Linear Superposition as Temporal Oscillations

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Abstract:

The linear superposition principle and the quantum entanglement phenomenon play crucial roles in the fields of quantum computing and information. Their current interpretations are not satisfactory. To reduce the measurement-bias of the current interpretation, this paper presents an alternative interpretation for the quantum linear superposition principle: A physical quantity of a quantum object keeps oscillating between the allowed values of the physical quantity. Thus, a quantum system is inherently deterministic, but it appears to be probabilistic because of randomness in timings of measurements. Then, to show that the so-called quantum entangled need not interact or communicate with each other, the paper presents an alternative interpretation of the quantum entanglement phenomenon: Quantum objects appear to be entangled if and when each physical quantity of these objects undergoes synchronous oscillations. An experimental method is presented to validate this interpretation. Quantum entanglement due to synchronous oscillations can lead to more and better ways of emulated quantum computers. A possible schema of an emulated quantum computer is presented.

1. Introduction

At the heart of the rapidly advancing fields of quantum computing and quantum information [1] is the phenomenon of so-called quantum entanglement [2] [3] [4]. Nelson and Chuang [1] have called quantum entanglement “iron to the classical world’s bronze age”, and “a fundamental resource of Nature, of comparable importance to energy, information, entropy, or any other”. Thus, a sound understanding of this phenomenon is of paramount importance for the progress of these fields. At the heart of the phenomenon of quantum entanglement is the principle of so-called linear superposition [5]. Therefore, a sound understanding of this principle is of paramount importance for understanding the phenomenon of quantum entanglement.

The linear superposition principle is a foundational principle of quantum mechanics [5]. The current probabilistic interpretation [6] [7] of this principle and of quantum mechanics gives too much weight to measurements [8]. This interpretation indirectly implies that a quantum system’s actual state is irrelevant without measurements; it is like saying that there is no sound unless it is heard. This interpretation cannot satisfactorily explain the quantum entanglement phenomenon [2] [3] [4]. Some physicists [9] had attempted to explain quantum mechanics in terms of hidden variables or pilot waves. However, such explanations were too laden with words and were proved to be invalid. To avoid these shortcomings, this paper presents an alternative interpretation: A physical quantity of a quantum object keeps oscillating between the allowed values of the physical quantity. For example, an electron has pendulum-type spin (oscillating between two values) instead of a gyroscopic spin (having a fixed value). Thus, a quantum system is inherently deterministic, but it seems to be probabilistic only because of randomness in timings of measurements.

There have been tremendous efforts in recent years to better understand and nail down the phenomenon of quantum entanglement. However, our understanding so far is far from satisfactory. The current interpretation implicitly assumes that two so-called quantum-entangled objects have to interact with each other for their measured values to synchronize. It indirectly implies a spooky action at a distance, and leads to the EPR paradox [10]. It cannot explain quantum entanglement observed in many biological [11] [12] and abnormal settings. To resolve these issues, this paper presents a different interpretation for the quantum entanglement phenomenon: Quantum objects appear to be entangled if and when a physical quantity of these objects undergoes synchronous oscillations. The paper proposes an experiment similar to experiments [13] carried out so far to validate this interpretation.

The interpretations proposed here have far-reaching implications and many practical applications. Quantum entanglement based on synchronous oscillations may rule out the possibility of quantum communication and teleportation. However, it implies more and better possibilities of quantum computing. It can lead to new types of hardware or software based emulated quantum computers [14] [15] [16] [12] [17], which can be more powerful and reliable than emulated quantum computers proposed earlier. The paper briefly describes a possible schema of an emulated quantum computer, based on quantum entanglement due to synchronous oscillations.

2. Linear Superposition

A quantum system ψ is generally expressed as a linear superposition [5] of its basis states.

$$\psi = \sum_{i=1}^{n} C_i \, |i\rangle$$

According to the currently-held probabilistic interpretations of quantum mechanics, a measurement of a quantum system reveals a random basis state $|j\rangle$ with a probability $\overline{C_j} C_j$. These interpretations attach too much importance to measurements, as if a system has no meaning until it is measured. These interpretations fail to explain why a measurement reveals only a certain basis state. Moreover, these interpretations fail to explain the quantum entanglement phenomenon adequately.

