Karlsruhe Institute of Technology

Division V – Physics and Mathematics

Physikalisches Institut (PHI)

Institute for Quantum Materials and Technologies (IQMT)

Quantum Networks

Enabling Intrinsically Secure Communication

Secure communication is indispensable in modern digital infrastructures. As computing power increases and quantum computers develop, traditional encryption methods are reaching their limits. Quantum networks offer entirely new possibilities: Cryptographic keys are distributed by means of individual photons, with the laws of quantum physics ensuring security.

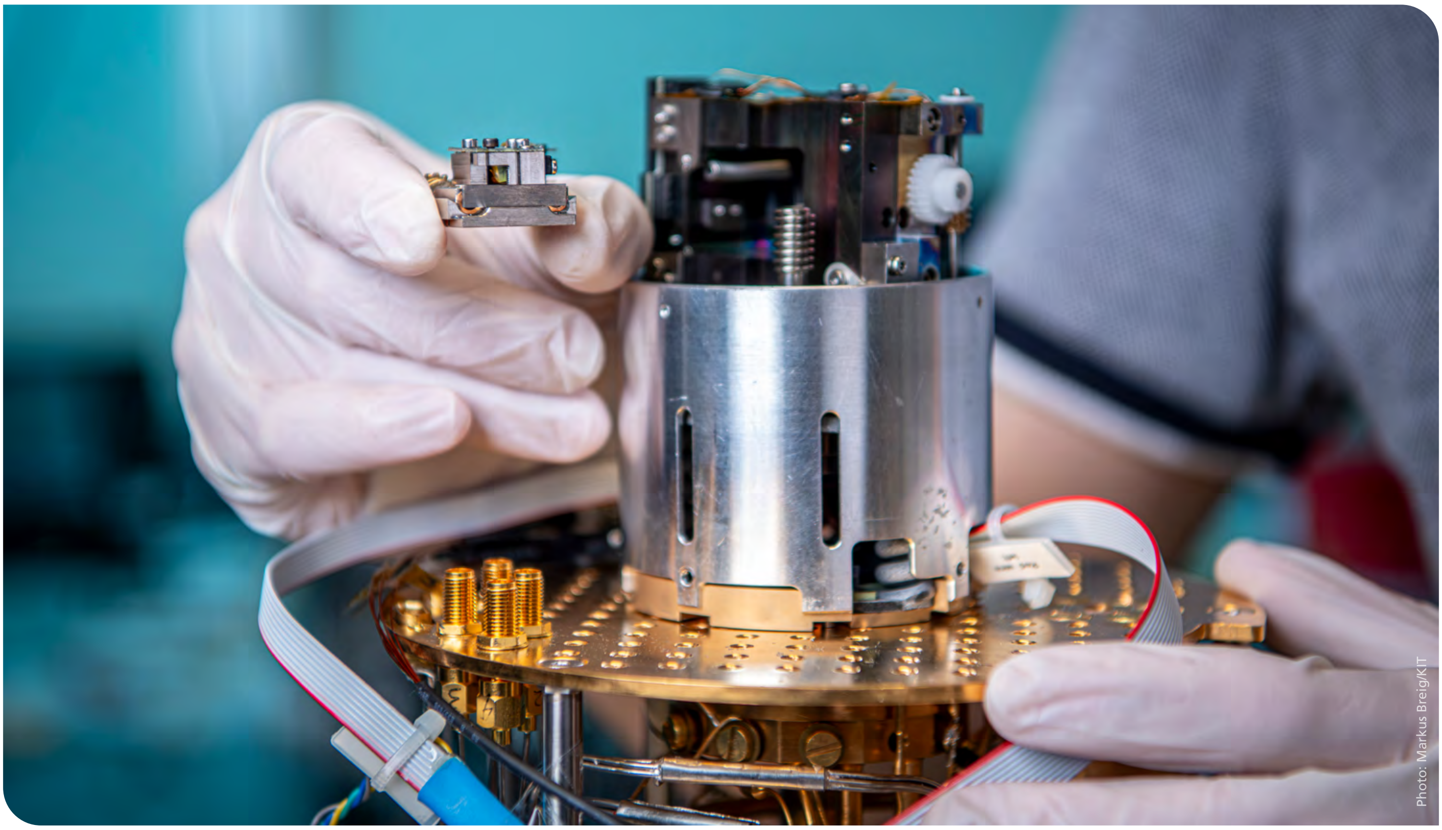
KIT researchers are developing technologies required for the implementation of quantum communication in practice. This includes special light sources, cryogenic systems to stabilize quantum states, and fiber-optic links to transmit quantum signals over long distances.

Challenge: Photon Loss with Increasing Distance

Quantum key distribution (QKD) enables verifiably secure communication by encoding information into the quantum states of light. Any attempt to intercept communication inevitably disturbs these states and is therefore detected immediately. However, photons transmitted via fiber optics are subject to exponential loss with increasing distance. After a few hundred kilometers, direct transmission is no longer feasible. Unlike classical signals, quantum states cannot be amplified without destroying the encoded information.

Solution: Quantum Repeaters

Implementation of quantum networks over long distances requires the use of quantum repeaters, in which robust, optically addressable quantum memories play a central role. Quantum repeaters divide long communication links into shorter segments and store quantum information in intermediate nodes. A platform developed at KIT integrates solid-state quantum emitters into fiber-coupled optical microresonators made by Qlibri GmbH, a company that has specialized in resonator-based optical interfaces. The resonator enhances light-matter interaction by confining photons to ultra-small optical mode volumes, thereby increasing coupling efficiency.



