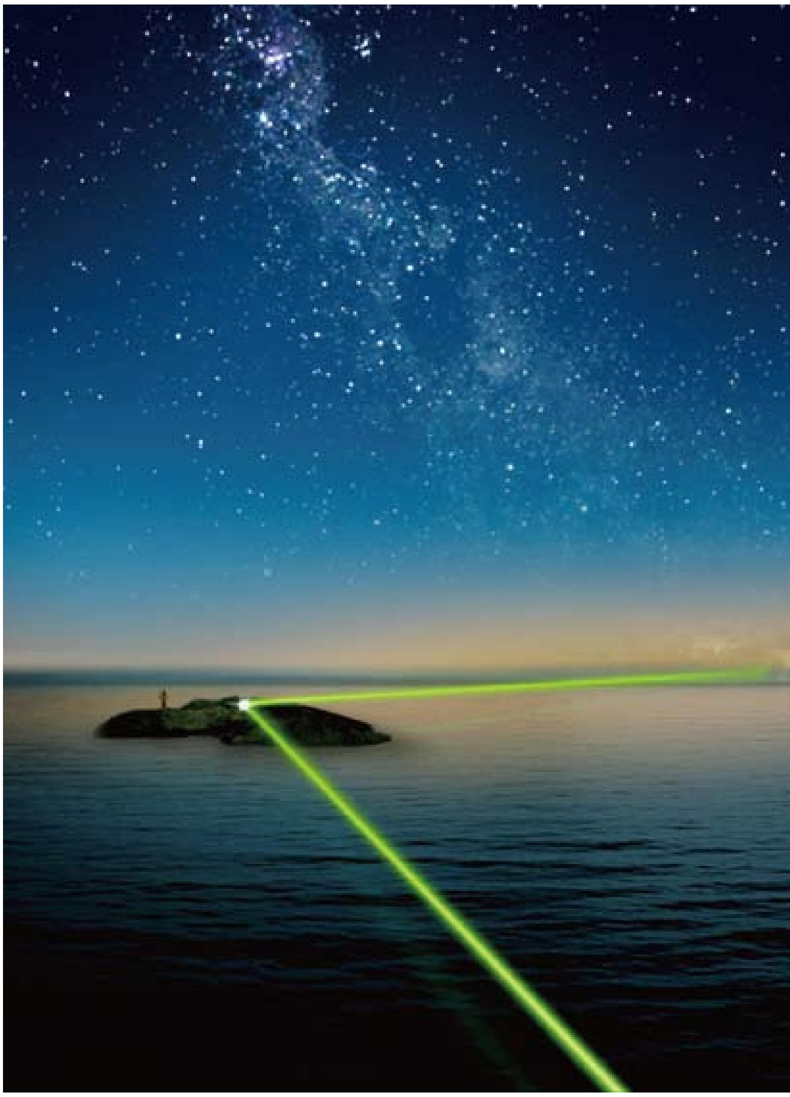
Major Achievements & Hallmark Advances during the Period of the 12th National Five-Year Plan

Quantum Communications

"It will confirm China's ascent in the field, from a bit-player a little more than a decade ago to a global powerhouse: in 2016, ahead of Europe and North America, China plans to launch a satellite dedicated to quantum-science experiments," commented science writer Zeeya Merali in a feature report published in December 2012 in *Nature*, after introducing the ambitious plan of a team at the University of Science and Technology of China (USTC) to send a satellite into space to perform experiments of quantum science. After over a decade's efforts to explore quantum teleportation, the team led by CAS Member Prof. PAN Jianwei aims to extend the safe distance of quantum teleportation to a record length. Now when the well-anticipated launch is approaching, we can look back to review the trajectory of the development of related research at USTC more clearly, with focus laid on what occurred in the five years from 2011 to 2015, exactly the period of the 12th National Five-Year Plan of China.

