Is it possible for humans to achieve the quantum teleportation of 3D-objects?

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4832 Words **Keywords:** particles, uncertainty, quantum, teleportation, Bell labs, entanglement, space, dimensions, measurement 4th August, 2021

Abstract After watching many science fiction films and reading many science novels, teleport becomes a skill which sounds magical and impossible. Peregrinating through a worm whole to a planet far away from the earth or just simply disappearing in one place and suddenly appear in another place has become a dream of most people. But all these ideas are some how possible in the field of quantum teleportation. This is an important area in quantum mechanics which hasn't been developed and studied much by humans compared to most areas in physics. This essay analyses the classical experiments done in quantum studies as well as explaining some of the key theories and ideas carried out by the great physicists in the past. Finally, at the theoretical level, the essay will prove that the quantum teleportation of 3D objects is actually possible.

Contents

1 Introduction

1.1 Moving an object between two places instantaneously

Every person certainly has a dream of travelling from one place to another all in a sudden, especially when there is a traffic jam. It sounds ridiculous to get disembodied in one place and reconstituted at a distant location, but is it really impossible to achieve? In 1997, scientists proved that quantum states can be teleported between two distant locations by doing experiments [1], which means the classical quantum teleportation studies [2]–[4] were theoretically founded. Quantum refers to quantity, amount. In quantum mechanics, quantum is more likely to be described as the "discrete quantities" in relation to energy, light and photons

1.1.1 Importance of delay-free transmission

What does delay-free [5] mean? Imagine sending and receiving messages faster than the speed of light, or having perfectly smooth gaming experience due to the zero-delay in the net... This is just so important in our lives in many different ways. For example, in financial markets large amount of money could be calculated and transferred within a second. Besides, people would not have to worry about their daily communication ever, even in the countryside they can chat freely with their friends. If delay-free transmission [6] could be actually achieved, massive amount of money and time would be saved. Therefore the extra resources can be used in other areas to help reduce the waste such as surplus money or electricity.

1.1.2 Relationship between quantum teleportation and delay-free transmission

So, why do we talk about quantum teleportation instead of just finding a way to achieve the delay-free transmission? The answer is obvious, quantum teleportation is the most efficient way for human to transfer things faster than the speed of light [7], two of the best examples are the experiment of the quantum teleportation across the Danube [8], and the quantum teleportation and entanglement distribution over 100-kilometre free-space channels experiment achieved in China [9]. These experiments showed that data and signals can be transferred with a much faster speed than the present methods we are using in the transmission of information. In other words, quantum teleportation technique is the tool for delay-free transmission.

1.1.3 Other reasons for using quantum teleportation

One of the most important reasons for using quantum teleportation which should be mentioned here is that the information transferred using quantum teleportation is absolutely encrypted, this is due to the reason that the quantum state cannot be copied [10]. Therefore the information transferred by quantum teleportation is almost absolutely safe, can not be easily stolen by others. For this reason, quantum teleportation will find application in transfer of confidential information, and become the first choice of large companies for information transmission.

1.2 An introduction to quantum physics

1.2.1 Quantum states

Quantum refers to quantity, amount. In quantum studies, quantum is more likely to be described as the "discrete quantities" in relation to energy, light and photons, whilst a quantum state [11] is a mathematical entity that provides a probability distribution for the outcomes of each possible measurement on a system. A system's behaviour can be predicted by using the knowledge of quantum state together with the rules included in the system's evolution. Quantum state included pure state and mixed state. For example, according to figure 1, if we say that a 'bit' can be either 0 or 1, then a 'quantum bit' can be both 0 and 1 at the same time.

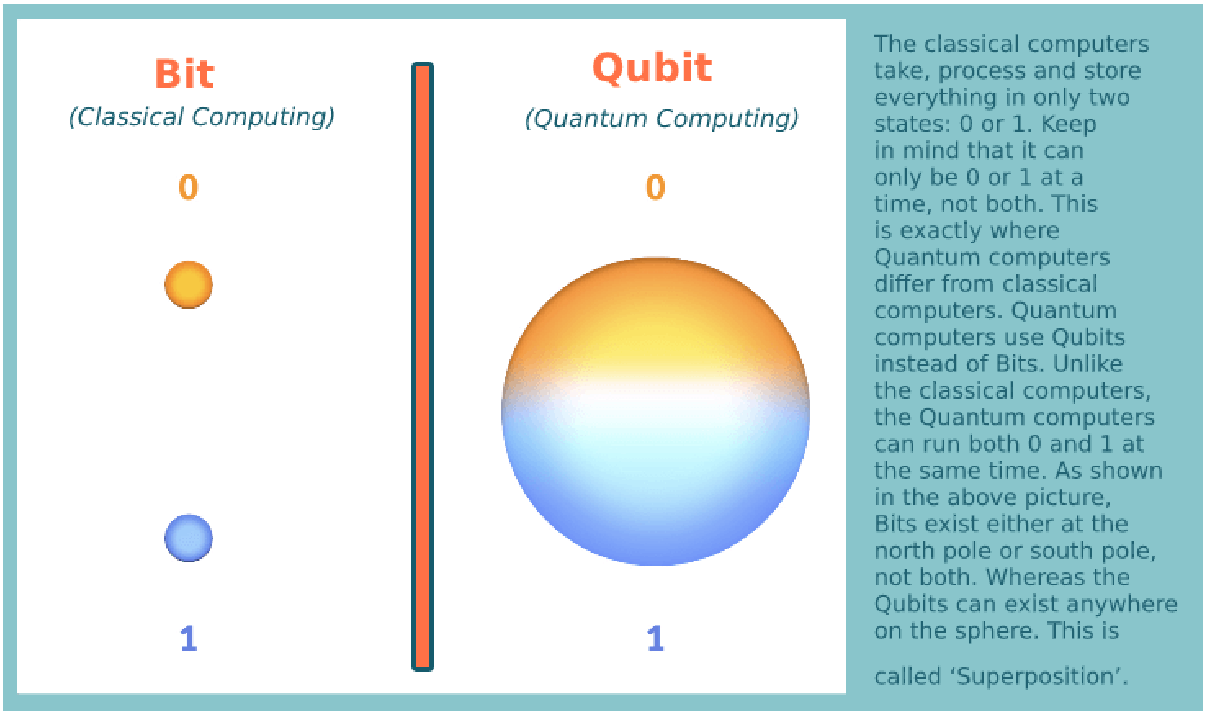

Fig. 1. Bit and quantum bit [12]. It's significant to notice that a quantum bit can hold more info than a bit.

