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Global Quantum Key Encryption: German Nano-Satellite QUBE Launches into Space

The research satellite QUBE, funded by the German Federal Ministry of Education and Research (BMBF), will for the first time test newly developed quantum communication technologies using a very small satellite in space. The objective is to support future secure, worldwide data transmission.

- The QUBE project (Quantum Key Encryption with CubeSat) launches first time a nano-satellite into Earth orbit to test newly developed modules for generating quantum-key-encrypted data.
- The researchers developed space-compatible miniature hardware for quantum communication, for optical data transmission, and for the necessary high-precision satellite pointing.
- After having successfully completed an extensive test program, the QUBE satellite is now ready for its experiments in Earth's orbit following the rocket launch planned for August 16, 2024 at 18:19 UTC.
- Use of quantum states to generate secret keys will ensure unbreakable security in the future, with satellites providing the global communication dimension.

After years of research, the interdisciplinary QUBE consortium is now launching its first satellite into orbit. "This is truly a milestone," says Harald Weinfurter, Professor of Experimental Quantum Physics at Ludwig-Maximilian-University of Munich (LMU). "So far, there are no small satellites in Earth's orbit that enable worldwide quantum key distribution." Only China has sent such technology into space, but their satellites are large and expensive.

Quantum Keys from Space

The BMBF-funded QUBE consortium,, led by LMU aimed to develop and test hardware for worldwide, secure communication using nano-satellites. By employing quantum states to generate secret keys, secure communication through quantum encryption can be achieved. In contrast to fibre-optic networks, which are limited to a few hundred kilometres due to signal losses, satellites can facilitate future global exchange of secret keys between multiple ground stations and satellites.

Miniature High-Tech for Space

To achieve this in an efficient way, leading research groups in optics and quantum communication collaborated intensively with innovative companies and institutions in communication, satellite, and aerospace technologies. The consortium successfully developed technology and necessary compact components for generating quantum keys to fit into a very small satellite, known as a CubeSat. With a total mass of 3.53 kilograms, the entire module with dimension 10 cm x 10 cm x 30 cm is not larger than a shoebox.

Interdisciplinary Teamwork in Research

The independent research institute Zentrum für Telematik (ZfT) in Würzburg was responsible for developing and realizing the appropriate small satellite. "A particular technology challenge was miniaturisation of the required satellite functions, especially the high-precision pointing towards the ground station in order to establish a stable optical link. Here an unprecedented attitude accuracy with nano-satellites is achieved," emphasizes Prof. Dr. Klaus Schilling, president of ZfT. For information exchange between CubeSat and ground station, the Institute of Communications and Navigation at the German Aerospace Center (DLR) in Oberpfaffenhofen developed high-performance miniature optical communication systems. Researchers from LMU, the Max Planck Institute for the Science of Light in Erlangen (MPL), and Friedrich-Alexander University Erlangen-Nürnberg (FAU) provided the modules for generating and analysing quantum states. "Our miniaturized quantum communication components were developed to remain fully functional at the extreme vibrations, temperature, and radiation conditions during launch and operations in space," explains Christoph Marquardt, Professor at FAU.

Secure Communication Worldwide

Following QUBE's development, the team is working in next step on QUBE II - a satellite about twice the size, in order to exchange secure keys efficiently with ground stations thanks to higher energy budgets, improved optics and key generating hardware. The satellite company OHB and coordinates the follow-up project QUBE II. "Quantum key distribution is one of the first important applications of quantum technologies. There are already commercial devices for local fibre-optic networks," explains Norbert Lemke (OHB). "The hardware components developed in the projects QUBE and QUBE-II will enable cost-effective, global quantum key generation via small satellites." With the satellite launch in August, a significant step toward secure, global communication will be taken.

Rocket Launch Scheduled for August 16, 2024

After having successfully completed an extensive test program, the QUBE satellite has arrived in June at the launch site in Vandenberg, California. Integrated into a Falcon-9 rocket from SpaceX its launch into a sun-synchronous orbit was expected July 2024. Due to failure in the rocket's second stage at July 11, FAA stopped subsequent launches, but recovered after identification of malfunctions in August. In the satellite control centre of ZfT in Würzburg, the rocket launch will be broadcasted live for researchers and guests. Following the launch, the satellite operations are there initiated and handled. Over the next months, the individual satellite components will be activated and tested, before the first quantum signals will be received and analysed with the ground station at DLR Oberpfaffenhofen during overflights at night time.

The launch party is scheduled for the planned rocket launch in the test hall at ZfT in Würzburg, where intensive tests of the QUBE attitude control system were conducted. Models of the satellite and the quantum technology payload will be exhibited there.