USTC has been dedicated to tackling fundamental issues in quantum teleportation and to removing technological barriers against high-speed, long-distance quantum communication networks. For this sake, the University has attracted talented scientists to establish a team for science excellence in this field, and assumed a series of major projects, particularly the Strategic Priority S&T Program for Quantum Communications supported by the Chinese Academy of Sciences.

Led by Prof. PAN, the team has been continuously working for over a decade to solve fundamental issues in quantum mechanics, and has developed a series of expandable technologies for quantum information processing, which have found their applications in quantum communications, quantum computation and accurate surveying. Based on this, the team further made crucial breakthroughs in their systemic R&D of wide area quantum communication technology. Mainly due to



Shown is an artistic impression of the quantum teleportation, the mysterious real-time synchronization between two entangled photons despite long distance. Scientists endeavor to solve a series of scientific and technological issues to utilize this quantum mechanics phenomenon for information encryption.

USTC's contributions, China has got the ticket to the very exclusive club of quantum communications.

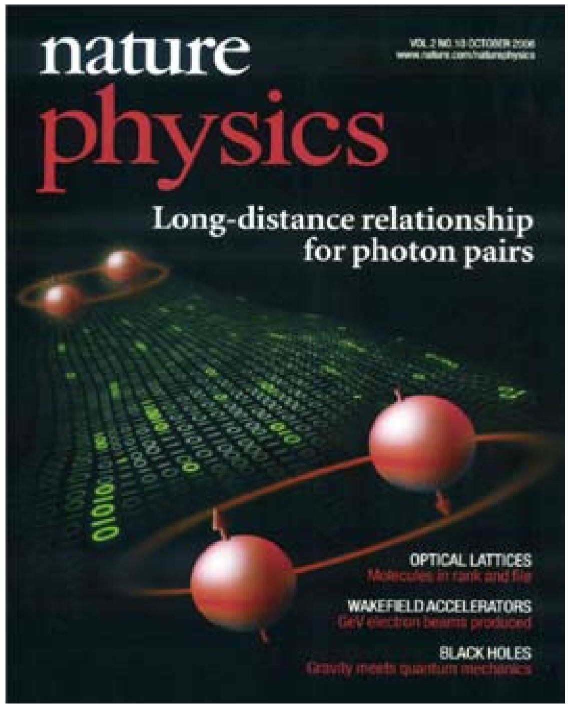
In terms of R&D of technologies oriented toward industrialization, the team has maintained a leading position on the frontier. As early as in 2008, the team succeeded in building the first general quantum communication network in Hefei, the capital city of east China's Anhui Province, and built up a special "quantum communication hotline" between important nodes to help secure smooth communication for the military parade celebrating the 60th anniversary of the founding of the People's Republic. In 2009, the team took the lead in extending the distance of decoy state quantum communications to 200 km.

In recognition of his outstanding scholarship and contributions, PAN was elected a Member of Chinese Academy of Sciences in 2011. This seemed to have marked a new start for his exploration, with further ambitions to solve key issues impeding the applications of quantum teleportation in communications.

