ADVANCE STUDY OF TELEPORTATION

Gargi Gupta[1], Jyoti Chaudhary[2]

UG, [1,2] Department of Electrical and Electronics Engineering,
Raj Kumar Goel institute of technology for Women, UP (India)

ABSTRACT

As we know that people have been inventing new ways to travel faster from one place to another. Though the automobile, airplane and rocket have been invented to decrease the amount of time to reach our destinations, yet each of these forms of transportation share the same flaw, i.e. they consume more time with respect to their physical distance. Continued research over the years on such a method of travel, where we can reach our destination without using any physical distance has resulted in improved performamance as compared to initial travelling methods. Basically it's a property of telecommunications and transportation to achieve a system called teleportation. In this paper, we aim to provide an overview about experiments that have actually achieved teleportation with photons, and how we might be able to use teleportation to travel anywhere, at anytime and here Teleportation is going to be used practically for quantum key distribution in very near future by separating its unique features. We also provide an insight into some of the open problems and challenges facing researchers in this field in the near future.

Key Words: *Telecommunication, Transportation, Teleportation*

I. INTRODUCTION

In March 1993 Charles H. Bennett from IBM proposed a scheme, based on Quantum Mechanics, which in principle could be used to teleport an object. The scheme was experimentally verified by Dik Bouwmeester et al. in the fall of 1997. In 2004 researchers at the University of Vienna and the Austrian Academy of Science used an 800m-long optical fibre fed through a public sewer system tunnel to connect labs on opposite sides of the River Danube to achieve such teleportation.

Here we explore this phenomenon of Quantum Teleportation. We will then extend the discussion to Quantum Information and Quantum Cryptography. The document is based on a discussion with an upper year course in modern Physics without mathematics given at the University of Toronto. Although the discussion is almost totally non-mathematical, it requires considerable understanding of the Quantum Correlation experiments used in describing Bell's Theorem. A document on Bell's Theorem is available here total file size including graphics is about 47k.

Teleportation

Quantum Teleportation is a process by which we can transfer the quantum state of a system and its correlation to another system. Or in a simple way we can say that Teleportation is the transfer of matter from one point to another, more or less instantaneously. It is a recent phenomenon developed in the 1990's. Recent experiments confirm that quantum teleportation is possible at least for states of photons and nuclear spins. The quantum teleportation is not only a curious effect but a fundamental protocol of quantum communication and quantum computing. The principles of the quantum teleportation and the entanglement swapping are explained, and physical realizations of teleportation of optical and atomic states are discussed.

Etymology

The word teleportation was coined in 1931 by American writer Charles Fort to describe the strange disappearances and appearances of anomalies, which he suggested may be connected. He joined the Greek prefix tele- (meaning "distant") to the Latin verb portare (meaning "to carry"). Fort's first formal use of the word was in the second chapter of his 1931 book, Lo, According to it "Mostly in this book I shall specialize upon indications that there exists a transportry force that I shall call Teleportation."

History

In 1993 an international group of six scientists Richard Jozsa, Willian K. Wpploters, Gilles Brassard, Claude Crepeau, Asher Peres and IBM Fellow Charles H. Bennett, confirmed the intuitions of the majority of science fiction writers by showing that perfect teleportation is indeed possible in principle, but only if the original is destroyed.

This revelation, first announced by Bennett at an annual meeting of the American Physical Society in March 1993, was followed by a report on his findings in the March 29, 1993 issue of Physical Review Letters. Since that time, experiments using photons have proven that quantum teleportation is in fact possible.

In 1998, physicists at the California Institute of Technology (Caltech), along with two European groups, turned the IBM ideas into reality by successfully teleporting a photon, a particle of energy that carries light. The Caltech group was able to read the atomic structure of a photon, send this information across 3.28 feet (about 1 meter) of coaxial cable and create a replica of the photon. As predicted, the original photon no longer existed once the replica was made.

In subsequent years, other scientists have demonstrated teleportation experimentally in a variety of systems, including single photons, coherent light fields, nuclear spins, and trapped ions.

Steps involved

The general idea behind the process of teleportation seems to be that the original object is scanned in such a way as to extract all the information from it, then this information is transmitted to the receiving location and used to construct the replica, not necessarily from the actual material of the original, but perhaps from atoms of the same kinds, arranged in exactly the same pattern as the original. The steps are

1. Scanning

Firstly, the object is completely scanned to extract all the information about it. For example, this may mean that some device scans a space explorer on board her spaceship to find out what she's like. This includes finding her height, her mass, the colour of her hair, what sort of shoes she is wearing etc..