It is important to keep in mind that not all allowed states of a system, whether classical or quantum, can be reversible. In the famous thought experiment of Schrodinger's cat, the cat has two allowed states: 'living' and 'dead'. These two allowed states are of quite different nature; a 'living' state can transfer to a 'dead' state, but a 'dead' state cannot transfer to a 'living' state. While the cat is in a 'living' state, it can have allowed sub-states of 'sitting', 'standing', and 'moving'. Unlike a 'dead' state, these states are reversible, in the sense that the cat transfer from one of these three states to any of the other two states (if the cat is not sick).

In the thought experiment of Schrodinger's cat, it is not necessary to open the door and disturb the cat to know whether the cat is living or dead. If the box makes continuous or intermittent sounds, it can indicate that the cat in a living state. If the box remains silent for a prolonged period, it can indicate that the cat in a dead state. There is no proof so far that a quantum system's state cannot be known without disturbing its state.

Schrodinger's cat is not living and dead at the same time. When it is living, it is not sitting, standing, and moving at the same time. Depending upon when the observer cares to review the cat's status, the cat may be found living or dead, and if living, the cat may be found sitting or standing or moving. There is no proof so far that this logic cannot be valid for the quantum world.

The following oscillations-based interpretation would remove undue importance from measurements and give due importance to the quantum system. It would also explain why a measurement would reveal a certain basis state.

- A quantum system is inherently deterministic. It appears to be random or probabilistic only because of randomness or probabilistic nature in timings of measurements.
- The system oscillates among its basis states one after the next one.
- $\overline{C_i} C_i$, the product of Hermitian conjugate of j-th coefficient in the above equation with the j-th coefficient, denotes the fraction of the time the quantum system spends in the j-th basis state.

- C_i , the j-th coefficient in the above equation, has value of 1 for times t between $t_{k,j-1}$ and $t_{k,j}$, and has values of 0 for other times. The subscript k here denotes the cycle number of oscillations.
- The cycle time of oscillations is roughly of the order of the Planck time. It is so small that a measurement sees a random basis state depending on when the measurement is taken.
- The system's oscillations can be periodic, aperiodic with some pattern, or aperiodic.
- The system's oscillations are periodic in the beginning, but the system's passage through the environment can make the oscillations erratic.
- The system can shift from one basis state to another if the environment so necessitates. For example, in a double slit experiment, if an electron finds a slit to be too crowded, it would tend to transfer to a less-crowded slit.

Figure 1 is a schematic of oscillations of a quantum system among its up and down spin states.

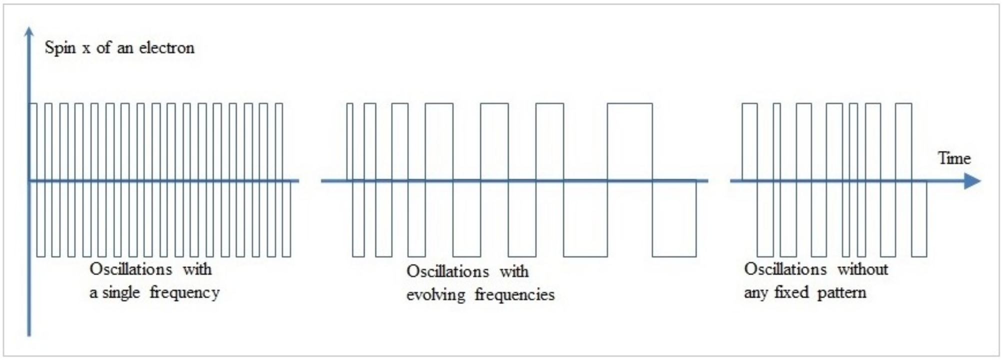

Fig. 1. Oscillations of a quantum system among its up and down spin states

It is worth noting that a quantum system with oscillations among allowed states can offer an enormous number of ways of storing information the form of the pattern of oscillations. In future, the field of quantum information may be able to tap and exploit this way of storing information.