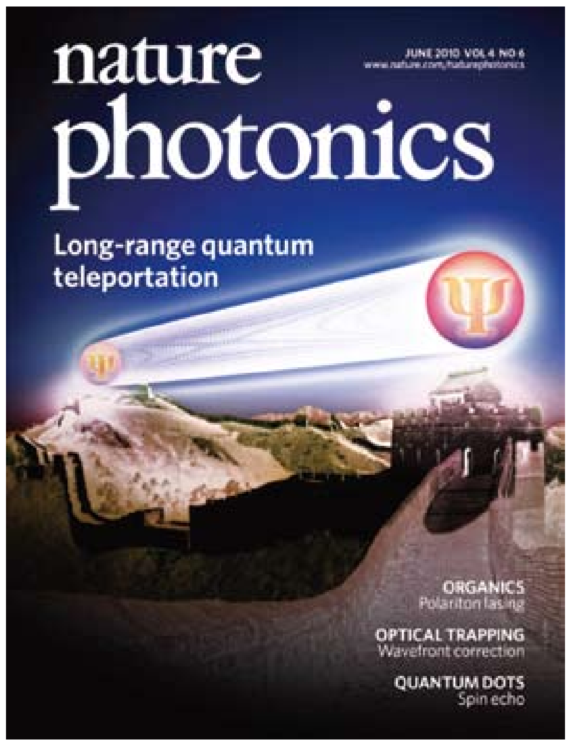
In 2012, the team completed building a large-scale (composed of a total of 46 nodes) quantum communication network covering the whole city of Hefei, the first of this kind in the world. This marked the maturity of technologies for large-capacity quantum communication network in metropolitan areas. The same year, PAN's team built a quantum communication network for finance information verification together with the Xinhua News Agency, marking the first successful application of quantum communication network in the world for secured transmission of finance information. At the end of 2012 in Beijing, the team put into operation a set of advanced quantum communication equipment developed by them, to guarantee information security of the city and even the nation. Later, the year 2013 witnessed the establishment of another quantum communication network by the team in the urban area of Jinan, capital city of Shandong Province, featuring updated equipment properties and hence better performance. With the operation of this network, the team built up valued experience for further improvement and management.

The same year also saw their further important progress in developing core devices for quantum communications, overcoming a major setback in existing equipment and made it immune to potential eavesdropping.

Theoretically in a quantum cryptography system no eavesdropping is possible, as any effort to intercept or copy the secret key being sent from the sender to



Early start: The team articulates how they achieved teleportation of a complex quantum system in *Nature Physics* in 2006.