2. Disassembling

As it's difficult to send the whole information simultaneously thus after the extraction of data at the sending station the object is disassembled to send the bit by bit information about the object to the receiving end. It means nextly the machine "disassembles" the space explorer and sends or "beams" all the things that she's made up of to some uncharted planet nearby. These include, for example, all the atoms in her body. The machine also sends a message to the planet containing everything that it found out about her.

3. Reassembling

Finally, after collecting all the data sent, at the receiving station the object is again reassembled to get the exact replica of the object sent i.e. we resemble the space explorer on the nearby planet using all the things she's made up of and the message. Teleportation is now complete.

Concepts Behind Teleportation

Teleportation is the process of moving from one place to another without travelling through the intervening space. Teleportation involves dematerializing an object at one point, and sending the details of that object's precise atomic configuration to another location, where it will be reconstructed. What this means is that time and space could be eliminated from travel - we could be transported to any location instantly, without actually crossing a physical distance. Teleportation can be explained with the following object

1.Experiments on photons

2. Human Teleportation

3. Quantum Teleportation

2.1. Photon experiment

As we have discussed in our previous section, in the year 1993 physicists of California institute of technology (Caltech), along with two European groups turned the ideas of IBM into reality by successfully teleporting a photon, a particle of energy that carries light.

The Caltech group was able to read the atomic structure of a photon, send this information across 4 meter(3.28 feet) of coaxial cable and create a replica of photon.

Principles of photon experiment

Teleportation involves dematerializing an object at one point, and sending the details of that object's precise atomic configuration to another location, where it will be reconstructed. What this means is that time and space could be eliminated from travel -- we could be transported to any location instantly, without actually crossing a physical distance.

In performing the experiment, the Caltech group was able to get around the two principles

1. **Heisenberg Uncertainty Principle**, the main barrier for teleportation of objects larger than a photon.
2. **Entanglement**, the basis of teleportation

Heisenberg Uncertainty Principle

Statement

This principle states that it's impossible to determine both the location and speed of an object simultaneously. Measurement of one value changes the others value.

Limitation

According to the uncertainty principle, the more accurately an object is scanned, the more it is disturbed by the scanning process, until one reaches a point where the object's original state has been completely disrupted, still without having extracted enough information to make a perfect replica. This sound like a solid argument against teleportation: if one cannot extract enough information from an object to make a perfect copy, it would seem that a perfect copy cannot be made. In order to teleport a photon without violating the Heisenberg Principle, the Caltech physicists used a phenomenon known as entanglement.

Entanglement

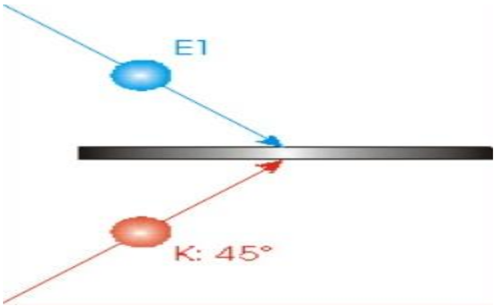
It solves the difficulty of measuring that we encountered in Heisenberg Uncertainty principle. Two particles are said to be entangled when they come in contact. Measurement of one of the entangled sub-system puts the other sub-system in the corresponding state.

Entanglement is a term used in quantum theory to describe the way that particles of energy/matter can become correlated to predictably interact with each other regardless of how far apart they are.

Particles, such as photons, electrons, or qubits that have interacted with each other retain a type of connection and can be entangled with each other in pairs, in the process known as correlation. Knowing the spin state of one entangled particle - whether the direction of the spin is up or down - allows one to know that the spin of its mate is in the opposite direction. Even more amazing is the knowledge that, due to the phenomenon of superposition, the measured particle has no single spin direction before being measured, but is simultaneously in both a spin-up and spin-down state. The spin state of the particle being measured is decided at the time of measurement and communicated to the correlated particle, which simultaneously assumes the opposite spin direction to that of the measured particle.

Principle

- Two photon E1, K and beam splitters (it splits a light into two equal parts) are required.
- We direct one of the entangled photons, say *E1*, to the beam splitter.

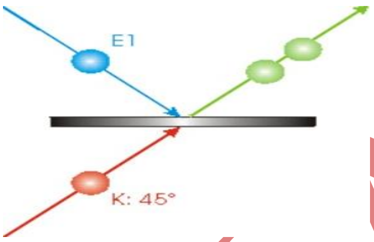


Figue1- Photon E1 and K incident with a 45 degree angle on the beam splitter.

Meanwhile, we prepare another photon with a polarization of 45 degree, and direct it to the same beam splitter from the other side as shown in the figue1

This is the photon whose properties will be transported; we label it K. We time it so that both E1 and K reach the beam splitter at the same time.