To illustrate this alternative interpretation, consider spin of an object. If the spin has a fixed directional value, the spin represents a uni-directional gyroscopic spin. On the other hand, if the spin oscillates between up and down values, the spin represents a bi-directional pendulum-type spin [18]. Figure 2 contrasts these two types of spins.

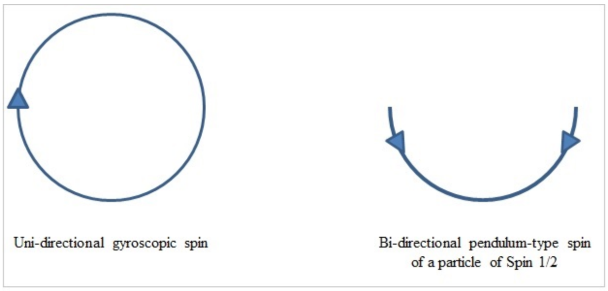

Fig. 2. Uni-directional gyroscopic spin versus bi-directional pendulum-type spin

A particle known to have a spin of ½ or 1 or 2 rotates ½ circle or 1 circle or 2 circles in one direction before reversing its direction of rotation.

3. Quantum Entanglement

When two quantum 'objects' are in a *so-called* quantum-entangled state [2] [13] [4], measurement of a physical quantity, such as spin, of one objcet reveals the physical quantity of the other object, without any time delay. The current interpretation implicitly assumes that two quantum-entangled objects have to interact with each other for their measured values to synchronize. It indirectly implies a spooky action at a distance, and leads to the EPR paradox [10]. It is fair to say that naming this phenomenon has been a source of great confusion and misinterpretations.

The following interpretation of the quantum entanglement phenomenon would not require the quantum-entangled particles to interact with each other, and would thus resolve some of the issues.

- When two particles are ejected from a common source, their physical quantities oscillate, synchronously with respect to each other, thereby making them appear as 'entangled'.

$$S_1(t) = S_{10}.sin(\omega t)/|sin(\omega t)|$$

$$S_2(t) = S_{20}.sin(\omega t)/|sin(\omega t)|$$

- Different environments surrounding the two particles disturb oscillations of the particles and make the oscillations asynchronous, thereby removing their entanglement.
- For quantum entanglement to be present, oscillations of physical quantities of quantum-entangled objects need not be with a single frequency; they may obey some other pattern.

Figure 3 illustrates synchronous oscillations of spin x of two quantum-entangled electrons.

A quantum system of two quantum-entangled objects can be represented as a Bell state [19]:

$$(|0\rangle_A \otimes |0\rangle_B + |1\rangle_A \otimes |1\rangle_B) or (|0\rangle_A \otimes |1\rangle_B + |1\rangle_A \otimes |0\rangle_B)$$

In general, a quantum system of two objects can be represented as

$$C_{00}(|0\rangle_A \otimes |0\rangle_B) + C_1 1(|1\rangle_A \otimes |1\rangle_B) + C_0 1(|0\rangle_A \otimes |1\rangle_B) + C_1 0(|1\rangle_A \otimes |0\rangle_B)$$

The quantum entanglement index of such a system is given by

$$abs(C_{00} + C_{11} - C_{01} - C_{10})/abs(C_{00} + C_{11} + C_{01} + C_{10})$$

4. Experimental Validation

Figure 3 shows a schematic of an experiment [13] that can be carried out to determine whether two electrons are entangled and whether their entanglement is due to synchronous oscillations.

An atom emits two electrons: electron A and electron B. A light transceiver sends two similarly polarized lights simultaneously to the two electrons. The electrons return polarized lights to the light transceiver. The light transceiver measures polarizations of the lights returned by the electrons.

Polarizations $[a_x(t), a_y(t), a_z(t)]$ of the light returned by the electron A at time t, and polarizations $[b_x(t), b_y(t), b_z(t)]$ of the light returned by the electron B at time t are measured.

