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Johannes Gutenberg-Universität Mainz
Kathrin Voigt

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New joint project to investigate quantum repeaters designed to provide for secure quantum communication networks

German Federal Ministry of Education and Research will fund the new partnership project with EUR 20 million for three years / Subproject at Mainz University involves both theoretical modeling and experimental realization

There are reports of IT sabotage, cyber espionage, and other acts of hybrid warfare almost every day. Communication networks based on quantum physics could help eliminate threats of this kind. Researchers throughout Germany have already been working on developing those networks based on quantum repeaters for several years. In January 2025, the German Federal Ministry of Education and Research (BMBF) started funding a new research project, entitled Quantenrepeater.Net (QR.N), which aims to demonstrate the viability of quantum repeaters over test networks outside the protected lab environment. The BMBF will be providing a total of EUR 20 million over three years. The QR.N project coordinator is Professor Christoph Becher of Saarland University. Johannes Gutenberg University Mainz (JGU) contributes a subproject to the joint undertaking.

Quantum repeaters for fiber-based, long-range quantum communication

We all know repeaters as devices that tend to lurk in remote power sockets at home, boosting the signal provided by the Wi-Fi router to reach every corner of an apartment or a house. When positioned correctly, these little gadgets can significantly extend the range of data transmission. Researchers are also very interested in repeaters – not the ones you buy at the local electrical store, but much more complex quantum repeaters. In the new BMBF-funded QR.N project, 42 partners from research and industry are collaborating to make further progress in developing and implementing quantum communication networks.

Quantum networks for secure communication and the coupling of future quantum computers

In the future, quantum networks could be crucial for free and democratic societies and for the protection of critical infrastructure, as cyber sabotage, espionage, and hacking rapidly increase and threaten the sustainability of our interconnected world. Quantum networks would provide for a new level of security, because these networks would operate based on the laws of quantum physics, making them next to invulnerable to hacking or sabotage. The development of quantum repeaters able to ensure the secure transmission of information over longer distances would make quantum networks possible and represent significant progress towards the realization of a quantum-secured IT infrastructure. In addition, they would offer the prospect of the secure networking of future quantum computers.

However, researchers are faced with a major challenge. The quantum states necessary for quantum communication need to be generated in high quality, while transmission losses must be reduced to a minimum. In order to build a whole network from a simple connection between two points, nodes are required that are capable of temporarily caching the quantum states and transmitting them to the next node – as this is what repeaters do.

JGU subproject on the theoretical modeling and experimental realization of concepts

The new QR.N project is based on the Quantenrepeater.Link (QR.X) project, which was also funded by the BMBF – from 2021 to 2024 – and identified the basic requirements for the development of a quantum repeater. Part of both projects was and is a subproject at JGU, in which researchers consider quantum communication from experimental and theoretical perspectives.

The experimental research team, led by Professor Ferdinand Schmidt-Kaler of the JGU Institute of Physics, will be focusing on a specific platform – so-called defect centers in diamond – to be used as light storage interfaces. The diamond silicon-vacancy color centers that will be the subject of experimentation are characterized by narrow bandwidth light emission that is to be used for the spatial transmission of so-called quantum mechanical entangled states in the form of single-photon emission and detection. In addition to the color centers, the overall joint project will also concentrate on experimentally investigating atoms, ions, and semiconductor systems for their relevance to quantum repeater functioning. The theoretical project at JGU, headed by Professor Peter van Loock, will play a leading role in the theoretical modeling of all experimental quantum repeater platforms. "In addition to modeling quantum repeater systems as realistically as possible, we will explore new approaches that make greater use of the concept of quantum error correction, a technique known in quantum computing, and adapt it to the needs of a quantum repeater. The resultant quantum repeater should make it easier in the experimental context to deal with the very complex issues relating to robustness and life span of quantum storage systems. Perhaps it will even prove possible to create optical quantum repeaters that can operate without transient storage," explained van Loock.

The project consortium aims to develop the basic framework for "quantum-secure" communication to be established in Germany in the next few years. This is of major societal relevance, especially with regard to the security of IT systems and the protection of critical infrastructures. However, quantum repeaters are not intended to become a mass-produced electronic product for everyday private use.

General background

Quantenrepeater.Net (QR.N) was launched on 1 January 2025. The German Federal Ministry of Education and Research will fund the project with EUR 20 million to be provided over three years. A total of 42 research institutions and enterprises are cooperating in QR.N with the aim of developing the basic requirements for a quantum-communication network structure based on quantum repeaters. The QR.N project will take up the results of the Quantenrepeater.Link (QR.X) project, funded by the BMBF from 2021 to 2024. Coordinated by Professor Christoph Becher of Saarland University, this project identified the basic requirements for the development of a quantum repeater, itself building on various related projects undertaken since 2010.

Related links:
• https://www.oqit.uni-mainz.de/ – Optical Quantum Information Theory group of Professor Peter van Loock at the JGU Institute of Physics
• https://www.quantenbit.physik.uni-mainz.de/quantum-network-and-repeaters/ – Quantum network and repeaters project in the Quantenbit group of Professor Ferdinand Schmidt-Kaler at the JGU Institute of Physics
• https://www.uni-saarland.de/en/chair/becher.html – Quantum Optics group of Professor Christoph Becher at the Physics Department at Saarland University

Read more:

- https://press.uni-mainz.de/a-physical-qubit-with-built-in-error-correction/ – press release "A physical qubit with built-in error correction" (2 Feb. 2024)
- https://press.uni-mainz.de/eur-16-million-for-photonic-quantum-processors/ – press release "EUR 16 million for photonic quantum processors" (1 Feb. 2022)
- https://press.uni-mainz.de/quantum-communication-research-network-launched/ – press release "Quantum communication research network launched" (10 Dec. 2021)
- https://press.uni-mainz.de/miliquant-putting-quantum-technology-into-practice/ – press release "MiLiQuant: Putting quantum technology into practice" (1 July 2019)
- https://press.uni-mainz.de/full-steam-ahead-to-the-quantum-web-mainz-university-is-involved-in-european-flagship-on-quantum-technologies-program/ – press release "Full steam ahead to the quantum web: Mainz University is involved in European Flagship on Quantum Technologies program" (30 Oct. 2018)

wissenschaftliche Ansprechpartner:

Professor Dr. Peter van Loock
Quantum, Atomic, and Neutron Physics (QUANTUM)
Institute of Physics
Johannes Gutenberg University Mainz
55099 Mainz, GERMANY
phone: +49 6131 39-23628
e-mail: loock@uni-mainz.de
https://www.oqit.uni-mainz.de/members/peter-van-loock/

Professor Dr. Ferdinand Schmidt-Kaler
Quantum, Atomic, and Neutron Physics (QUANTUM)
Institute of Physics
Johannes Gutenberg University Mainz
55099 Mainz, GERMANY
phone: +49 6131 39-26234
e-mail: fsk@uni-mainz.de
https://www.quantenbit.physik.uni-mainz.de/members-of-ag-schmidt-kaler/