1.2.2 Quantum measurement and uncertainty

In quantum physics, a measurement [13] is the testing or manipulation of a physical system in order to yield a numerical result. The state of a certain system would be in superposition until it is measured [14]. For instance, the photon can either be spinning vertically or horizontally, with 50-50 chance, once you measure it, then the state of it can be completely analysed, with either 100 percent of vertical spinning or horizontal spinning.

Compare to classical measurement, where no change is had on the system by measuring it. However, the quantum state of an object will be changed when it's observed to measure, this is explained by the uncertainty principle [15] carried out by Germany physicist Werner Heisenberg [16] in 1927, which shows we cannot measure the speed and position of an electron accurately at the same time. But applying the Schrodinger wave equation [17] we are able to calculate the probability of an electron to be at a certain place.

$$-\frac{h^2}{8\pi^2 m}\frac{\alpha^2\psi(x,t)}{\alpha x^2}+V(x)\psi(x,t)=\frac{ih}{2\pi} \tag{1}$$

Therefore it has become possible for human to calculate the quantum state and solving the wave function since then.

1.2.3 A brief introduction to quantum teleportation technique

Quantum teleportation [18] is a technique for transferring quantum information from a sender at one location to a receiver some distance away. In quantum teleportation, two communicating parties in two distant places first share a pair of entangled particles, which means the two particles are intrinsically related and dependent on one another even if miles apart. Then one side will be transferred to the quantum state of the particle (generally not related to the entangled particles), after that, tell the other side of the resolution. The other party would then perform corresponding operations according to the obtained information. Referring to figure 2, the schematic diagram of quantum teleportation looks like:

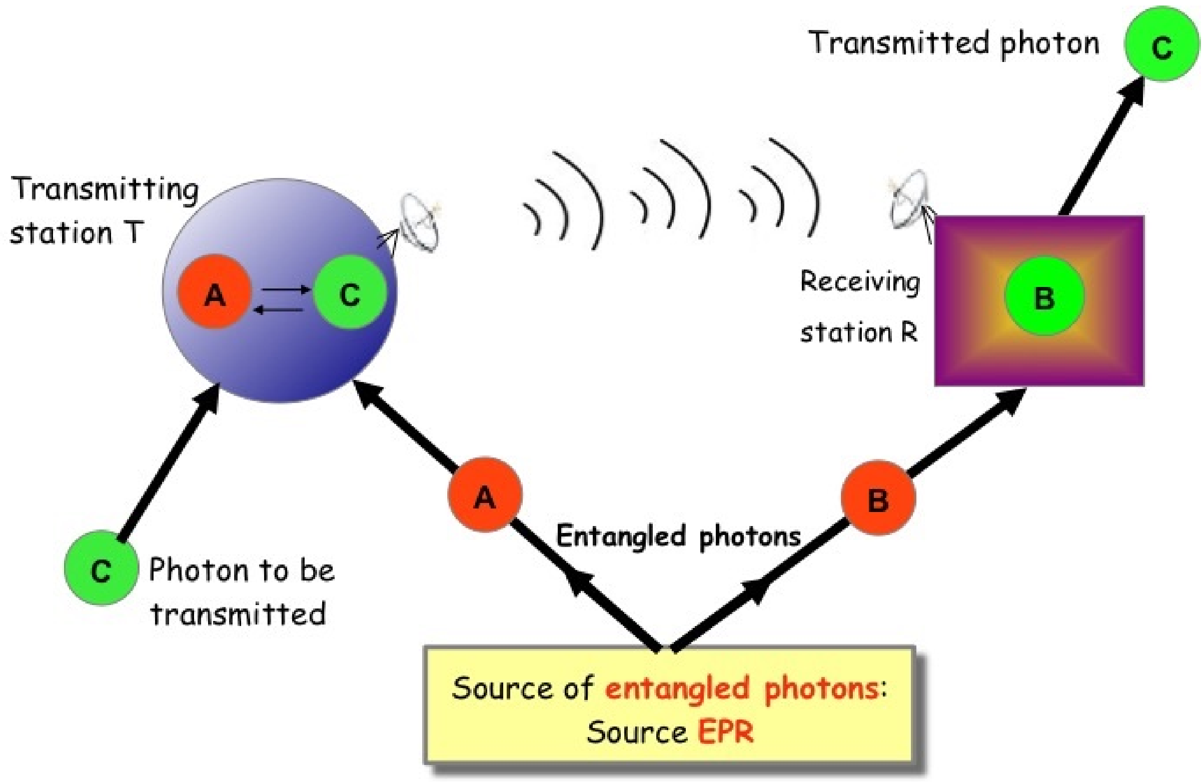

Fig. 2. Schematic diagram of quantum teleportation [19].

2 Literature review

2.1 Introduction to quantum behaviour

2.1.1 A brief history of discovery of quantum behaviour

The development of quantum mechanics began with the discovery and study of black body radiation [20]. Black body [21] is an idealized object that can absorb all the external electromagnetic radiation without any reflection or transmission. In other words, the absorption coefficient of the black body for any wave length is 1 and the transmission coefficient is 0. Physicists used this as a standard for studying thermal radiation.

In 1901, Max Planck [22] published a report about his research, which showed that the spectrum of the emitted light wave of the black body [23] at equilibrium which is predicted with quantum assumptions [24] is in perfect agreement with the experimental data. He made a special mathematical hypothesis to quantify the electromagnetic radiation energy emitted or absorbed by harmonic oscillators (the atoms that make up the surface of a black-body wall) based on quantum assumptions. Referring to figure 3, diagram of the intensity versus wavelength black body curves can be produced with real data, in this figure, the peak wavelength in the black body curve shifts as the source temperature is decreased.