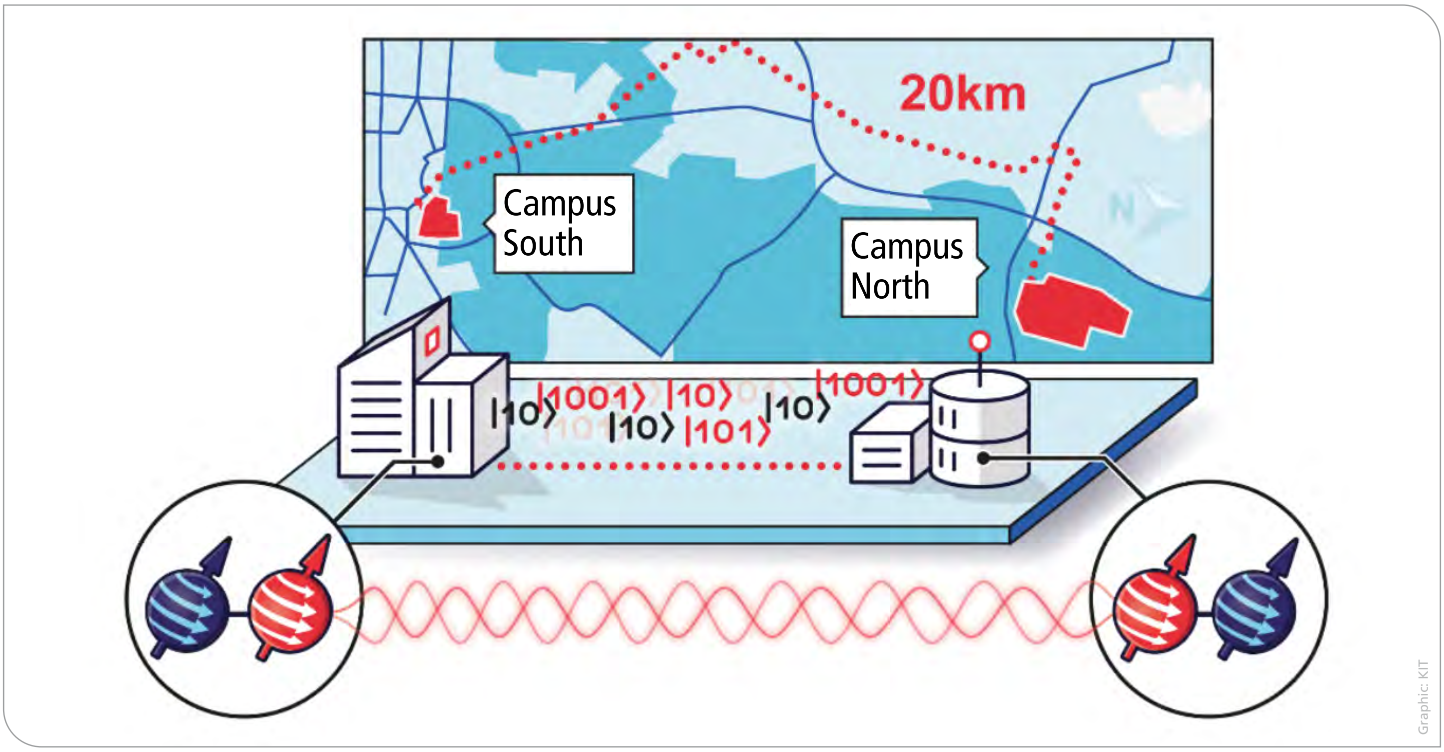
Cryogenic quantum platform: Dilution cryostat with fiber-coupled microresonator platform.

Secure communication at risk: A powerful attacker tries to intercept communication.

Operation at extremely low temperatures is made possible by a dilution cryostat developed by Qinu GmbH, a spinoff of KIT that has specialized in compact cryogenic systems. The cryogenic environment suppresses thermal noise and enables long-lived spin states that act as quantum memory.

Fiber-optic Testbed

The fiber-optic telecommunications link installed between KIT's Campus North and Campus South is used for quantum communication experiments. This link allows to study the transmission of individual photons, attenuation, synchronization, and environmental stability under realistic conditions. With such field-scale demonstration experiments, KIT combines fundamental research in quantum physics with the development of quantum communication infrastructures for future use.



Testbed between the campuses: Fiber-optic quantum communication link between KIT's Campus North and Campus South.

Karlsruhe Institute of Technology (KIT)
Physikalisches Institut (PHI)
Institute for Quantum Materials and Technologies (IQMT)

Prof. Dr. David Hunger
Wolfgang-Gaede-Str. 1
76131 Karlsruhe, Germany
Phone: +49 721 608-43510
Email: david.hunger@kit.edu
Web: www.phi.kit.edu

Prof. Dr. Wolfgang Wernsdorfer
Hermann-von-Helmholtz-Platz 1
76344 Eggenstein-Leopoldshafen, Germany
Phone: +49 721 608-43510
Email: wolfgang.wernsdorfer@kit.edu
Web: www.phi.kit.edu

Karlsruhe Institute of Technology (KIT) · President Professor Dr. Jan S. Hesthaven · Kaiserstraße 12 · 76131 Karlsruhe · Germany