The E1 photon incident from above will be reflected by the beam splitter some of the time and will be transmitted some of the time. Similarly for the K photon that is incident from below. So sometimes both photons will end up going up and to the right as shown in figure 2.



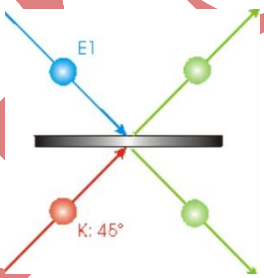


Figure 2- Resultant of both the photons , Figure 3- Resultant of both the photons

Similarly, sometimes both photons will end up going down and to the right.

However, in the case of one photon going upwards and the other going downwards, we cannot tell which is which. Perhaps both photons were reflected by the beam splitter, but perhaps both were transmitted.

This means that the two photons have become entangled.

In entanglement, at least three photons are needed to achieve quantum teleportation:

Photon A: The photon to be teleported

Photon B: The transporting photon

Photon C: The photon that is entangled with photon B

If researchers tried to look too closely at photon A without entanglement, they would bump it, and thereby change it. By entangling photons B and C, researchers can extract some information about photon A, and the remaining information would be passed on to B by way of entanglement, and then on to photon C. When researchers apply the information from photon A to photon C, they can create an exact replica of photon A. However, photon A no longer exists as it did before the information was sent to photon C.

Quantum entanglement allows qubits that are separated by incredible distances to interact with each other immediately, in a communication that is not limited to the speed of light. No matter how great the distance between the correlated particles, they will remain entangled as long as they are isolated.

Entanglement is a real phenomenon (Einstein called it "spooky action at a distance"), which has been demonstrated repeatedly through experimentation. Much current research is focusing on how to harness the potential of entanglement in developing systems for quantum cryptography, quantum computing and teleportation.

2.2 Human teleportation

For a person to be teleport, a machine have to be built that can pinpoint and analyze all of the ‘10 to the power 28’ atoms that made up the human body. That is more than a trillion trillion atoms. This machine would then have to send this information to another location, where the person’s body would be reconstructed with exact precision. Molecules could not be even a millimetre out of the place, let the person arrive with some severe neurological or physiological defects.

Teleportation would combine generating cloning with digitization. In this bio digital cloning, tele-tavelers would have to die, in a sense. Their original mind and body would no longer exist. Instead, their atomic structure would be recreated in another location, and digitization would recreate the traveller’s memories, emotions, hopes and dreams. So the travellers would still exist, but they would do so in a new body, of the same atomic structure as the original body programmed with the same information.

Figure 4- Teleporting a human body from one place to another.

2.3. Quantum teleportation

Quantum teleportation has achieved a new milestone or, should we say, a new ten-milestone: scientists have recently had success teleporting information between photons over a free space distance of nearly ten miles, an unprecedented length. The researchers who have accomplished this feat note that this brings us closer to communicating information without needing a traditional signal, and that the ten miles they have reached could span the distance between the surface of the earth and space.

Quantum teleportation, or entanglement-assisted teleportation, is a technique used to transfer quantum information from one quantum system to another. It does not transport the system itself, nor does it allow communication of information at superluminal (faster than light) speed. Neither does it concern rearranging the particles of a macroscopic object to copy the form of another object. Its distinguishing feature is that it can transmit the information present in a quantum superposition, useful for quantum communication and computation.

Procedure

Stated more precisely, quantum teleportation is a quantum protocol by which a qubit *a* (the basic unit of quantum information) can be transmitted exactly from one location to another. The prerequisites are a conventional communication channel capable of transmitting two classical bits, and an entangled Bell pair of qubits, with *b* at the origin and *c* at the destination.

Quantum teleportation involves entangling two things, like photons or ions, so their states are dependent on one another and each can be affected by the measurement of the other's state.

When one of the items is sent a distance away, entanglement ensures that changing the state of one causes the other to change as well, allowing the teleportation of quantum information, if not matter. However, the distance particles can be from each other has been limited so far to a number of meters.

Teleportation over distances of a few hundred meters has previously only been accomplished with the photons traveling in fiber channels to help preserve their state. The two photons are entangled using both spatial and polarization modes and sent the one with higher energy through a ten-mile-long free space channel. It was found that the distant photon was still able to respond to changes in state of the photon they held onto even at this unprecedented distance.