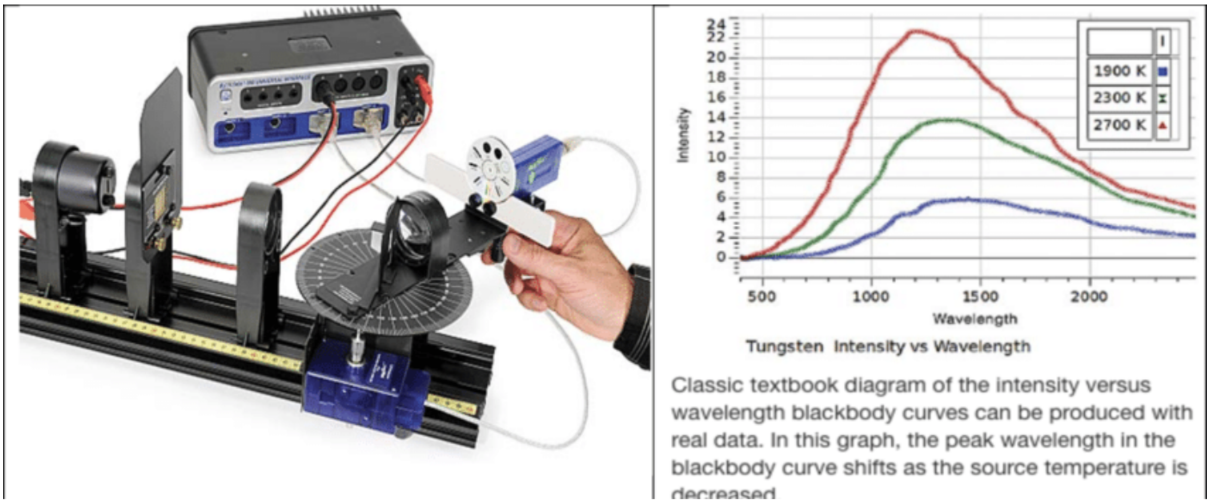

Fig. 3. Black body radiation experiment [25].

He called this kind of discrete energy 'quantum' [26]. He defined letter h as the discrete energy, which was later called the Plank Constant:

$$h = 6.626176 \times 10^{-34} Nms(Js) \tag{2}$$

Then he carried out a representation for thermal energy:

$$E = nhf \tag{3}$$

Where E is thermal energy, n is an integer, h is Plank's Constant, and f is the frequency. This equation explains the observations in the black body experiment perfectly.
Later, he published Theory of Heat Radiation, and explained the well-known Planck's law [27] in the book. The law shows the relationship between wavelength and frequency of electromagnetic wave:

$$\lambda = \frac{c}{v} \tag{4}$$

And the law can also be written as a spectrum of energy density:

$$\begin{aligned} u_v(v,T) &= \frac{4\pi}{c} I_v(v,T) \qquad (5)\\ &= \frac{8\pi h v^3}{c^3} \frac{1}{e^{\frac{hv}{kT}} - 1} \qquad (6) \end{aligned}$$

At the same time, spectrum of energy density can be written as a function of wavelength:

$$u_\lambda(\lambda,T) = \frac{8\pi hc}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda kT}} - 1} \tag{7}$$

Where I is radiance, v is frequency, λ is wavelength, T is the temperature of the black body, h is Plank's Constant, c is the speed of light, e is Euler number, and k is Boltzmann constant.

In 1905, Albert Einstein [28] gave out an explanation on photoelectric effect [29]. He described a beam of light as a bunch of discrete quantum (which is called 'photon' now) instead of a continuous fluctuation. His argument explains why the energy of a photo electron depends only on its frequency and not on its radiation.

Eleven years after that, American scientist Robert Millikan [30] conducted the Oil-drop experiment [31] that confirmed Einstein's theory about the photoelectric effect. Since then, Physicists have been forced to admit that light has particle properties as well as wave properties, which I would explain as 'wave-particle duality' in the next paragraph.

2.1.2 Wave-particle dualism

Wave-particle duality [32] means that all particles or quantum can be partly described not only in terms of particles, but also in terms of waves. This means that the classical concepts of particles and waves have lost their ability to fully describe physical behavior within the quantum range.

Albert Einstein [28] described it in this way: 'Sometimes we have to use either one set of theories or another set of theories to describe the behaviour of these particles, but sometimes we must use both the two theories, this difficulty forces us to use two conflicting points of view to describe reality. Two ideas alone cannot fully explain the phenomenon of light, but together they can [33].'

The wave-particle duality is one of the fundamental properties of microscopic particles. In 1905, Einstein proposed a quantum explanation of the photoelectric effect, and people began to realize that light waves had the dual properties of both waves and particles. In 1924, De Broglie [34] proposed the matter wave hypothesis, which believed that all matter, like the light, showed wave-particle duality. According to this hypothesis, electrons should also have interference and diffraction wave phenomena, which was later confirmed by the electron diffraction experiments [35].

2.2 Quantum states

In quantum physics, 'quantum state' describes the state of an isolated system, including all the information related to the system [36]. Once the quantum state of a certain system is analysed, the result of the measurement of that system can be given.

2.2.1 Bloch sphere

In quantum mechanics, the Bloch sphere, named after Felix Bloch [37], an expert in spin physics and nuclear magnetic resonance, is a geometric representation of pure state space in a two-state system that is often used in the context of quantum bits [38].Referring to figure 4, the equation can be explained by a 2D-diagram.

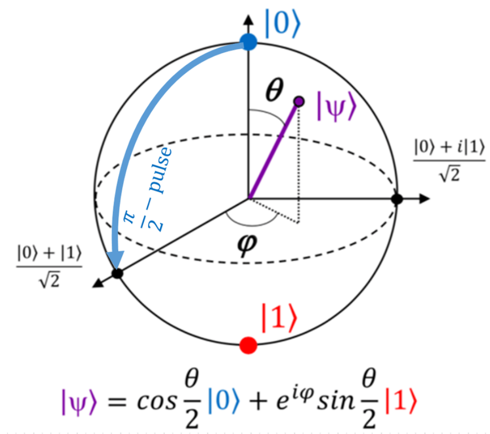

Fig. 4. A diagram of two level quantum state on a Bloch sphere [39].

According to quantum mechanics, the total probability of the system has to be one [40] (the total probability of one certain electron's top spin and back spin is 100 percent due to the 50-50 chance of either top spin or back spin):

$$\langle \psi | \psi \rangle = 1 \tag{8}$$

Given this constraint, we can write $|\psi\rangle$ using the following representation:

$$\begin{aligned} |\psi\rangle &= \cos\left(\theta/2\right)|0\rangle \; + \; e^{i\phi}\sin\left(\theta/2\right)|1\rangle & (9) \\ &= \cos\left(\theta/2\right)|0\rangle \; + \; \left(\cos\phi + i\sin\phi\right)\,\sin\left(\theta/2\right)|1\rangle & (10) \end{aligned}$$

The equation must satisfies the following two conditions:

$$0 \leq \theta \leq \pi \, 0 \leq \phi < 2\pi \tag{11}$$

The representation is always unique, because, although the value of ϕ is not unique when $|\psi\rangle$ is one of the key vectors $|0\rangle$ or $|1\rangle$, the point represented by θ and ϕ is unique.

