PRESS RELEASE

Fraunhofer ILT puts quantum internet node into operation - starting point for European networking

Fraunhofer ILT has started operating a quantum internet node that it developed with its Dutch partner TNO. The system is almost identical to the network nodes with which the Dutch research center QuTech demonstrated a quantum entanglement link between The Hague and Delft. The new node will serve as a research platform. Fraunhofer ILT is testing it with partners from industry and science in a local network and continuing to develop the technology. The institute is focusing on photonic components: quantum frequency converters, lasers, optics or single photon sources.

The quantum internet is still in its infancy. It can be used to transport entangled quanta, which should protect data from unauthorized access. The Dutch QuTech has reached an important milestone on this path: It has entangled two stationary qubits in Delft and The Hague over 25 km of conventional telecoms fiber optics; in other words, it has put them into a joint quantum state. Photons serve as the transport medium, being inherently entangled with the quantum state of the NV center. By deliberately superimposing these photons, the Dutch researchers were able to transfer the entanglement to the qubits of the network nodes. As long as such a connection exists, the transmission is considered tap-proof because any attempt to disrupt or copy the entanglement immediately destroys it.

"An internet secured by quantum entanglement would enable secure remote access to quantum computers –also via photonic clients in the future – so that the limited quantum hardware available would be accessible to many users," explains Dr. Bernd Jungbluth, head of the Strategic Mission Initiative Quantum Technology at Fraunhofer ILT. In addition, the quantum internet is seen as an enabler of a new generation of digital applications that would not be feasible with conventional infrastructure; for example, with the quantum internet, users could delete transmitted information completely and irreversibly. Methods based on quantum physics could also be used to ensure that information is transferred anonymously, for example in whistleblowing. Blind quantum computing is also considered promising. This allows users to access the computing power of remote quantum computers without their operators being able to view the input data, algorithms or results. The interconnection of several distributed quantum computers to form a high-performance overall system is another conceivable application of the future.

Photonic key components

In quantum internet development, research is mainly focusing on photonic network nodes such as those in The Hague, Delft and now Aachen. At their heart are color center qubits in diamond, known as NV centers, which are nitrogen vacancies in the crystal lattice of diamonds. But other defects are also possible. Excitation creates an additional electron in the vacancy and, thus, a quantum system whose energy states the researchers can control using laser light, microwaves and electric and magnetic fields. If they follow the appropriate protocols, the excited NV center emits a single photon in the visible spectral range on demand, which is entangled with the electron spin in this system, and which can be used for entanglement with other nodes connected via the optical fiber.

However, this photonic transmission reaches its limits over longer distances, but Fraunhofer ILT has developed a solution to overcome this limit: An almost noise-free quantum frequency converter shifts the wavelength of the photons into the low-loss telecom spectrum around 1,550 nm. "To exchange the superposition states between the network nodes, we have to get as many photons as possible to the other end of the line," says Jungbluth.

Within a project funded by the state of North Rhine-Westphalia (NRW), his team has now developed the new network node together with TNO. In addition to its quantum frequency converter, they are also using optical assemblies they developed. Following construction, testing and successful commissioning at TNO in Delft, Jungbluth's team transferred the system to Aachen and installed it at Fraunhofer ILT. Here, the system is integrated into a local fiber infrastructure. The institute plans to test the node in the local network and to continue to develop it with partners from industry and science, focusing on key photonic components. In addition to the quantum frequency converter, these components also include the single photon sources, detectors and the lasers and optics. In cooperation with Dr. Florian Elsen's junior research group at RWTH Aachen University, the team will also be working on interfaces to other qubit platforms – in order to develop the basis for future heterogeneous quantum networks.

Nucleus for the quantum internet of the future

The team in Aachen is creating an open test and development environment for photonic quantum hardware around the node. The platform is not only open to partners from NRW, but also to European research institutions and companies. Their aim is to jointly develop interfaces, protocols and components for the quantum internet of the future, and to keep an eye on their compatibility right from the start. "Fraunhofer ILT is thus making a concrete contribution to European networking – as is also being pursued by the Quantum Internet Alliance (QIA)," says Jungbluth. Now that the basis has been created with the node technology, there is an opportunity to establish it as a central link in a future European test network.

The start of operations in Aachen also marks a milestone for the quantum technology state of NRW: As the first of its kind, the node can potentially act as a starting point for developing the quantum internet in Germany. “There are plans to integrate it into a metropolitan-scale quantum network in the future,” reports Jungbluth, adding that the initial focus is on testing, optimizing and miniaturizing the photonic building blocks. This work also serves to transfer know-how from basic research to industry, an area in which Fraunhofer ILT has specialized for over 40 years.

Complex transfer process

Photonics is needed to solve many challenges when fiber-based quantum networks are constructed, including phase stabilization and the extremely precise timing of photons. The required accuracy is sometimes in the nanometer range. This is shorter than a single oscillation period of light, but is crucial for a successful entanglement exchange, since indistinguishable photons from different nodes must arrive at the midpoint exactly in phase and be superimposed in a Bell state measurement. It must not be possible to determine which node the photon originates from, a requirement that places the highest demands on the stability of the stationary qubits. However, these are highly sensitive: Even the slightest changes in the magnetic field or temperature result in measurable changes in the emitted wavelength. At the same time, only photons emitted by the qubits may enter the optical fiber. Lamps or switched-on smartphones should be strictly used near the detectors since the entangled photons would otherwise disappear in a sea of noise.