As the figure above suggests, the unscanned part of the information is conveyed from **A** to **C** by an intermediary object **B**, which interacts first with **C** and then with **A**. What? Can it really be correct to say "first with **C** and then with **A**"? Surely, in order to convey something from **A** to **C**, the delivery vehicle must visit **A** before **C**, not the other way around. But there is a subtle, unscannable kind of information that, unlike any material cargo, and even unlike ordinary information, can indeed be delivered in such a backward fashion. This subtle kind of information, also called "Einstein-Podolsky-Rosen (EPR) correlation" or "entanglement", has been at least partly understood since the 1930s when it was discussed in a famous paper by Albert Einstein, Boris Podolsky, and Nathan Rosen. In the 1960s John Bell showed that a pair of entangled particles, which were once in contact but later move too far apart to interact directly, can exhibit individually random behaviour that is too strongly correlated to be explained by classical statistics. Experiments on photons and other particles have repeatedly confirmed these correlations, thereby providing strong evidence for the validity of quantum mechanics, which neatly explains them. Another well-known fact about EPR correlations is that they cannot by themselves deliver a meaningful and controllable message. It was thought that their only usefulness was in proving the validity of quantum mechanics. But now it is known that, through the phenomenon of quantum teleportation, they can deliver exactly that part of the information in an object which is too delicate to be scanned out and delivered by conventional methods.

II. CONCLUSION

In all the theories we can conclude that, if we can teleport a single photon then it is possible to teleport many photons simply by repeating the experiment in series many times. But this roughly works on two disjoint photons. To teleport a single object comprised of many photons is still out of reach of the present experiment.

There are about 10^{29} matters particles comprising of a human person, each of which has position and momentum. In all we can conclude that we might also need to teleport the photons and other energy particles comprising a person. Teleport all that is going to be harder than few thousand photons. As we know nothing is impossible so, many scientist are just doing their best to teleport a human being without using any physical distance to travel. And the basic idea to teleport a object is with the help of photon experiment and quantum teleportation theory. Quantum teleportation does not transport the information itself rather is a technique used to transfer quantum information from one quantum system to another.

REFERENCES

[1]. Jammer, m. , "*The philosophy of quantum mechanics, The Philosophy of Quantum",* Wiley-interscience, new York, pp. 507-521, (1974).

[2]. Eric W.Davis*,"Teleportation Physics Study*",

[3]. Title W., Bendel,j.,Zbinden H. and Gisin, N. *"Quantum cryptography using Entangled photon in energy –Time Bell states,"* Phys.Rev.Left,84,4737-4740, 2000.

[4]. Vaidman L. "*Teleportation of quantum states,"* Phys.Rev.A, 49, 1473-1476, 1994.

[5]. Pan.J-W.et al "*Experimental entanglement swapping* ,"Phys. Rev. Left, 80, 3891-3894, 1998.

[6]. Opatrny T. and Kuizki,G,"*Matter-WavevEntanglement and Teleportation by Molecular Dissociation and Collisions,"* Phys,Rev Lett,86, 3180, 2001.

[7]. Lamas-Linares, A , Howell, J.C. ans Bouwmeester, D. "*Stimulated emission of polarization-entangled photons,"* Nature, 412,887-890, 2001.

[8]. Aczel, A.D., "*Entanglement: The Greatest Mystery in Physics, Four Walls Eight windows Press"*, New York, 2001.

[9]. Aharonov, Reznik, b. and Sten, A.,"*Quantum limitations of superluminal propagation,''* Phys. Rev. lett., 81, 2190-2193, 1998.

[10]. Aharonov, Y. and Albert, D., "*Can we make sense of the measurement process in relativistic quantum mechanics?,*'' Phys. Rev. D, 24, 359-370, 1981.

[11]. Aspect, A., rangier, P. and Roger, G., *"Experiment Realization of Einstein-Podolsky-Rosen-Bohm Gedanken experiment: A New Violation of Bell's Inequalities*," Phys. Rev. Letters, 49, 91,1982

[12]. Bennett, C.H., et al., *"Teleporting an unknown quantum state via dual classic and Einstein-Podolsky-Rosen channels,"* Phys. Rev. Lett., 70, 1895-1899, 1993

[13]. Bennett, C.H. and Wiesner, S.J., *"Communication via one and two-particle operators on Einstein-Podolskey-Rosen states,"* Phys. Rev. Lett.,69, 2881-2884, 1992.

[14]. Boschi, D. , *"Experimental realization of teleporting an unknown pure quantum state via dual classical and Einstein-Podolski- Rosen channels,"* Phys. Rev. Lett., 80, 1121-1125, 1998.

[15]. Bose, S. and Home, "*Generic Entanglement Generation, Quantum Statistics, and complementarily,"* Phys. Rev. lett. , 88, 050401, 2002.

[16]. Bouwmeester, D., *"Experimental quantum teleportation*," Nature, 390, 575-579, et al. 1997.

[17]. Brassard, G., Braunstein, S. and Cleve, R. (1998), "Teleportation as a quantum computation," Physica D, 120, 43-47

[18]. Wheeler, J.A. and Zurek, "Quantum Theory and Measurement," Princeton University Press, 1983.