2.3 Quantum measurement

In quantum physics, the measurement of quantum is distinct to the 'measurement' in classical physics, quantum measurement can affect the quantum system being measured, such as changing the state of it. Quantum systems in the same state can be measured to obtain completely different results, corresponding to a kind of probability distribution until we measure them [41].

Quantum measurement is the key area used by quantum mechanics to explain the systems. Quantum measurement can be represented by a set of measurement operators '(M,m)', it acts on the state space of the system. For instance, if the state of the system before measurement is represented by:

$$|\psi > \tag{12}$$

The probability for it to obtain a result 'm' is represented by:

$$p(m) =< \psi | M *_m M_m | \psi > \tag{13}$$

The state of the system after being measured is changed to the representation:

$$M_m|\psi > \sqrt{(< \psi|M *_m M_m|\psi >)} \tag{14}$$

The measurement operator must satisfy the following conditions of completeness:

$$\sum_m (M *_m M_m) = I \tag{15}$$

The above completeness conditions are equivalent to the following equation, which means that the completeness conditions can determine the sum of probabilities of each measurement result to be 1:

$$1 = \sum_m (p_m) \tag{16}$$

$$= \sum_m (< \psi|M *_m M_m|\psi >) \tag{17}$$

2.3.1 An explanation for the wave function

Wave function [42] is a function describing the state of a system in quantum mechanics. In classical mechanics, the position and momentum (or velocity) of a particle are used to describe the state of a macroscopic particle. This is the classical description of the state of a particle, which highlights the particle property of a particle.

Due to the wave-particle duality of microscopic particles, the position and momentum of particles cannot be determined simultaneously, and the reason is explained in details in Heisenberg's uncertainty theory [15], and the matter wave behaves as the expected value of probability wave function at macroscopic scale.

In 1926, Max Born [43] proposed the concept of probability amplitude and successfully explained the physical meaning of wave function. The classical plane waves can be represented by:

$$\psi(t, x) = Ae^{-i(2\pi vt - \frac{x}{\lambda})} \tag{18}$$

$$= Ae^{-i\omega(t-kx)} \tag{19}$$

The motion state of microscopic particles can be described by wave function using:

$$E = hv \tag{20}$$

$$p = \frac{h}{\lambda} \tag{21}$$

$$k = \frac{2\pi}{\lambda} \tag{22}$$

Where E is energy, h is the Plank's Constant, and v is the wavelength.
So we get the wave function of a certain particle:

$$\psi(t, x) = \psi_0 e^{-i\frac{2\pi}{h}(Et-px)} \tag{23}$$

$$= \psi_0 e^{-\frac{i}{\hbar}(Et-px)} \tag{24}$$

In 1927, the first step was taken in the study of the multibody wave function by Douglas Hartree [44] and Vladimir Fock [45]. They developed the Hartrey-Fock equation to approximate the solution of the equation.

2.3.2 Observer Effect

Observer effect [46] refers to every method used to observe and measure a certain object will certainly affect the object itself in some ways. To put it more broadly, there's almost nothing we can do without affecting what we're looking at but to a greater or lesser degree.

2.3.3 Photoelectric effect

Photoelectric effect [47] is an interesting and important part in Physics, under the irradiation of electromagnetic waves higher than a certain frequency, the electrons inside some substances absorb energy and escape to form a current, that is, photoelectricity.

Photoelectricity was discovered by Germany physicist Heinrich Rudolf Hertz [48] in 1887, but the correct explanation of it was carried out by Albert Einstein [28]. In the process of studying the photoelectric effect, physicists gained a better understanding of the quantum properties of photons, which had a major impact on the concept of wave-particle duality [32]. In particle terms, light is composed of discrete photons.

Referring to figure 5, when a photon is irradiated to a light-sensitive substance, such as selenium, its energy can be absorbed by an electron in the substance. After the electron absorbs the energy of the photon, the attractive forces of the nucleus is immediately increased, if kinetic energy increase enough to overcome the nucleus of its gravity, the electron can fly in one over one billion of a second time to escape the metal surface, become photoelectron. The greater the number of incident photon runaway from the photoelectron per unit time is, the stronger the photocurrent is [47].

The behaviour for the light energy converting into the electricity automatic discharge phenomenon is called the photoelectric effect. In the photoelectric effect, the direction of electron ejection is not completely directional, but most of them are perpendicular to the metal surface injection. The greatest kinetic energy a photoelectron can have is represented by:

$$
\begin{aligned}
K_{max} &= hv - W \qquad (25) \\
&= h(v - v_0) \qquad (26)
\end{aligned}
$$

Where 'hu' is the energy carried by a photon of optical frequency 'u' and absorbed by an electron.

Independent of the direction of light, light [49] is a form of electromagnetic wave, but light is the high-frequency oscillation in the orthogonal electromagnetic field, therefore the amplitude is small, will not affect the direction of electron injection.

2.3.4 The Copenhagen interpretation

The Copenhagen interpretation [51] is an interpretation of quantum mechanics. According to the Copenhagen interpretation, the quantum state of a quantum system can be described by a wave function in quantum studies. The wave function is a mathematical function specially used to calculate the probability that a particle is in a certain position or in a certain state of motion.
The Schrodinger wave equation is represented by:

$$
-\frac{h^2}{8\pi^2 m}\frac{\alpha^2\psi(x,t)}{\alpha x^2} + V(x)\psi(x,t) = \frac{ih}{2\pi} \qquad (27)
$$

