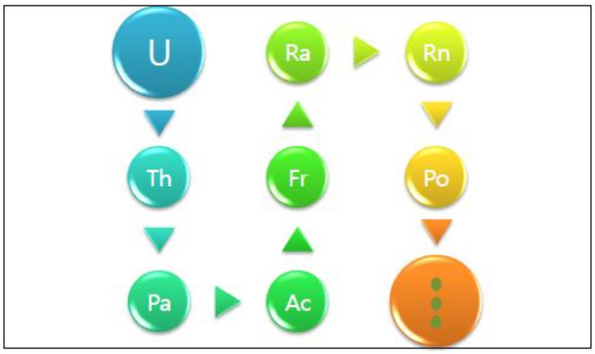

Fig. 10. Simplified decay chain of the uranium nuclear waste form [11].

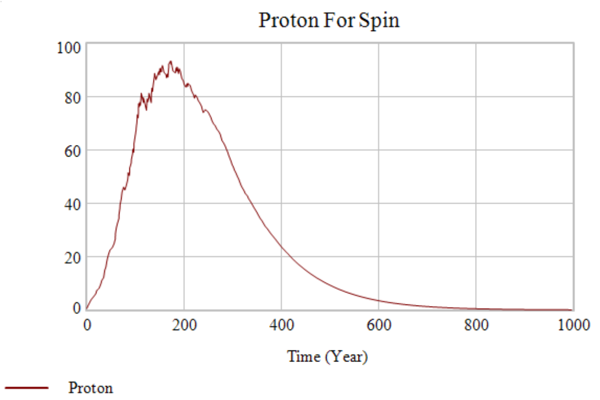

Fig. 11. Proton numbers in a region.

Fig. 12. Conceptual changing of cross section.

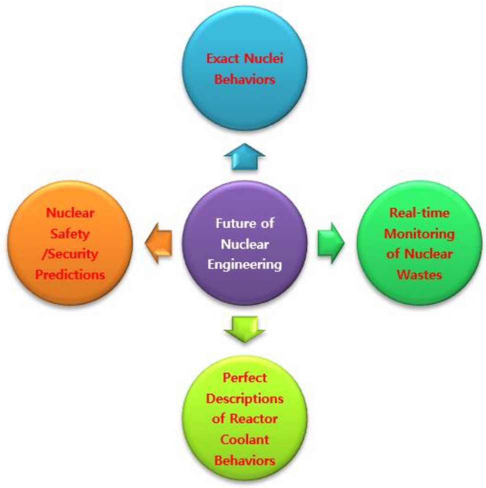

Fig. 13. Future of the nuclear science and technology by the quantum computing.

Table I: List of selected physical implementations in quantum [8]

Quantum	Information	∣ 0⟩	∣ 1⟩
Electron	Spin	Up	Down
	Charge	None	One electron
Nucleus	Spin	Up	Down
Optical Lattices	Spin	Up	Down
Quantum Dot	Dot Spin	Down	Up
Photon	Polarization of Light	Horizontal	Vertical

Table II: List of spins in quantum [11]

	Fermion	Boson
Quantum	Proton, Neutron, Electron, Neutrino	Photon, Gluon, Higgs, Gravity
Spin	Half-integer	Integer

Table III: List of the quantum states [12]

	Singlet	Doublet	Triplet
Spin	0	1/2	-1, 0, +1