Latest updates will be available on the website **live.telematik-zentrum.de** . *Attached are two photos for your editorial use. For additional photo material, please contact the media representative below.*

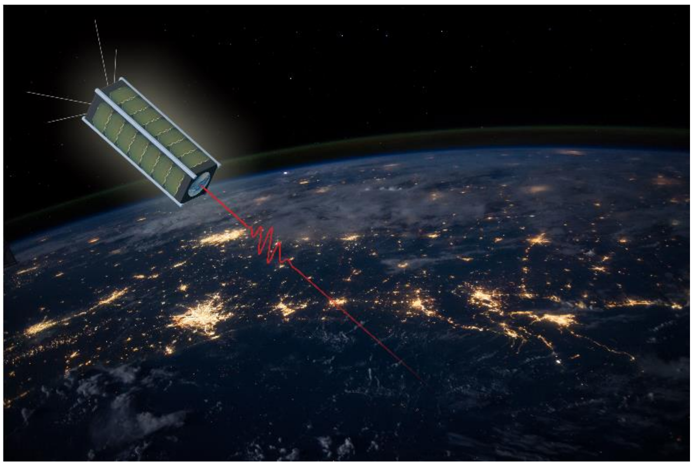

Photo 1: QUBE technologies for quantum key distribution (© Zentrum für Telematik)
The objective of the QUBE nano-satellite is to transmit quantum keys with a laser to the ground station, supporting future secure communication on Earth.

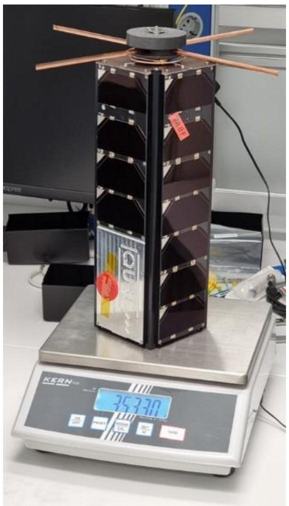

Photo 2: QUBE mass determination (© Zentrum für Telematik)
The flight model of the completed QUBE exhibits only a mass 3.533 kg to provide all functionalities for technology tests on quantum key generation and transmission.

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Contributors to QUBE Research Mission:

The research group at **Ludwig-Maximilians-University**, led by Dr. Lukas Knips and Prof. Dr. Harald Weinfurter, works on experiments related to fundamentals of quantum physics and applications of quantum communication. As a member of the MCQST (Munich Center for Quantum Science and Technology) excellence cluster and associated with the Max Planck Institute for Quantum Optics in Garching, they initiated and led the BMBF-funded QUBE consortium and contributed the module for generating a secure key with near-infrared light.

The team of Prof. Dr. Christoph Marquardt at the **Max Planck Institute for the Science of Light** and **Friedrich-Alexander University** Erlangen-Nürnberg focuses on research of quantum phenomena and their implementation in practical applications. Their long-term work has led to leading roles in national and international research consortia for quantum communication, including the BMBF project QuNET and the EU Flagship project QSNP. The chair of Christoph Marquardt serves as the scientific lead of the largest current ESA project for quantum communication, EAGLE-I. The professor of the High-Tech Agenda Bavaria is also co-founder of the start-up KEEQuant. In the QUBE project, the group is responsible for a highly integrated quantum random number generator, a source of coherent quantum states, and the satellite's payload controller.

The **Institute of Communications and Navigation of the German Aerospace Center (DLR)** is dedicated to mission-oriented research in communication and navigation. Their work ranges from theoretical foundations to demonstrating new methods and systems in real-world environments and is embedded in the DLR programs Space, Aeronautics, Transport, Digitalization, and Security. Their focus includes development of laser communication terminals for high data rate transmission in space and distribution of quantum keys for secure future communication. In satellite-based quantum communication, the institute is involved in the satellite missions QUBE, QUBE-II (both funded by BMBF), and Eagle-1 (ESA), and is a core partner in the QuNET initiative (also funded by BMBF). In the QUBE project, the institute provides the miniaturized optical communication system, developed from the world's smallest laser communication terminal OSIRIS4CubeSat.

The **Zentrum für Telematik (ZfT)** focuses on the interdisciplinary combination of *tele*communications, auto*mat*ion, and informat*ics* methods (= telematics) for advanced commercial applications. In space activities, the focus is on small satellites, especially using advanced software and control technologies to compensate miniaturization deficits. Under the leadership of Prof. Dr. Klaus Schilling, ZfT has developed and operated in orbit numerous innovative approaches related to distributed, networked small satellite systems for a broad range of customers (e.g., ESA, EU, DLR, BMBF, BMWi, DFG). ZfT's development of a miniature high-precision attitude control system is required in quantum key transmission to enable the high-pointing accuracy for the optical telecommunication system at the level of a CubeSat. In the QUBE and QUBE-II projects, ZfT is responsible for building and testing the small satellites to provide a suitable satellite infrastructure for operating the quantum payloads.

The company **OHB**, specialized in satellite systems and space applications, advised the QUBE project on general space-specific requirements and specifically on electronics development for space applications. OHB coordinates project management in the QUBE-II project, including launch, operations, and verification of QUBE.