Jungbluth believes that the challenges can be solved thanks to the highly developed photonics industry in Germany and Europe and the expertise it has acquired over decades. The task now is to make the technology so robust and efficient that companies can transform it into market-ready products at a reasonable cost and in a reasonable amount of time. His team will also be working together with Delft Networks, a QuTech spinout whose founders include Ronald Hanson, who was responsible for the successful link between Delft and The Hague, and Stephanie Wehner, Director of the Quantum Internet Alliance (QIA). The Delft Networks team will contribute their combined expertise in protocols and algorithms for quantum networks as well as node hardware. "We ourselves will use our expertise at Fraunhofer ILT to develop photonic enabling technologies and subsystems further," he explains.

Opportunity for Germany - players meet at the World of Quantum

The quantum internet opens up a unique opportunity for German and European industries. This is because these industries can draw on the comprehensive expertise of highly specialized photonics providers when setting up secure networks: Expertise in timing and frequency control in the quantum-secured Internet is available, as are lasers and optics or the metrological know-how to detect individual photons and quantum states. The same applies to system packaging and production technology. NRW is well positioned to play an early and substantial role in the development of the quantum internet given its central location in Europe and its dense ecosystem of universities, research institutes and photonics companies.

Many suppliers will come together at the World of Quantum in Munich from June 24 to 27, 2025. “You can meet Fraunhofer ILT there on the Quantum Future Boulevard in **hall A1.439-1** and at the booth of EIN.QUANTUM.NRW in **hall A1.139**, where we will also be presenting our rolling roadmapping process and our current position paper together with EIN Quantum NRW,” says Jungbluth. He cordially invites interested parties to visit the stand to find out about opportunities for collaboration on the quantum internet node and other projects in this field.

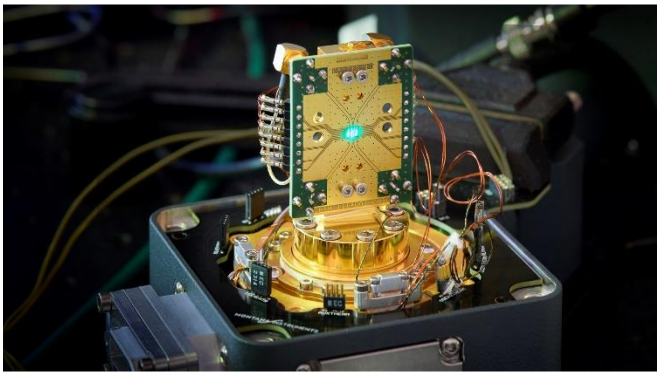

Image 1:
The stationary qubit of the quantum internet node with a color center. When excited, such defects in lab-grown diamonds emit single photons on demand, which are entangled with the state of the qubit and are able to transport this information.
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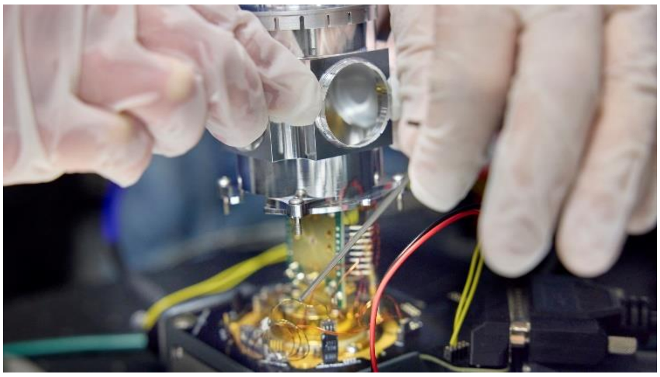

Image 2:
During disassembly in Delft, the Fraunhofer ILT team gained deep insights into the network node. It was this knowledge and the support of TNO that formed the basis for the successful recommissioning in Aachen.
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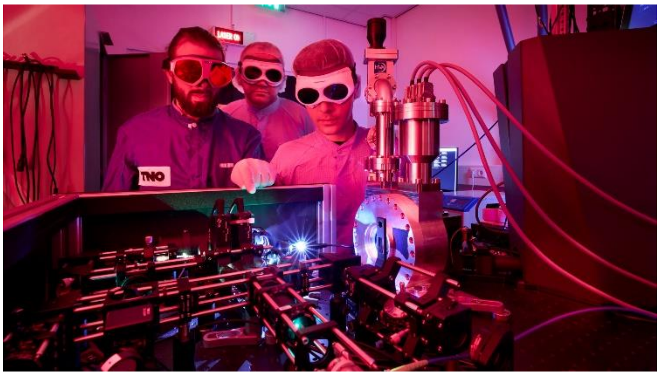

Image 3:
The Fraunhofer ILT will now systematically optimize the system with partners from industry and research. The focus will be on its photonic components. The long-term goal: protect data transfers with entangled qubits from unauthorized access.
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