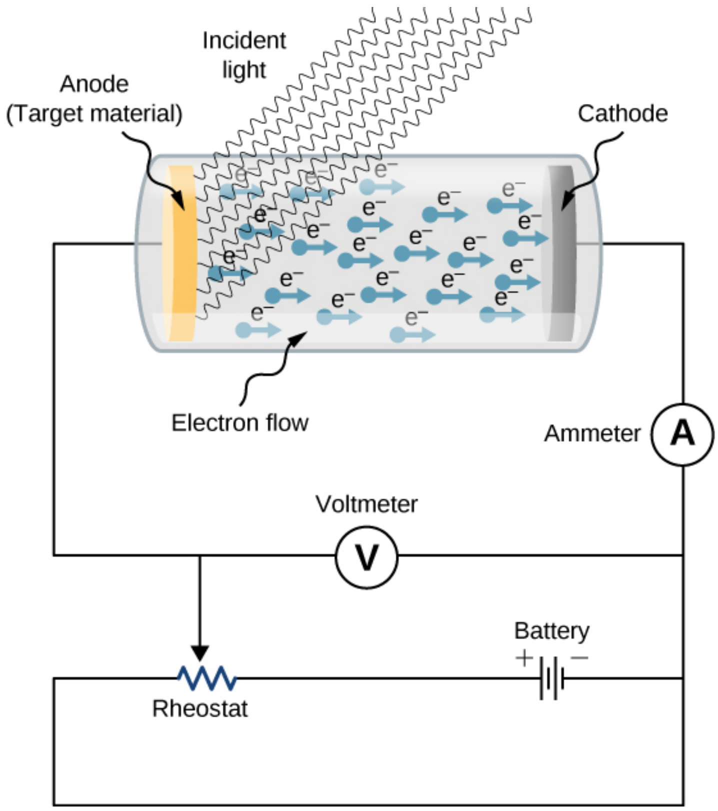

Fig. 5. Photoelectric effect experiment [50]. As shown by the figure, the incident light significantly increases the kinetic energy of the electrons by allowing them to absorb the energy from the emitted photons, then the electrons will escape the metal surface, becoming photoelectrons.

The action of measurement causes the collapse of wave function, and the original quantum state collapses into a quantum state allowed by measurement. In order to explain this point better, one classical experiment should be mentioned here, which is called Schrodinger's cat [52].

2.3.5 The Schrodinger's cat experiment

Schrodinger's cat [52] is a thought experiment by the physicist Erwin Schrodinger [53]. Referring to figure 6, in the experiment, a cat is confined in an airtight container with small amounts of radium and cyanide inside.

There is a chance that radium will decay. If radium decays, it will trigger the mechanism to break the bottle containing cyanide, and the cat will die. If the radium does not decay, the cat will survive. According to the theory of quantum mechanics, since radioactive radium is in the superposition of the two states of decay and non-decay, the cat should also be in the superposition of dead and alive. The cat that is both dead and alive is called the 'Schrodinger cat'.

However, the cat that is both dead and alive does not exist, so the result could only be determined once the container is opened for observation. This experiment tries to demonstrate the problem of the superposition of quantum states which happens in a microscopic scale from a macroscopic scale, cleverly linking the microscopic matter whether it exists as a particle or a wave after observation with the macroscopic cat to determine the existence form of the

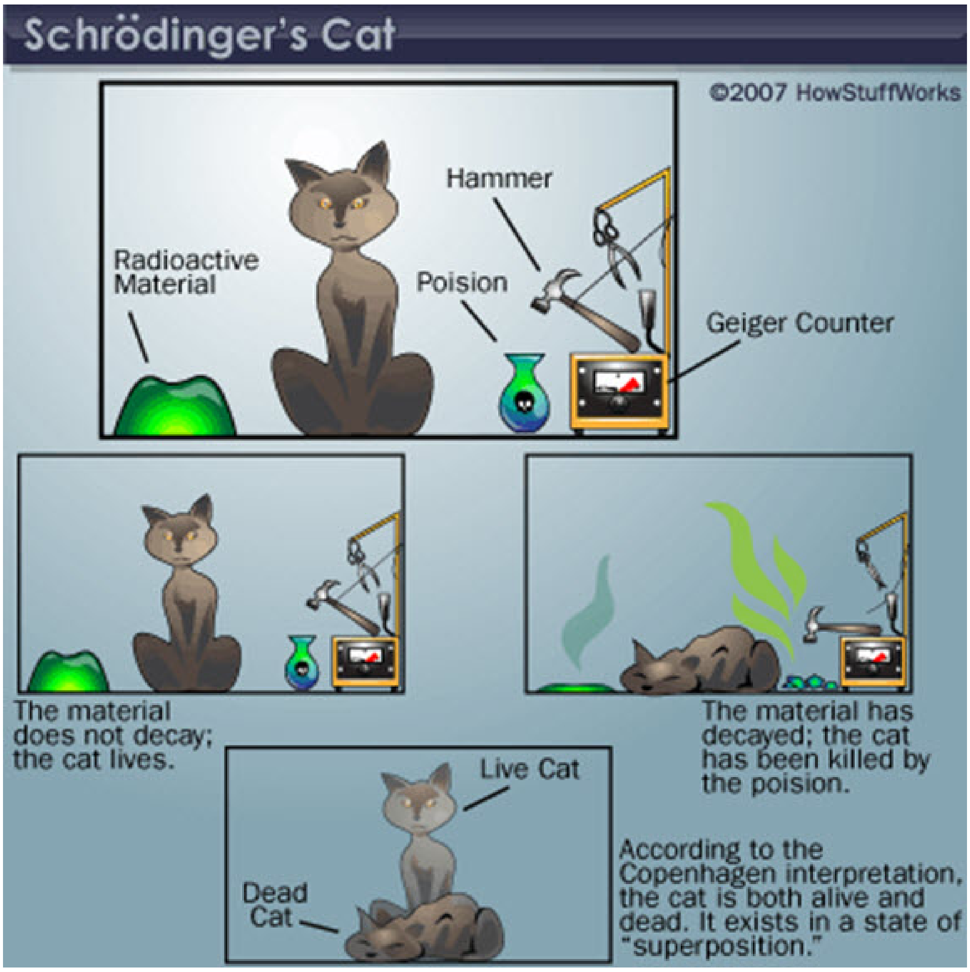

Fig. 6. Schrodinger's cat experiment [54].

quantum when the observation takes place.

With the development of quantum physics, Schrodinger's cat also extended the parallel universe and other physical problems and philosophical disputes.

2.4 Quantum uncertainty

2.4.1 An explanation for Heisenberg's uncertainty theory

The uncertainty principle [15] was formulated by Werner Heisenberg [16] in 1927. This theory explains that we cannot know the position of a particle and its velocity at the same time, and the uncertainty of position and the uncertainty of momentum comply with the inequality:

$$\triangle x \triangle p \geq \frac{h}{4\pi} \tag{28}$$

Where h is the Plank's Constant.

