World's first Quantum satellite launched by China will enable it to build global unhackable ground and space network infrastructure

China's quantum satellite has produced its first successful result. In a paper published in Science, researchers from the Chinese Academy of Sciences announced the satellite had successfully distributed entangled photons between three different terrestrial base stations, separated by as much as 1,200 kilometers on the ground. The result is the longest entanglement ever demonstrated, and the first that spanned between the Earth and space. Researchers say the system "opens up a new avenue to both practical quantum communications and fundamental quantum optics experiments at distances previously inaccessible on the ground.

China launched the world's first quantum communications satellite officially known as Quantum Experiments at Space Scale, or QUESS, satellite. The launch took place at 17:40 UTC Monday (16th Aug 2016) from the Jiuquan Satellite Launch Centre in the Gobi Desert, with a Long March 2D rocket sending the 620 kilogram (1,367 pound) satellite to a 600 kilometer (373 mile) orbit at an inclination of 97.79 degrees. "In its two-year mission, QUESS is designed to establish 'hack-proof' quantum communications by transmitting uncrackable keys from space to the ground," Xinhua news agency said. China then plans to put additional satellites into orbit China hopes to complete a QKD system linking Asia and Europe by 2020, and have a worldwide quantum Network.

"The newly-launched satellite marks a transition in China's

role – from a follower in classic information technology development to one of the leaders guiding future achievements," Pan Jianwei, the project's chief scientist, told the agency. Quantum communications holds "enormous prospects" in the field of defense, it added.

In November 2015, at the 18th Party 8 Congress' 5th Plenum, Xi Jinping included quantum communications in his list of major science and technology projects that are prioritized for major breakthroughs by 2030, given their importance from the perspective of China's long-term strategic requirement.

Many other countries like United States, Canada, Japan, and some EU countries are all racing to develop quantum communication networks as they are virtually un-hackable. Researchers from these countries are closely watching the China's tests.Researchers at the National Institute of Information and Communications Technology (NICT) in Japan and recently published in the journal Nature Photonics, demonstrated Satellite based "unhackable" Quantum Key Distribution, or QKD.

Satellite based Quantum key cryptography

Quantum technology is considered to be unbreakable and impossible to hack. A unique aspect of quantum cryptography is that Heisenberg's uncertainty principle ensures that if Eve attempts to intercept and measure Alice's quantum transmissions to Bob, her activities must produce an irreversible change in the quantum states that are retransmitted to Bob. These changes will introduce an anomalously high error rate in the transmissions between Alice and Bob, allowing them to detect the attempted eavesdropping.

Quantum key distribution (QKD), establishes highly secure keys between distant parties by using single photons to transmit

each bit of the key. Photons are ideal for propagating over long-distances in free-space and are thus best suited for quantum communication experiments between space and ground. The unit of quantum information is the “qubit” (a bit of information “stamped” in a quantum physical property, for instance the polarization of a photon).

QKD thus solves the long-standing problem of securely transporting cryptographic keys between distant locations. “Even if the keys were transmitted across hostile territory, their integrity could be unambiguously verified upon receipt,” say Thomas Jennewein, Brendon Higgins and Eric Choi in SPIE.

Fiber optic based QKD systems are commercially available today, however are point to point links and limited to the order of few hundreds kms because of current optical fiber and photon detector technology. One way to overcome this limitation is by bringing quantum communication into space. An international team led by the Austrian physicist Anton Zeilinger has successfully transmitted quantum states between the two Canary Islands of La Palma and Tenerife, over a distance of 143 km. The previous record, set by researchers in China was 97 km. The process called quantum teleportation allows the state of one of the two entangled photons to be changed immediately without delay by changing the state of other photon even though they may be widely separated.

The biggest challenge, Alexander Ling, principal investigator at the Centre for Quantum Technologies in Singapore said, is being able to orient the satellite with pinpoint accuracy to a location on Earth where it can send and receive data without being affected by any disturbances in Earth’s atmosphere. Ling said. “You’re trying to send a beam of light from a satellite that’s 500 kilometres (310 miles) above you.”

Record breaking accomplishments

In the spacecraft's first record-breaking accomplishment, reported June 16 in Science, the satellite used onboard lasers to beam down pairs of entangled particles, which have eerily linked properties, to two cities in China, where the particles were captured by telescopes (SN: 8/5/17, p. 14). The quantum link remained intact over a separation of 1,200 kilometers between the two cities — about 10 times farther than ever before. The feat revealed that the strange laws of quantum mechanics, despite their small-scale foundations, still apply over incredibly large distances.

Next, scientists tackled quantum teleportation, a process that transmits the properties of one particle to another particle (SN Online: 7/7/17). Micius teleported photons' quantum properties 1,400 kilometers from the ground to space — farther than ever before, scientists reported September 7 in Nature. Despite its sci-fi name, teleportation won't be able to beam Captain Kirk up to the Enterprise. Instead, it might be useful for linking up future quantum computers, making the machines more powerful.

The final piece in Micius' triumvirate of tricks is quantum key distribution — the technology that made the quantum-encrypted video chat possible. Scientists sent strings of photons from space down to Earth, using a method designed to reveal eavesdroppers, the team reported in the same issue of Nature. By performing this process with a ground station near Vienna, and again with one near Beijing, scientists were able to create keys to secure their quantum teleconference. In a paper published in the Nov. 17 Physical Review Letters, the researchers performed another type of quantum key distribution, using entangled particles to exchange keys between the ground and the satellite.

