PRESS RELEASE

QuNET initiative: One step closer to highly secure quantum communication

Quantum key successfully distributed between two points with combination of free-space and fiber links

Jena (Germany)

Researchers from Jena, Berlin, Erlangen-Nuremberg and Wessling have successfully distributed quantum keys between two points using a combination of free-space and fiber links under everyday conditions. On a heterogeneous test bed in Jena, they achieved key rates in the kilobit range per second in daylight. The experiment was implemented as part of the QuNET initiative, a pilot project funded by the German Federal Ministry of Education and Research (BMBF) to develop highly secure communication systems based on quantum technologies.

The communication of the future is to become more secure with the help of light particles. This is the goal of the QuNET initiative by the BMBF. The initiative's partners - the Max Planck Institute for the Physics of Light, Friedrich Alexander University Erlangen-Nuremberg, the DLR Institute of Communications and Navigation, and the two Fraunhofer Institutes for Applied Optics and Precision Engineering IOF and the Heinrich Hertz Institute HHI - have now taken an important step toward quantum-safe networks: With a key experiment, they have shown how multiple quantum-secured point-to-point links can be realized and combined for future scalable quantum-safe networks. They not only combined transmissions of quantum keys via free-space and fiber links, but also achieved transmission rates in the kilobit range per second in daylight.

"One goal of the key experiment was to demonstrate the distribution of quantum keys in heterogeneous ad-hoc links in daylight," explains Dr. Thorsten Goebel, coordinator in the QuNET Office at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF. "Heterogeneous in this case means that we distribute quantum keys between two points with a combination of free-space and fiber links to bridge fiber gaps. And all of this with an ad-hoc character, i.e., establishing the connection as quickly as possible."

Test bed over two kilometers in the urban area of Jena

In this specific case, the researchers established a quantum-secured connection on a nearly two-kilometer-long test track in Jena. The quantum key distribution was implemented in two stages: The journey began on the roof of the Jena public utility company. There is a green container with a telescope for sending quantum keys in its

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belly. From here, light particles, which form the basis for generating a highly secure quantum key, first fly over 1.7 kilometers as the crow flies to the Beutenberg Campus Jena. There, they are picked up by a receiving station in another container on the grounds of the Fraunhofer Institute. From this intermediate node, the signal is fed into a fiber link and forwarded via 300 meters of fiber to a building adjacent to the institute. There, a quantum key is finally generated from the measurements on the light particles.

Even in the case of longer transmission distances i.e., when a direct distribution of quantum keys is not possible, the researchers have taken precautions: By suitably combining keys at trusted intermediate stations along these longer distances, the key distribution becomes possible over even greater distances.

Mobile quantum link allows bridging of fiber gaps

"Our key experiment thus demonstrates how the combination of multiple links can succeed in bridging fiber gaps, i.e., distances where the lack of lines makes fully fiber-based transmission impossible," Dr. Goebel continues. "An often-cited example here would be a summit in rural regions with patchy fiber infrastructure." But natural boundaries, such as bridging a river, are also a conceivable application scenario for a point-to-point connection between transmitter and receiver that can be established for a short time.

Another important aspect of the experiment is its mobile character. The two quantum containers used by the researchers, also called QuBUSes, are basically transportable. They could, for example, be taken to any location by a vehicle and could establish a quantum-secured connection there as needed. In this way, quantum communication can be implemented at the most diverse locations.

Researchers achieve key generation rates in the kilobit range

With their experiment, the researchers also achieved key generation rates in the kilobit range per second, even in direct midday sunlight. The researchers thus also achieved an important criterion for practical use, because intense solar radiation usually impairs the exchange of quantum-based keys. In many experiments, the quantum keys were therefore distributed at night and pre-stored for daytime communication. With the development of special filters, daytime key generation is now possible.

In addition, one aspect of this experiment was the demonstration of hybrid quantum key distribution. This involves the simultaneous implementation of different protocols for key distribution, which was thus able to demonstrate the agility of the developed infrastructure, in particular the QuBUS platform, in terms of the protocols used. This is important, since the development of quantum key distribution still offers many possibilities for expansion, and these should not be restricted by the infrastructure used. Thus, the developed infrastructure is also future-proof and can be used for any protocols of quantum key distribution without major adaptations.

For this purpose, protocols for quantum key distribution were also tested, which measure the electric fields instead of individual light particles. The researchers were able to show that this approach, which is very close to the technology used in classical telecommunications, is suitable for quantum key distribution without additional filters even in the case of fluctuating transmission channels of the free-space link in daylight.

First quantum-secured videoconference already realized in 2021

The experiment in Jena is the second public demonstration of technology development in the QuNET initiative: QuNET researchers had already successfully implemented a quantum-secured videoconference between two federal agencies in August 2021. At that time, a connection between the Federal Ministry of Education and Research and the Federal Office for Information Security (BSI) was implemented.