Besides, the theory suggests that particles in the microscopic world behave very differently from macroscopic matter. The uncertainty principle involves a lot of profound philosophical questions, and in Heisenberg's own words: 'in the statement of causation, if one knows exactly what is now, one can foresee the future, it's not a conclusion, it's a premise that we don't know all the details of the present, it's a matter of principle.' However, using Schrodinger wave equation [17] carried by Austrian physicist Erwin Schrodinger [53] we can solve the probability of a certain electron to be in a certain place by solving its wave function.

In 1926, Max Born [22] proposed the concept of probability amplitudes, successfully explaining the physical meaning of wave functions but Schrodinger, like Einstein, was not in favor of this statistical or probabilistic approach and its attendant discontinuous wave function collapse.

2.5 Quantum entanglement

In quantum mechanics, when several particles interact with each other, the properties of each particle have been integrated into the overall properties, unable to describe the properties of each particle alone [55]. As a result, we can only describe the properties of the whole system, this phenomenon is called quantum entanglement [55].

Suppose a zero spin neutral π meson decays into an electron and a positron and the two decay products each move in opposite directions. An electron moves to area A, Alice, the observer there, will observe the spin of the electron along a particular axis. The positron moves to region B, an observer there, Bob, would also observe the positron spin along the same axis. Before the measurement, the two entangled particles together formed an entangled state $|\psi\rangle$ with zero spin, which is the superposition of two product states, in terms of Dirac notation:

$$|\psi\rangle = \frac{1}{\sqrt{2}}(|\uparrow\rangle \bigotimes |\downarrow\rangle - |\downarrow\rangle \bigotimes |\uparrow\rangle) \tag{29}$$

In the equation, $|\uparrow\rangle$ and $|\downarrow\rangle$ represent the upward spin and downward spin of the particle respectively.

However, when a measurement is taken for the system, the state of superposition of top and back spin will be transformed into the state of either top or back spin, with 100 percent probability of either condition [55].

2.5.1 The photon entanglement experiment

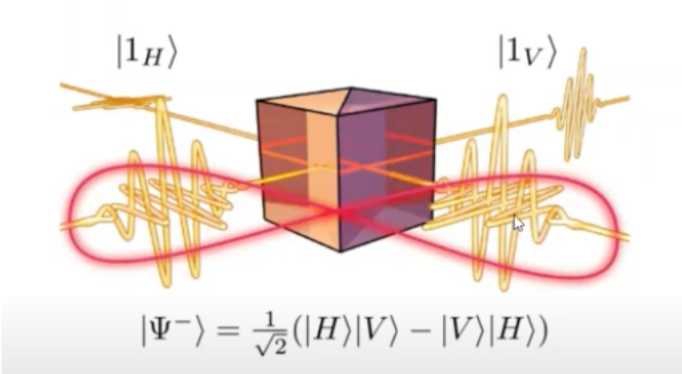

Fig. 7. The quantum entanglement of two particles determine the combined condition [38].

The first term in parenthetical notation says that the electron has a spin up if and only if the positron has a spin down; The second term says that the spin of the electron is down if and only if the spin of the positron is up. When these two conditions are combined, each of them is possible, and it is not clear which one will happen, so the electrons and positrons become entangled, forming an entangled state. Without measurements, there is no way to know the spin of either particle, which, according to the Copenhagen interpretation [51], does not exist. The two particles in this single state are inversely related to each other. If the spin of the electron is up, the spin of the positron is down, and vice versa. If the electron spins down, the positron spins up, and vice versa.

Referring to figure 7, quantum studies can't predict which set of numbers it is, but it can predict that there is a 50-50 chance of getting any set of numbers.

2.6 Quantum teleportation

2.6.1 The discovery of quantum teleportation technique

In 1997, Austrian science group Zeilinger [8] completed the first experimental verification of quantum teleportation in the laboratory, which has become a classic work in the field of quantum information experiment.

In 2004, using the fiber channel at the bottom of the Danube river [8], the group successfully increased the quantum teleportation distance to 600 meters. However, due to the loss and decoherence effect in the fiber channel, the distance of quantum teleportation was greatly limited. How to greatly improve the quantum teleportation distance has become an important research direction in the field of quantum information experiment.

At the same year, researchers such as Jianwei Pan and Chengzhi Peng [56] of the University of Science and Technology of China began to explore the possibility of quantum communication over longer distances in free space channels. In 2005, the Chinese group set the world record for two-way quantum entanglement distribution of 13 kilometers in Hefei [56], and the feasibility of distributing entangled photon pairs between outer space and the Earth was also verified.

In 2009, the furthest distance quantum teleportation in the world was successfully realized [57], which confirmed the feasibility of quantum teleportation process through the atmosphere, and laid to a reliable foundation for the global quantum communication network based on satellite relay in the future.

On Sep, 2020, physicists from the University of Vienna and the Austrian Academy of Sciences have achieved a new world record for teleportation of quantum states at a distance of 143 kilometers [58]. Which is the present farthest distance achieved by quantum teleportation.

2.6.2 Bell states

Bell states [59] is a term belonging to the field of quantum informatics that describes the four maximum entangled states of a two-qubit system. It is named after the Irish physicist John Stewart Bell [60]. If two bits are quantum entangled, the states of the two qubits are related [55], so in the case of maximum entanglement, the two bits must measure the same or different, in one of these four ground states, also known as the Bell states. Quantum teleportation requires the sender and the receiver share a pair of Bell states, which is also called the EPR pair.