For each measurement set, a CHSH quantity [19] [20]

$$((a_x(t) + a_y(t))b_x(t) + (a_x(t) - a_y(t))b_y(t))$$

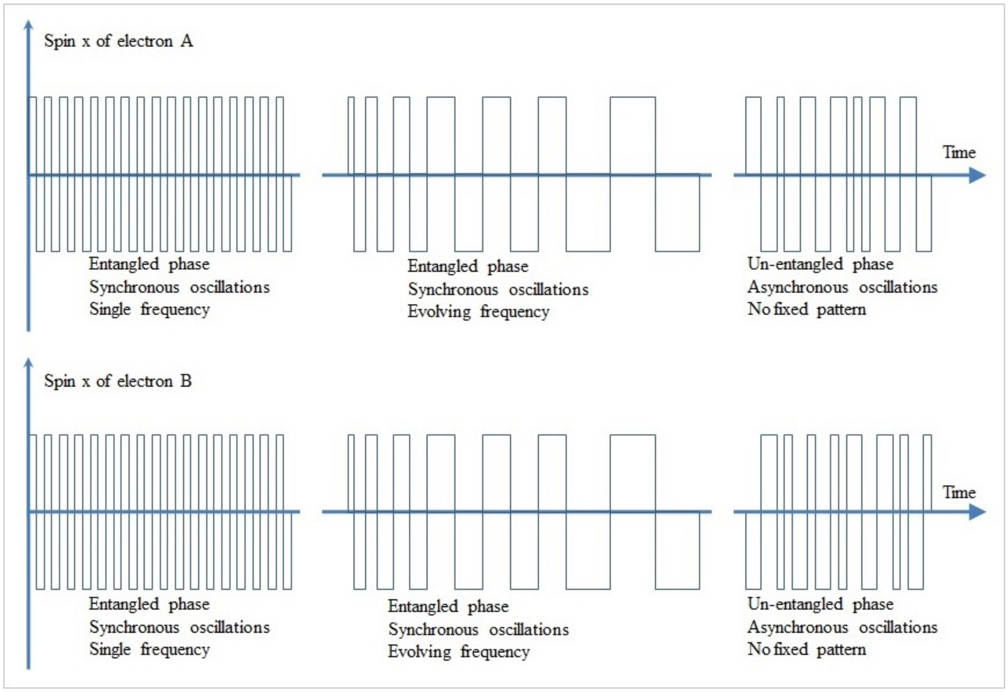

Fig. 3. Synchronous oscillations of spin x of two quantum-entangled electrons

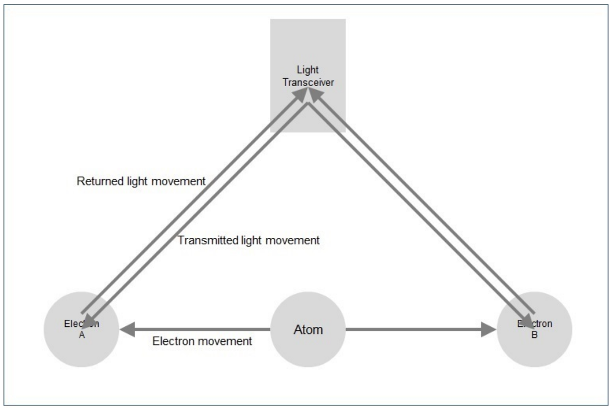

Fig. 4. Experimental set-up to study quantum entanglement

is computed; its individual values should be 2 or -2. Values computed for the CHSH quantity for different values of t are averaged. If the averaged value is other than 0, 2, or -2, it would imply that the two electrons are quantum entangled.

The ratio of the number of sets for which $[a_x(t), a_y(t), a_z(t)]$ equals $[b_x(t), b_y(t), b_z(t)]$ to the total number of sets is computed, and likewise, the ratio of the number of sets for which $[a_x(t), a_y(t), a_z(t)]$ equals $[-b_x(t), -b_y(t), -b_z(t)]$ to the total number of sets is computed. The higher of these two ratios gives the quantum entanglement index of the two electrons. Value of 0 for this index implies absence of quantum entanglement, value of 1 for this index implies complete quantum entanglement, and any other value implies partial quantum entanglement.