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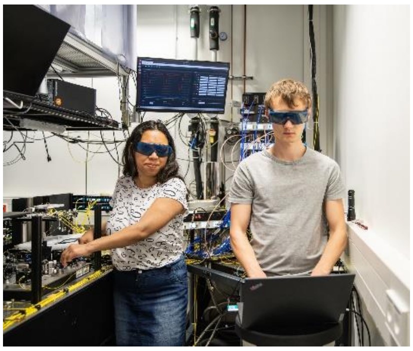
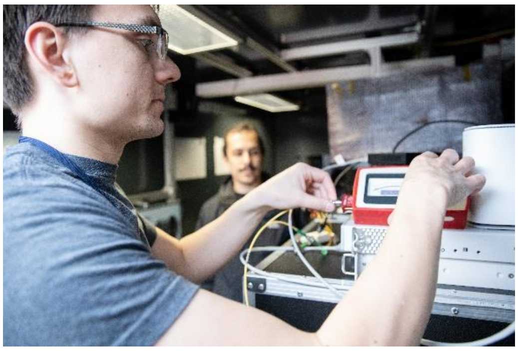
Press Images

The following images are available for download in the Fraunhofer IOF press area at https://www.iof.fraunhofer.de/en/pressrelease.html.

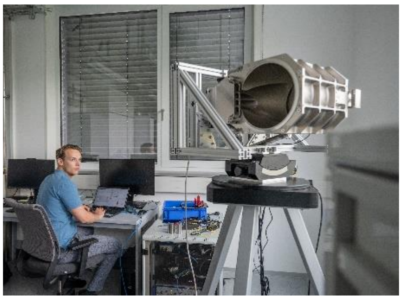


From the lab out into the application: The QuNET key experiment tests hybrid point-to-point connections under real conditions. © Fraunhofer IOF



In the QuNET initiative, researchers from the Fraunhofer and Max Planck Societies work together with the German Aerospace Center and the Friedrich Alexander University of Erlangen-Nuremberg. © Fraunhofer IOF

The experiment in Jena is the second public demonstration of technology development in the QuNET initiative. © Fraunhofer IOF



A special metal mirror telescope is used to distribute quantum keys via free-space. © Fraunhofer IOF

A green container on the roof of the Jena municipal utility houses the telescope for sending the quantum keys. The Fraunhofer IOF is located 1.7 kilometers away as the crow flies. © Fraunhofer IOF

The left photo shows the perspective from the roof of the Jena public utility company in the direction of the Fraunhofer IOF with an enlargement of the receiving container (QuBUS). The right photo shows the opposite perspective: from the QuBUS in the direction of the public utility with an enlargement of the container there. © QuNET

On the roof of the QuBUS, which is located on the premises of the Fraunhofer IOF, is the unit for receiving the quantum keys sent via free-space from the Jena public utility.
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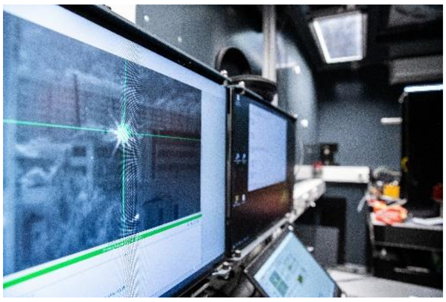
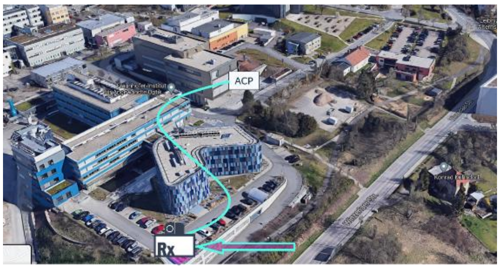


Inside the QuBUS on the Beutenberg Campus, the quantum keys sent via free-space are then coupled into an optical fiber link and forwarded. © Fraunhofer IOF

The outdoor area of the Fraunhofer IOF with the free-space (blue line) drawn in between the Jena municipal utility (not shown here) and the fiber link (red line) leading to the quantum laboratory in the Abbe Centre of Photonics, which is adjacent to the Fraunhofer Institute. There, in the quantum lab, the light particles are converted into a quantum key after a total of two kilometers of hybrid transmission.



Aerial view at the Beutenberg Campus: The receiving station (QuBUS) on the Fraunhofer IOF site is located at the "Rx" marker. The blue line here symbolizes the 300-meter-long fiber link to the neighboring Abbe Centre of Photonics.

Facts and figures about the QuNET initiative

Start:	Fall 2019
Duration:	7 years
Sponsor:	German Federal Ministry of Education and Research
Partners:	Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Fraunhofer Heinrich Hertz Institute (HHI), Max Planck Institute for the Science of Light (MPL), DLR Institute of Communications and Navigation, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)
Volume:	125 million euros funding (planned)
Website:	https://www.qunet-initiative.de/

QuNET initiative: Questions and answers

Why this initiative?

