FROM THE SATELLITE TO THE GROUND, THE QUANTUM CODE IS TRANSMITTED; FROM THE GROUND TO THE SATELLITE, QUANTUM STEALTH TELEPORTATION

THE *MOZI*, A CREATIVE HIGHPOINT IN THE RACE FOR QUANTUM TECHNOLOGY

Wu Yuehui

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[The Chinese government has invested heavily in quantum technology, and the applications there are to all accounts more advanced than in any other country, including the United States. This document, a kind of popular-science account of what is to the vast majority of humankind an obscure and difficult subject, discusses the use of quantum physics to encrypt messages in a way that it is not possible to decipher them, and to transmit the messages rapidly over far distances—indeed, spanning the entire globe. The satellite is named after Mozi (c.470-391 BC), the founder of a philosophical school rival to that of Confucius (his name is sometimes, but rarely, Romanized as Micius, the rendition preferred for the satellite in official Chinese translations). Among the notable characteristics of the Mozi school is an emphasis on the development of logical reasoning, perhaps explaining the choice of the name of the satellite.

Some of the discussion may come across as unintelligible. In part this may be because popular accounts of the more arcane fields of science may often leave out information necessary to understand what is going but that would only confuse more the general *reader. A more serious drawback, though, is the translator's ignorance both of the vocabulary and the physics of this particular area.]*

The China Academy of Sciences held a press conference the other day to announce that the *Mozi* quantum experimental satellite has fully accomplished three scientific goals, showing that our country continues to lead the world in the development of quantum information technology and in basic problems in spatial scale (?—空间尺度) quantum physics, continuing experimental research in establishing a firm scientific and technological basis,

Professor Pan Jianwei, of China Science and Technology University, with his colleague Peng Chengzhi and others of his research team joined with the research team of Wang Jianyu at the Physics Institute of the Shanghai branch of the China Science Academy; the Micro-Satellite Innovation Research Academy; the Electronics Technology Research Institute; the National Observatory; the Cijin Mountain Observatory; the Nanjing Astronomical Instruments Corporation; the State Space Science Center—all these organizations, have under the guidance of the strategic space science plan of the China Academy of Sciences opened a new page in the advance of technique. Making use of the *Mozi* Quantum Experimental Satellite they have succeeded for the first time in the whole world in transmitting quantum code from a satellite to the ground and achieving quantum stealth teleportation from the ground to a satellite. The two achievements were published at the same time online on August 10 in the prestigious international scientific journal *Nature*. This follows upon the publication in the leading international scientific journal *Science* of the first successful transmission of quantum code over 1000 kilometers from the sky to the ground and the success of the experiment in nonlocalized (?) quantum energy. Our country's scientists have used the *Mozi* Experimental Quantum Satellite for yet another breakthrough in space quantum physics research.

Bai Chunli, President of the China Academy of Sciences and Secretary of its Party committee, says that the *Mozi* has opened up a wide gate for globalized quantum communications, space quantum physics, and quantum gravitation experimentation. Our country has reached a new high point worldwide in quantum science. We have set the international standard and hold first place in the race.

Secret quantum communication is currently humanity's only known way for absolute security in communications, incapable of being overheard or deciphered.

Secure communications are basic needs for state security and for human social and economic life. The quest for these has been going on for hundreds of thousands of years, as people have been searching without cease for communications security. However, given the complexity of calculations required in traditional techniques for assuring secrecy there is in principle the possibility that such communications can be deciphered. With the ever increasing advances in mathematics and computing power, the ability to break classical codes grows day by day.

Pan Jianwei says: "This problem can be solved with quantum communications. That is to say, we can unite quantum physics with information technology, making use of quantum control technology, making use of a revolutionary method to encode, preserve, transmit, and manipulate information. In this manner we can guarantee information security, elevate the speed of transmission, and enhance its precision. With these and other methods we can break through the limitations of classical information technology."

The ordinary view is that the main focus of research in quantum communications includes the development of quantum codes (secret quantum communication) and quantum stealth teleportation.

Quantum codes are transmitted in a quantum state so that two widely separated locations receive the code with absolute security and that encoded information allows the one-time transmission in complete secrecy. This is currently the only known way to communicate in absolute security without the possibility of being intercepted or deciphered.

"To put it in plan terms, quantum code transmission is as if someone wanted to convey a secret to someone else. He might put the secret in a box and give a key to the box to the other person. The person who receives the key can get the secret only by using that key to open the box. Without that key, no one else is able to open the box; also, should the key for some reason fall into someone else's hands, this will be immediately discovered by the person who issued the key; the original key will be disabled and a new key issued, directly into the hands of the person who originally received the key." Thus says Pan Jianwei.

So then, how is it that, should the key be taken by someone else, this can be known instantly?

The reason is that scientists can convert quanta into a code by taking advantage of the fact that quanta exist in multiple states. In this way, should someone try to figure out or guess the quantum code, that will change its state, and scientists will be able immediately to see from this change that the key has been moved. Therefore, because a quantum cannot be cloned or split, quanta can be used as a means to transmit information with the absolute guarantee of secrecy.