An adequately high total number of sets of measurements is necessary to make sure that correlations in polarization measurements are not mainly due to measurement errors or some factors to be ignored. More sets of measurements and more computations are needed to determine whether a quantum entanglement is due to synchronous oscillations.

Fourier analyses of polarizations $a_x(t), a_y(t), a_z(t), b_x(t), b_y(t), and b_z(t)$ is carried out with respect to time t, thereby computing frequencies of polarizations. A very wide range of frequencies would imply absence of synchronous oscillations of the two electrons, and a few discrete values of frequencies would imply presence of synchronous oscillations of the two electrons.

5. Quantum Computing

The above interpretations have many far-reaching implications and important applications, such as follows.

- A quantum system is inherently deterministic, but it seems to be probabilistic only because of randomness in timings of measurements.
- Quantum entanglement based on synchronous oscillations does not involve any communication, and hence, possibilities of direct quantum communication [21] [22] or teleportation [23] are ruled out.
- Quantum entanglement based on synchronous oscillations implies more and better possibilities of quantum computing.
- New hardware-based or software-based emulated quantum computers can be designed, in which classical or software objects are artificially entangled by synchronous oscillations.
- Quantum phenomena observed in many biological systems [11] [12] [24] can be explained in terms of quantum entanglement due to synchronous oscillations.

Figure 5 shows a schematic of an emulated quantum bit for an emulated quantum computer.

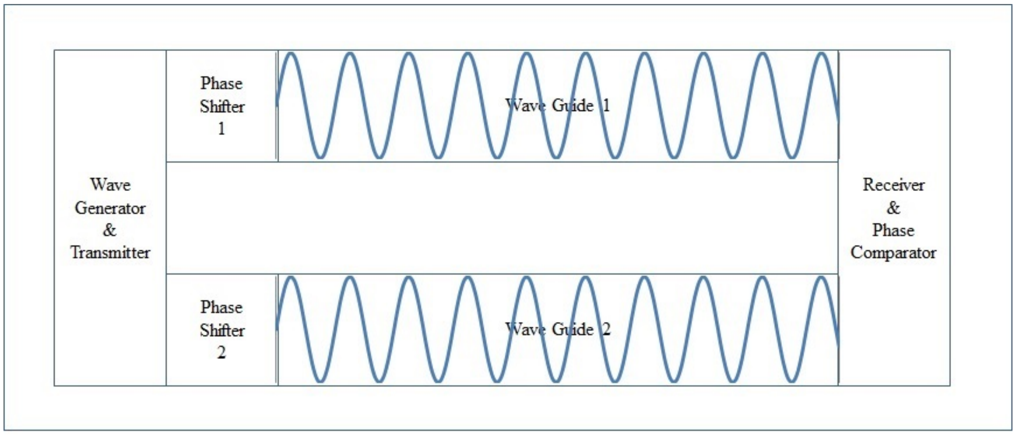

Fig. 5. Emulated quantum bit for an emulated quantum computer

Here, a wave generator-cum-transmitter generates two sinusoidal waves, and transmits them to phase shifters 1 and 2. Depending on a quantum transformation needed, phase shifters 1 and 2 shift phases of the waves received. Then, they pass the waves into wave guides 1 and 2. A receiver-cum-comparator receives the two waves and compares their phases.

This method of emulating quantum computing can get rid of the need for sophisticated cooling and vacuum equipment, can allow a high number of such qubits, and can thereby enable more powerful quantum computers. This method is better than previously-proposed methods of emulating quantum computing, based on pendulums [16] [24] [17] or gears [14].

6. Conclusions

The periodic oscillations interpretation of quantum linear superposition can reduce the measurement-bias of the current interpretation, and can make quantum mechanics less questionable. The synchronous oscillations interpretation of the quantum entanglement phenomenon can explain the root cause of this phenomenon without leading to issues like the EPR paradox. Quantum entanglement due to synchronous oscillations can lead to more and better ways of emulated quantum computers.

7. Backmatter

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8. References

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