Increasingly powerful digital technologies are impacting today's data networks and are more and more a threat to the security of the data and critical infrastructure of the modern information society. This is driven by the advancing development of quantum computing. With the ability to compute and analyze a multitude of possible options simultaneously, not only new opportunities but also new risks are being created. Most of the currently used core components of encryption can be broken with envisioned quantum computers of the future. As a result, the government, organizations, the healthcare system, and security-critical enterprises need to rethink and renew their security infrastructures.

What is the goal of the initiative?

The primary goal of QuNET is the application-oriented development of the physical-technical fundamentals as well as the necessary technologies for highly secure communication networks under real conditions using quantum physics. The initial focus is on practical applications for quantum-safe networking, for example of public authorities. However, QuNET enables more than just secure communication: The perspective applications of the transmissions of quantum states extend to networked quantum computers, the so-called quantum internet.

What is the state of the art in quantum communication?

Quantum communication offers many potential applications for the benefit of business and society. Of these, quantum key distribution (QKD) is probably one of the best studied and most internationally advanced examples.

How does quantum encryption work?

Quantum encryption takes advantage of the property of each individual quantum particle that it cannot be fully characterized by measurement and thus cannot be perfectly copied. For example, a quantum source generates light pulses with variable properties that are exchanged between two locations. From the results of a quantum mechanical measurement, manipulation or interception of the light pulses can be detected. Based on this, a key can be generated that is known only to the sender and receiver and can be used for encryption. This method is also secure against any future attacks by a quantum computer. To overcome larger distances, satellites with quantum sources can generate quantum keys over intercontinental distances, or the quantum repeaters currently under development (cf. the BMBF project QR.X) can be used.

Which research institutes are involved in the initiative?

The **Fraunhofer Institute for Applied Optics and Precision Engineering IOF**, based in Jena, Germany, conducts research on the development of light as a means of solving a wide range of problems and application scenarios. The work of the research institute, founded in 1992, therefore focuses on application-oriented research on light generation, light guidance and light measurement. Together with researchers from basic research and industry, innovative solutions are developed that provide a technological advantage in science and industry and open up new fields of application for photonics.

Innovations for the digital society of tomorrow are the focus of the research at the **Fraunhofer Heinrich Hertz Institute (HHI)** in Berlin. Founded in 1928, the institute is a world leader in research on mobile and optical communication networks and systems, as well as in the coding of video signals and data processing. Together with international partners from research and industry, Fraunhofer HHI works across the entire spectrum of the digital infrastructure - from basic research to the development of prototypes and solutions. The institute contributes significantly to the standards for information and communication technologies and creates new applications as a partner of industry.

The **Max Planck Institute for the Science of Light (MPL)** covers a broad spectrum of research, including nonlinear optics, quantum optics, nanophotonics, photonic crystal fibers, optomechanics, quantum technologies, biophysics and - in collaboration with the Max Planck Center for Physics and Medicine - links between physics and medicine. The MPL was founded in January 2009 and is one of over 80 institutes of the Max Planck Society that conducts basic research in natural sciences, biotechnology, humanities and social sciences for the benefit of the general public. Today, almost 400 people from around 40 nations work at the institute. Some of the researchers look back on decades of experience in the field of quantum communication. They also use telecom technology for the exchange of quantum keys, which allows the procedures to be quickly commercialized. In addition, the researchers from Erlangen have been investigating for more than ten years how the keys can be transmitted on the ground with laser light over several kilometers (known as a free-beam connection) or by satellite over greater distances. The MPL is playing a major role in many large national and international projects, also in cooperation with national industry.

The **DLR Institute of Communications and Navigation** is dedicated to mission-oriented research in selected areas of communications and navigation. Its work ranges from the theoretical foundations to the demonstration of new procedures and systems in real-world environments and is embedded in DLR's Space, Aeronautics, Transport, Digitization and Security programs. The institute currently employs around 200 people, including 150 scientists, at its sites in Oberpfaffenhofen and Neustrelitz. The institute develops solutions for the global networking of man and machine, for high-precision and reliable positioning for future navigation applications, as well as methods for autonomous and cooperative systems in transport and exploration. In addition, the institute is concerned with cyber security. Focal points in this area include post-quantum cryptography and the transmission of quantum keys via satellite.

The **Friedrich Alexander University (FAU)** was founded in 1743 and is the third largest university in Bavaria. The innovative university offers a wide range of subjects. The research-strong Department of Physics operates a close cooperation with the Max Planck Institute for the Physics of Light (MPL). The Chair of Optical Quantum Technologies, founded in 2022 as part of the Hightech Agenda Bavaria, focuses on the fundamentals of quantum information and the implementation of quantum protocols. This research group is an important partner in numerous national and international projects on quantum communication.