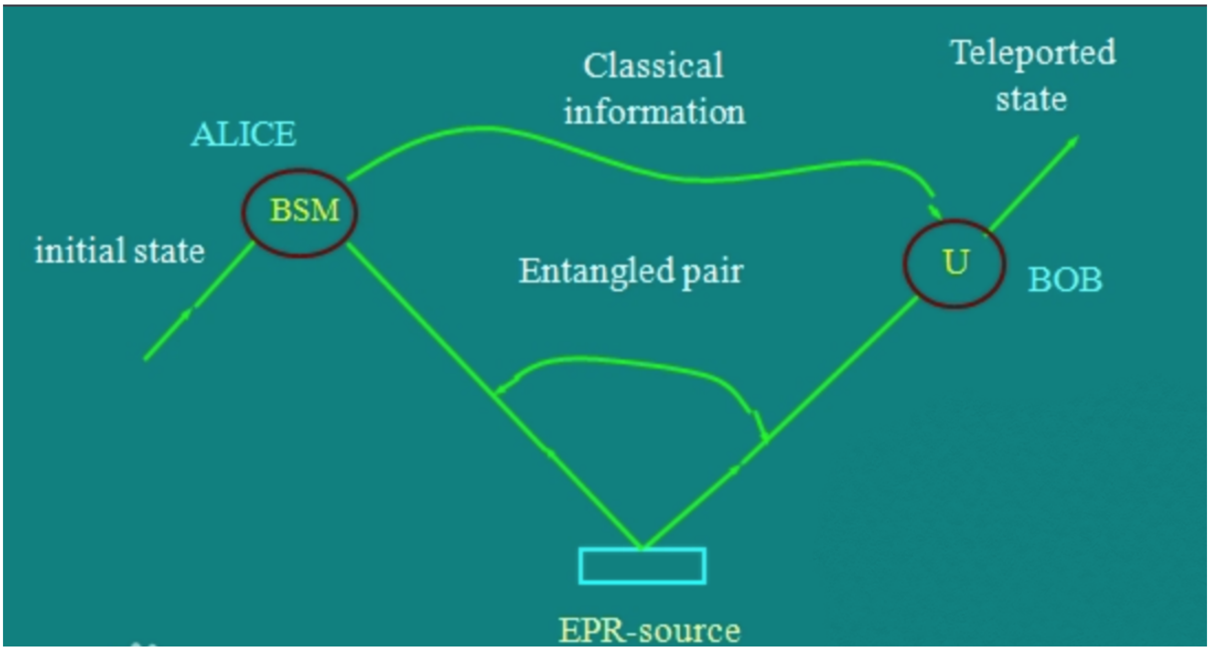

Fig. 8. Quantum teleportation technique [63].

2.6.3 The basic principle for quantum teleportation

Referring to figure 8, Joint Bell basis measurements [61] are made for the transmitted unknown quantum state and one of the particles in the EPR pair [62], where all the quantum information of the unknown state will be transferred due to the quantum non-local correlation properties of the EPR pair.

As for the second particle of the EPR pair, as long as the unitary transformation of the quantum state of the second particle of the EPR is carried out according to the Bell basis measurement results transmitted by the classical channel, the particle can be placed in the exact same quantum state as the unknown state to be transmitted, so as to realize the reproduction of the unknown state on the second particle of the EPR.

2.7 Quantum teleportation of 3D objects

2.7.1 An explanation to the '3D object' mentioned in the research question

The 3D object referred to my research question is actually meant by non-virtual objects [64], such as humans, animals, cars, and so on. They are the objects which can be clearly seen and felt, unlike signals or data.

The latest achievement by scientists on quantum teleportation is still only on photons [65], whether it's possible to achieve the quantum teleportation on the macro material [66] is still a discussion for scientists base on theories now.

2.7.2 Collapse of the quantum state

Many people start to worry if a human or an object would be copied through quantum teleportation, but in fact, these worries are totally unnecessary.

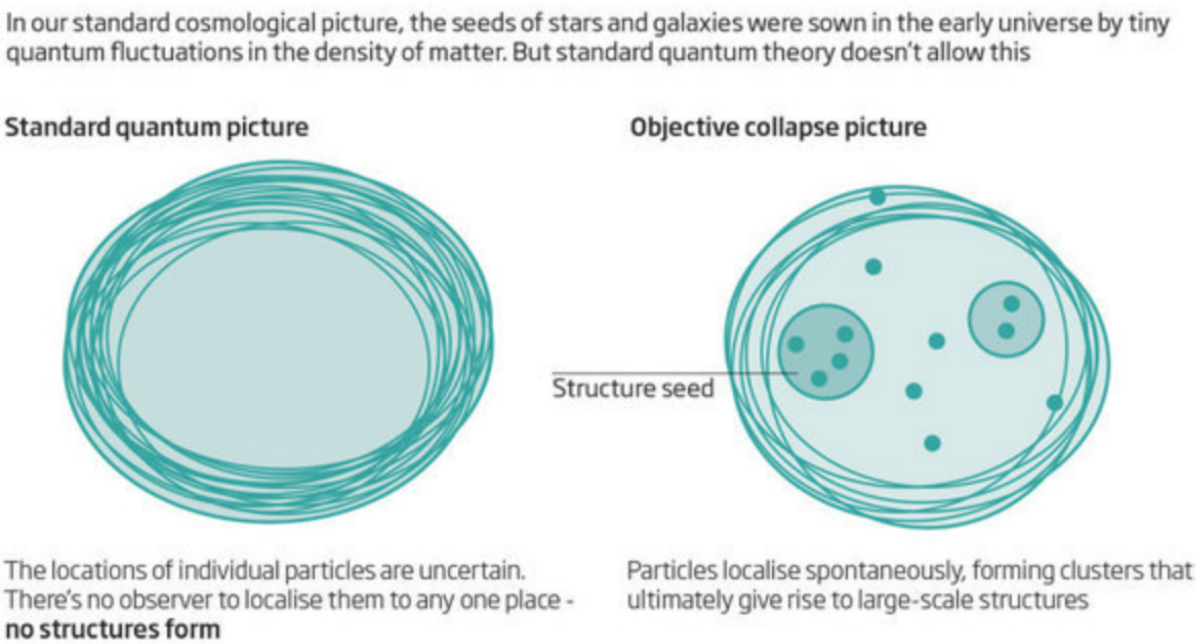

Fig. 9. The collapse of the quantum state [67]. Referring to figure 9, for a pair of entangled photon A and C, once the quantum state of A is applied on that of quantum C, the quantum state of A will collapse, and at the same time, all the property of A will be fully copied on photon C, which makes C exactly the same as A.

According to the theory of quantum state [68], quantum state of a particular particle cannot be copied, due to its unique property [10].

2.8 Conclusion of literature review

2.8.1 Summary of previous achievements on quantum teleportation

In 1997, Austrian science group Zeilinger [8] completed the first experimental verification of quantum teleportation in the laboratory. In 2004, the group successfully increased the quantum teleportation distance to 600 meters on Danube river [8]. In 2005, the Chinese group set the world record for two-way quantum entanglement distribution of 13 kilometers in Hefei, China. [56]. On Sep, 2020, physicists from the University of Vienna and the Austrian Academy of Sciences have achieved a new world record for teleportation of quantum states at a distance of 143 kilometers [58], which is the farthest world record for quantum teleportation up to now.

2.8.2 The ways quantum teleportation technique helps improve our current technology

The quantum teleportation of photons [65] achieved by scientists are now used in the field of quantum calculating and the data transmission [69], this helps us transferring information much faster than the transferring method we are using now, and the cost for quantum communication is much cheaper than that of traditional communication methods [70].