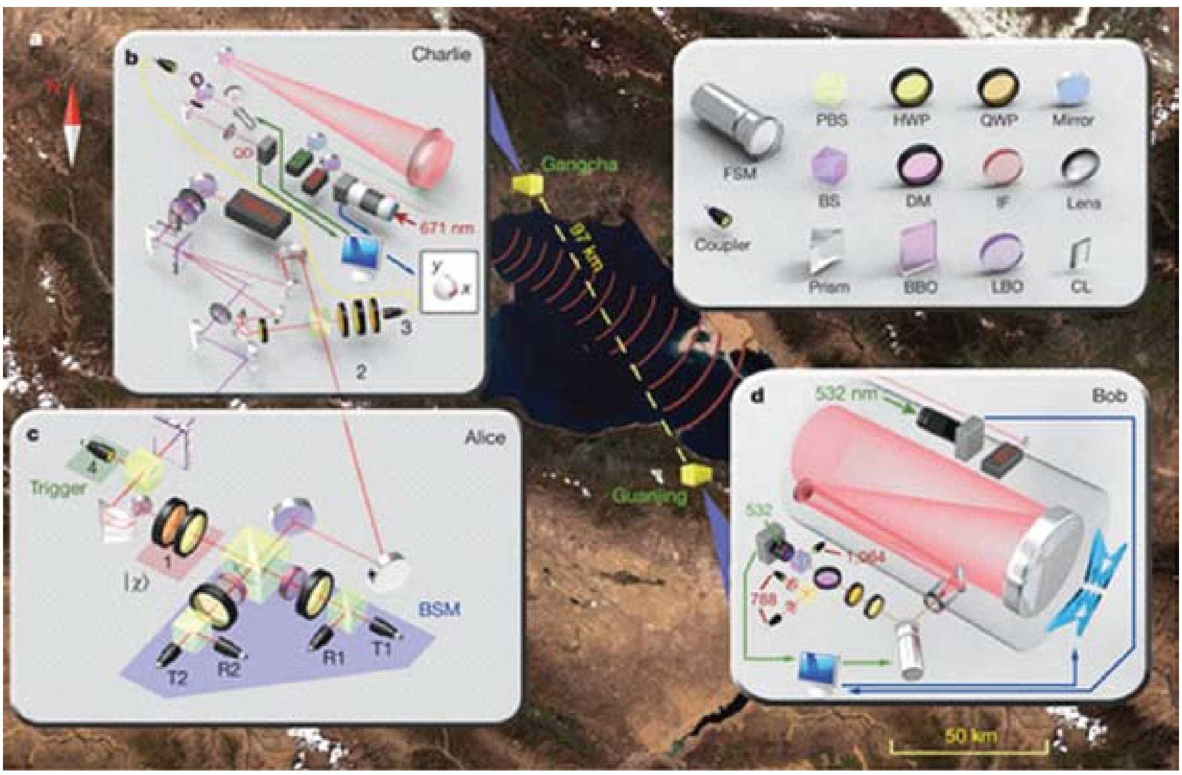


The team reports in *Nature Photonics* their successful quantum teleportation across a 16km-long distance in 2010, marking a milestone long-range transmission of quantum information.

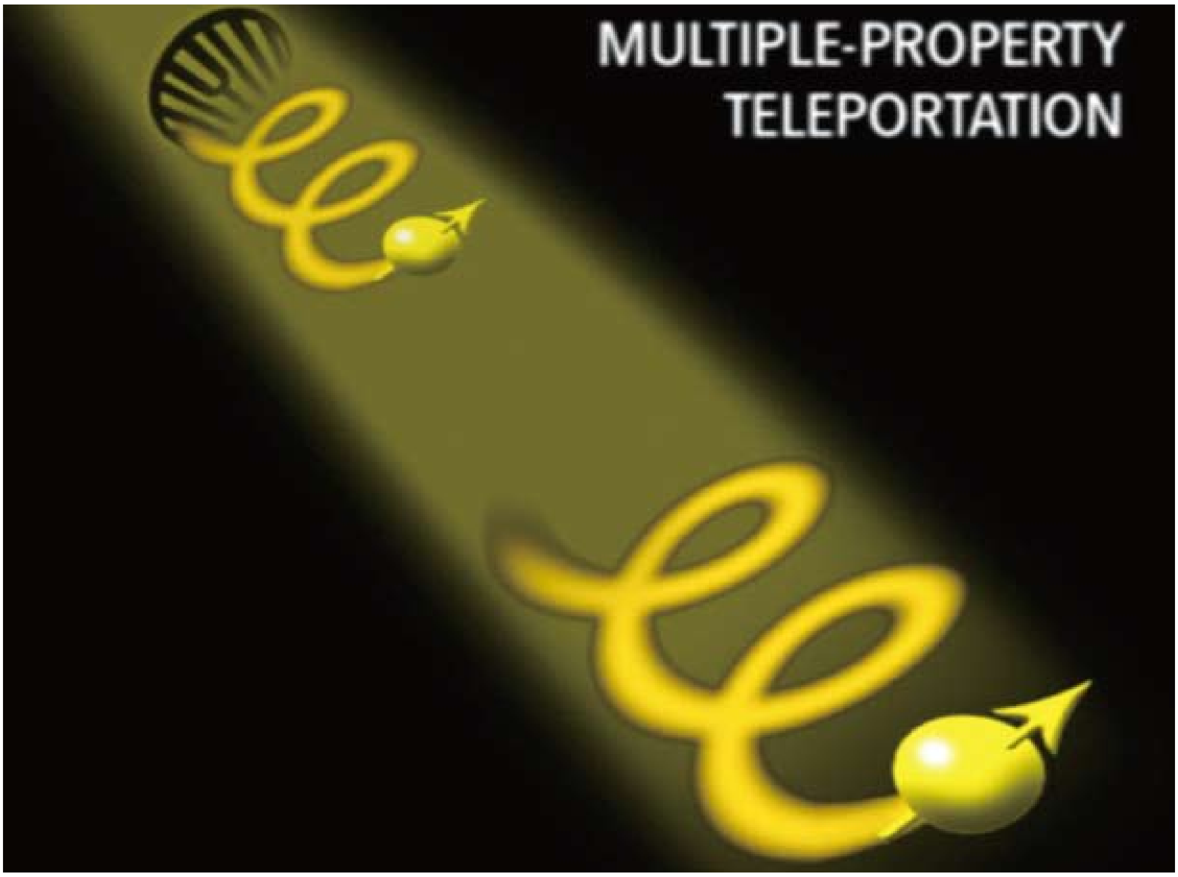
the receiver can change the state of the system due to inherent laws of quantum mechanics, and hence the attempt will fail to disguise itself. In practice, however, as demonstrated by scientists, defects in the detector could make the system vulnerable to hacking; therefore improved detectors were needed to protect the system from eavesdropping. PAN's team successfully developed a single-photon detector for communication wavebands at ambient temperatures, which is believed to be the most state-of-the-art until today due to its excellent immunity to hackers. With this detector, the team achieved "measurement-device-independent quantum key distribution (QKD)" for the first time in the world, sealing a loophole in existing single-photon detecting system that could result in data leaks. This marked a big leap forward of the quantum communication system, as it effectively solved a problem periling the security of the quantum communication system in practice. Based on this technology, the team successfully conducted "measurement-device-independent QKD" across a record distance of 200 km in 2014.