For quantum communication there is another important implication of the hidden status of quanta. The special entangled nature of quanta means that the unknown status of physical quanta can be transmitted to a distant place without using any material, in the transmission itself, allowing information to be transmitted in a stealth manner. Quanta transmitted stealthily over a distance can serve as the basic components of a network for quantum communication.

Since there is very little loss of optical signals in outer space, this means that with the use of satellites it is possible greatly to increase the range of quantum communications.

Quantum communication usually uses photons as its physical carrier. The most direct channel of transmission is through optical cables or free space on the ground. However, these channels become increasingly degraded with increases in distance or the number of digits to be conveyed. Since quanta cannot be cloned, the symbols in quantum communications cannot be enlarged in the manner of classical means of communications, so the previous world record for the range of quantum transmission was estimated to be 100 kilometers. According to calculations, with a 1200 kilometer light beam emitting 10 billion photons each second and a perfect detection device, it would take a million years to set up a bitcode (?). Therefore, how to achieve a secure, long-range, practical means of quantum communication is the greatest challenge in this sphere and the common goal the international scholarly community has been struggling for over the past few decades.

Wang Jianyu, a fellow of the Shanghai branch of the China Academy of Sciences, Deputy Chief Engineer of the Quantum Satellite Experimental Engineering group, and general director of the Satellite system, says: “Outer space approximates a vacuum, and therefore there is very little degradation of light signals. By making use of satellites we can vastly expand the range of quantum communication. At the same time, because satellites can easily survey the entire globe, this becomes the most promising path toward a global range for quantum coding and the stealth transmission of quantum states.”

From the beginning of this century, this direction has been the focus of intense attention by the global scholarly community. Pan Jianwei’s team has performed pioneering experiments in quantum communication between satellites and the ground.

In 2003 Pan Jianwei’s team proposed the use of satellites for ground-sky communication and set up a global-scale network for the transmission of secret quantum communications. In 2004 they achieved for the first time a range for sending and receiving quanta through free space for a range exceeding 13 kilometers (greater than the height of the atmosphere (?)). This proved the possibility of quantum communication through the atmosphere. In 2011 the Academy of Science formally stipulated a special guidance project for a producing a quantum science experimental satellite. In 2012 Pan Jianwei’s team at Qinghai Lake for the first time successfully sent and received a stealth quantum-state message over a distance of 100 kilometers, fully proving it is possible to use satellites in quantum communication. In 2013 the Academy of Sciences joined with the research team at Qinghai Lake to conduct experiments, using models in quantum communication between the ground and the sky without great degradation of content, definitely establishing the possibility of sending secret quantum code from a satellite to the ground. Subsequently that team through hard work overcame all kinds of difficulties, and finally succeeded in producing the *Mozi* experimental quantum experimental satellite. It was fired into space from the Jiuquan Satellite grounds on August 16 2016, orbiting for four months. On January 18 2017 formal experimentation began.

Building a Reliable Technical Base for a Global Network of Secret Quantum Communication

The successful completion of this experiment in sky-ground quantum code transmission is one of the scientific goals of the *Mozi* quantum satellite.

Peng Chengzhi, researcher at the China Science and Technology University, general director of the project for the development of a quantum satellite, and general director of the satellite division says: “The experiment was to see whether quantum signals transmitted by satellite could be received on the ground. In the course of its transit, the Mozi began communicating when it was in contact with the Xinglong Optical Station in Hebei, sending the signal at a distance from 645 kilometers to 1200 kilometers. At its greatest range of 1200 kilometers, the speed of the transmission was faster by a magnitude of 20 than that of optic cable communication from ground to ground at a comparable distance. The light source on the satellite as it puts the quanta into the excited state emits an average of 40 million signal photons each second. On each orbit it can send to the receiving station 300,000 bits of secret code, with a rate of 1100 bits per second.”

According to Pan Jianwei, this achievement is a reliable technological basis for the construction of a global-scale secret quantum communication system. “With the basis in the transmission of the quantum code from the satellite, the satellite can serve as a reliable medium, so that any two places on earth whatsoever can at pleasure have access to the code, and in the future the scope of quantum transmission will expand to the entire globe. In addition, terrestrial quantum communications and intercity fiber optic networks (such as the quantum communications net in Hefei, Jinan, or Beijing-Shanghai) can be joined with the global sky-earth network into an integrated secret quantum communications highway."

An experiment in stealthy quantum transmission from ground to sky was another scientific goal of the Mozi quantum satellite.

"The experiment in stealth quantum transmission consisted in sending entangled photons from the ground to a receiver in the sky. As Mozi crossed the border, it established a photon link with the receiving station at Ali, in Tibet, 5100 meters above sea level. The light source on the ground generated 8000 quantum state stealth matters (?) per second. The ground sent entangled photons to the satellite to test whether at a distance of 500 to 1400 kilometers all six carriers could work with 99.7 percent accuracy." Peng Chengzhi says: "The hypothesis is that if this were to be done with fiber optics, it would require 380 billion years (twenty times the age of the universe) to figure out the first matter. This achievement establishes a reliable technical basis for future research into a spatial scale quantum communications network and experimentation in quantum physics in space and quantum gravitation."