Besides, applying the quantum knowledge, we are able to calculate a huge amount of data within a second [71]. Car manufactures are also using quantum computers in their car-production for the statistics of all kinds of raw materials required and used, according to figure 10. These achievements all modify people's way of communication and data-transmission to a brand new stage.

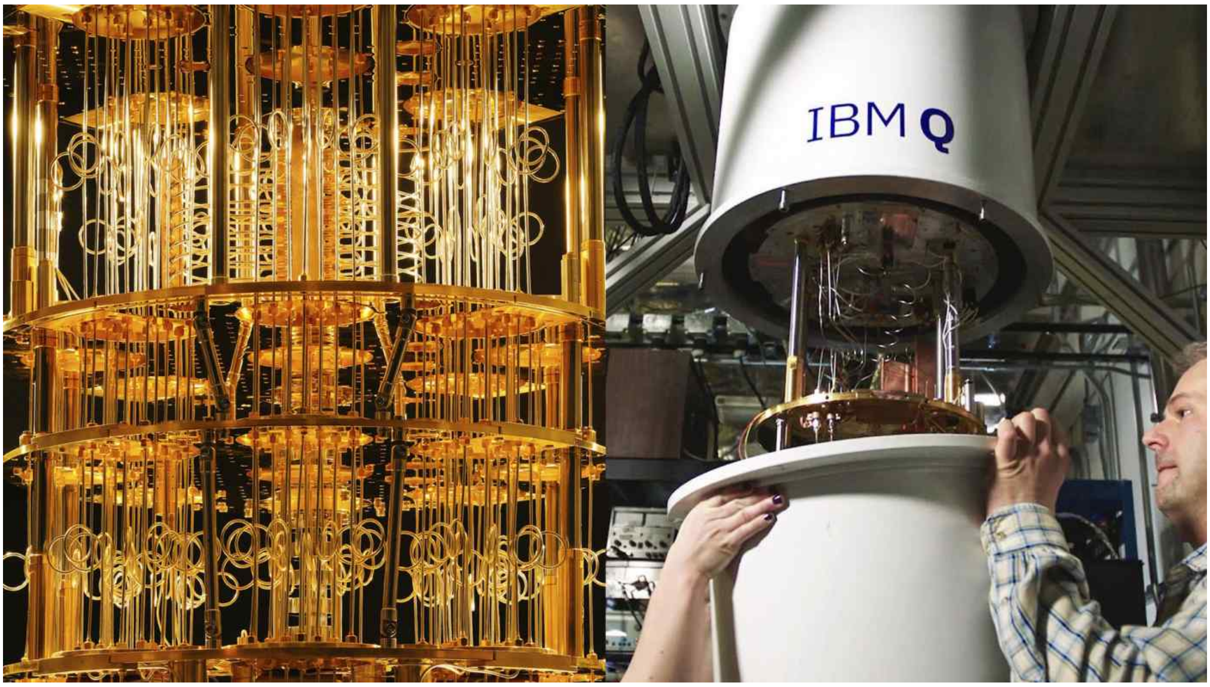

Fig. 10. Toyota using IBM quantum computer [72].

3 Discussion

3.1 Is it possible for human to achieve the teleportation in real-life objects theoretically?

The latest scientific result on the area of quantum teleportation technique is the successful teleportation of photons [65], and the teleportation of electrons [73] achieved in 2009 by a group of Chinese scientists [57] from Tsinghua University.

By contrast, all the macro matters are made up of the micro matters such as photons and electrons [74], and the microscopic particles all have quantum states [75]. It is commonly known that all matters are made up of microscopic particles [74], and the microscopic particles all have quantum states [75]. According to the current quantum mechanics, the difference between two photons is not only the frequency, but also the quantum state.

Quantum teleportation is not sending a photon to another place, but in two places, respectively, setting up a system. One is sent to, another is to receive the photons and measure its quantum state information, then receiving that information through the electromagnetic transmission. So we can reassemble the incoming photons which have the same quantum state as the outgoing photons. The essence of a macroscopic object is a combination of microscopic particles, so in my point of view, if the quantum teleportation of micro matters like photons is possible, the quantum teleportation of macro matters such as humans and cars, which are built up by the micro matters, should also be possible.

3.2 People's considerations about the teleportation to the 3D objects

So, what are people's opinions towards quantum teleportation of 3D objects? Of course most of them will consider this as a wonderful thing to happen. Just like I mentioned at the beginning of this essay, if you can move between two places instantaneously, everything would not seemed to be a worry, isn't it? It's really nice to fetch the pencil box or your homework that you forgot to bring to school within a second, so avoid the necessary punishment, or escape from the danger immediately by moving to an island millions of miles away on the Pacific Ocean... Everything will be possible and interesting.

3.3 Quantum teleportation of the animate and the inanimate

After all the explanation shown above, there is still one philosophical problem here to discuss. If the quantum teleportation of real-life objects is achieved one day, will the teleportation technique some how affect the animate being transferred?

Consider humans as an example, will the person lose his memory or personality after being transferred by quantum teleportation technique? This is a serious worry which we do not know the answer until we really achieved the quantum teleportation of 3D objects. There will be more challenges like this as we explore further in the field of quantum teleportation.

4 Conclusion

After studying carefully about most of the basic theories in quantum mechanics and the maths behind them, it can be proved theoretically that quantum teleportation of 3D objects can be achieved soon in the future, but with plenty of uncertainties and challenges.

In contrast, there are some limitations for writing this essay also for carrying out this research question. Most of the knowledge about quantum mechanics are studied and understood by me during the same time I write this essay, which means I haven't really learn about quantum physics before the essay is written. However due to my interest and passion in this field, I learn the basic knowledge quite fast and began to have some own thoughts about my research question.

One of the biggest limitations about this essay which should be mentioned here is certainly the fact that I cannot carry out any experiments due to the lack of experimental facilities and resources on quantum mechanics I can get access to. As a result, all of my explanations and ideas are carried out by studying carefully the work and experiments done by some famous physicists and scientists before, as well as all the basic theories and facts discovered by the great founders of quantum mechanics.

From my perspective, in the future, scientists and physicists will certainly be able to discover plenty of amazing facts and build up the fully developed technique in the field of quantum teleportation. This area will become one of the most important area in physics soon, massive of applications will be discovered in quantum teleportation, and people's lives will become much easier with the help of the brand new technology.

5 References

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