PAN's team has also dedicated themselves to the R&D of QKD relaying technologies for years. In 2008 they first achieved quantum entanglement capable of storing and decoding information, and perfectly demonstrated the use of quantum repeater in their experiments. Later in 2012, they advanced to develop a technology for quantum storage, making it possible to read the information in store at a very high efficiency. Quantum storage based on their technology proved to have been the most endurable and the best in terms of comprehensive performance. This accomplishment was recently updated by their own technology: they further improved the performance of the quantum storage; particularly in aspects of the lifetime and decoding efficiency, it has been improved up to the standards for long-distance QKD relaying.

To explore in free space quantum communications, the team made intensive efforts in 2012 and 2013 to realize quantum teleportation and entanglement distribution across a free space of 100 km distance, and verified the feasibility of satellite-earth quantum communication with comprehensive ground experiments. Such efforts adequately demonstrated the feasibility



A scheme showing the principle of free-space quantum teleportation. In 2012, the USTC team led by Prof. PAN Jianwei reported quantum teleportation and entanglement distribution over 100-kilometre in free-space channels in *Nature* (*Nature* 488, 185–188, 2012; doi: 10.1038/nature11332), and described the principle of quantum teleportation in their paper.



The team reports successful quantum teleportation of multiple degrees of freedom of a single photon in *Nature* in 2015, the final year of the Period of the 12th National Five-Year Plan.

to implement a global communication network based on satellites and that to perform quantum mechanics fundamental experiments of space dimension. Now, eventually the day to launch the satellite is approaching.

During the period of the 12th National Five-Year Plan, PAN's team repeatedly entered the spotlight due to their excellent contributions to quantum communications. In the year of 2012, their success in extending the safety distance of free-space quantum communication to 100 km level was voted into the annual top 10 news of S&T advances of China; in 2013, their solution to protecting QKD system from hacking via "measurement-device-independent QKD" was ranked into the "Highlights of the Year" nominated by the American Physical Society; in 2014, they were ranked again into the top 10 news of S&T advances of China due to the new record safety distance they achieved with quantum communication; and in 2015, their success in quantum teleportation of multiple degrees of freedom of a single photon (*Nature* 518, 516–519, 2015: doi:10.1038/nature14246), which laid a solid foundation for expandable quantum network technologies, was evaluated by the Institute of Physics of UK as a "Breakthrough of the Year". Lately in January 2016, PAN's team won the First Prize from the National S&T Awards for Natural Sciences, due to their systematic research in multiple-photon entanglement and interference measurement.

Taking advantage of the well-established buildup in quantum communications, the Chinese Academy of Sciences has set up a Centre for Excellence aimed at innovations on the frontiers of quantum information and quantum technology. Supported by the Ministry of Education of China, the Academy has also built a center for synergistic innovation by encouraging its own associated institutes in this field to joining forces with those from leading universities in China. Integrating major research resources in the field of quantum information, the Academy anticipates better and quicker developments in this area.