China’s Quantum Satellite Mission Objectives

The major goal is to test the possibilities of relaying quantum “keys” carried by photons, or light particles, over 500 to 1,200 kilometers from a satellite to ground stations to create a new kind of information transmission network that cannot be hacked without detection. The satellite will enable secure communications between Beijing and Urumqi, Xinhua said. Other missions include quantum teleportation and quantum entanglement, both for the first time in space.

“Initial tests on the satellite have reached a transmission rate that will allow us to finish these experiments within several weeks, so we will have time to add new experiments,” Pan said. He said the plans include more complex quantum tests between Micius and five ground stations across China this year, and then cross-continental quantum communication experiments to establish links with ground stations in Austria, Italy and Canada in 2018.

Pan Jianwei, the projects’ chief scientist also said that the 2,000-km quantum communication main network between Beijing and Shanghai will be fully operational in the second half of this year. The network would be used by the central government, military and critical business institutions like banks. Government agencies and banks in cities along the route can use it first.

“There are many bottlenecks in the information security. The Edward Snowden case has told us that the information in the transmission networks are exposed to risks of being monitored and being attacked by hackers,” Pan said. In 2012, Pan’s group built the world’s first metropolitan area quantum network in Hefei, linking 46 nodes to allow real-time voice communications, text messages and file transfers. The quantum satellite is part of the country’s Strategic Priority Program

on Space Science that started in 2011 and planned to launch four satellites by the end of the year.

The 620kg QUES satellite would seek breakthroughs in cryptography and test laws of quantum mechanics like teleportation and quantum entanglement on a global scale. The experimental satellite would contain a quantum key communicator, quantum entanglement emitter, entanglement source, processing unit and a laser communicator.

The aim of the new experiment conducted by a team led by physicist Pan Jian-Wei from the University of Science and Technology of China in Hefei is: “To see if we can establish quantum key distribution [the encoding and sharing of a secret cryptographic key using the quantum properties of photons between a ground station in Beijing and the satellite, and between the satellite and Vienna. Then we can see whether it is possible to establish a quantum key between Beijing and Vienna, using the satellite as a relay.”

The second step will be to perform long-distance entanglement distribution, over about 1,000 kilometres. We have technology on the satellite that can produce pairs of entangled photons. We beam one photon of an entangled pair to a station in Delingha, Tibet, and the other to a station in Lijiang or Nanshan. The distance between the two ground stations is about 1,200 kilometres. Previous tests were done on the order of 100 kilometres.

“In principle, quantum entanglement can exist for any distance. But we want to see if there is some physical limit… we hope to build some sort of macroscopic system in which we can show that the quantum phenomena can still exist,” Pan told Nature, in describing the theoretical premises for the experiment.

This could potentially facilitate super-fast, long-range communications, as well as lead to the creation of unbreakable

quantum communication networks.

China has collaborated with the Austrian Academy of Sciences to provide the optical receivers at a ground station in Vienna, while three more stations have also been planned across Austria. Eventually, the Chinese team is planning to launch about 10 additional satellites, which would fly in formation to allow for coverage across more areas of the globe.

Military Capability

“China is completely capable of making full use of quantum communications in a regional war,” China’s leading quantum-communications scientist, Pan Jianwei, said. “The direction of development in the future calls for using relay satellites to realize quantum communications and control that covers the entire army.”

Matthew Luce, a researcher with Defense Group Inc.’s Center for Intelligence Research and Analysis, thinks “A functional satellite-based quantum communication system would give the Chinese military the ability to operate further afield without fear of message interception.”

Militaries have become dependent on Satellites that provide intelligence of adversary’s activities by capturing high resolution images, radar and communication signals, providing wide area real time communications among battle troops and command and control. However, Satellites are vulnerable to jamming, cyber-attacks and other ASAT weapons. China is also developing technologies like electronic warfare, DEW and other ASAT weapons that can disrupt its adversary’s satellites. By developing satellite based quantum cryptology China shall be able to gain information superiority over other countries as it would be able to collect, process, and disseminate an uninterrupted flow of information while exploiting or denying

its adversary’s ability to do the same.

Although the Chinese government has not revealed the projects budget, scientists told state media that the construction cost would be ¥100m (£10.17m) for every 10,000 users, according to the South China Morning Post.

Global Satellite Quantum Network

China is also first country to release a detailed schedule to put this technology to large-scale use. Communications satellite would be a first step toward building a quantum communications network in the sky. China hopes to complete a Asia-Europe intercontinental quantum key distribution in 2020 and build a global quantum communication network by 2030.

The team’s future plans also include making use of China’s future space station, Tiangong, which is expected to be created by the end of the decade, to conduct “upgraded” quantum experiments. “We will have a quantum experiment on the space station and it will make our studies easier because we can from time to time upgrade our experiment (unlike on the quantum satellite).

Quantum Communication between Earth and Moon

In the future, Pan also hopes to create a signal transmitting system that could facilitate communication between the Earth and the Moon. “In the future, we also want to see if it is possible to distribute entanglement between Earth and the Moon. We hope to use the [China’s Moon program] to send a quantum satellite to one of the gravitationally-stable points in the Earth-Moon system,” he told the weekly.

“I think China has an obligation not just to do something for

ourselves – many other countries have been to the Moon, have done manned spaceflight – but to explore something unknown," Pen said. The scientist also predicted that the world will soon enter a quantum era with a revolution in quantum physics taking the world by storm and leading to the creation of super-fast quantum computers and large quantum communication networks, China's People's Daily reported.

References and resources also include:

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