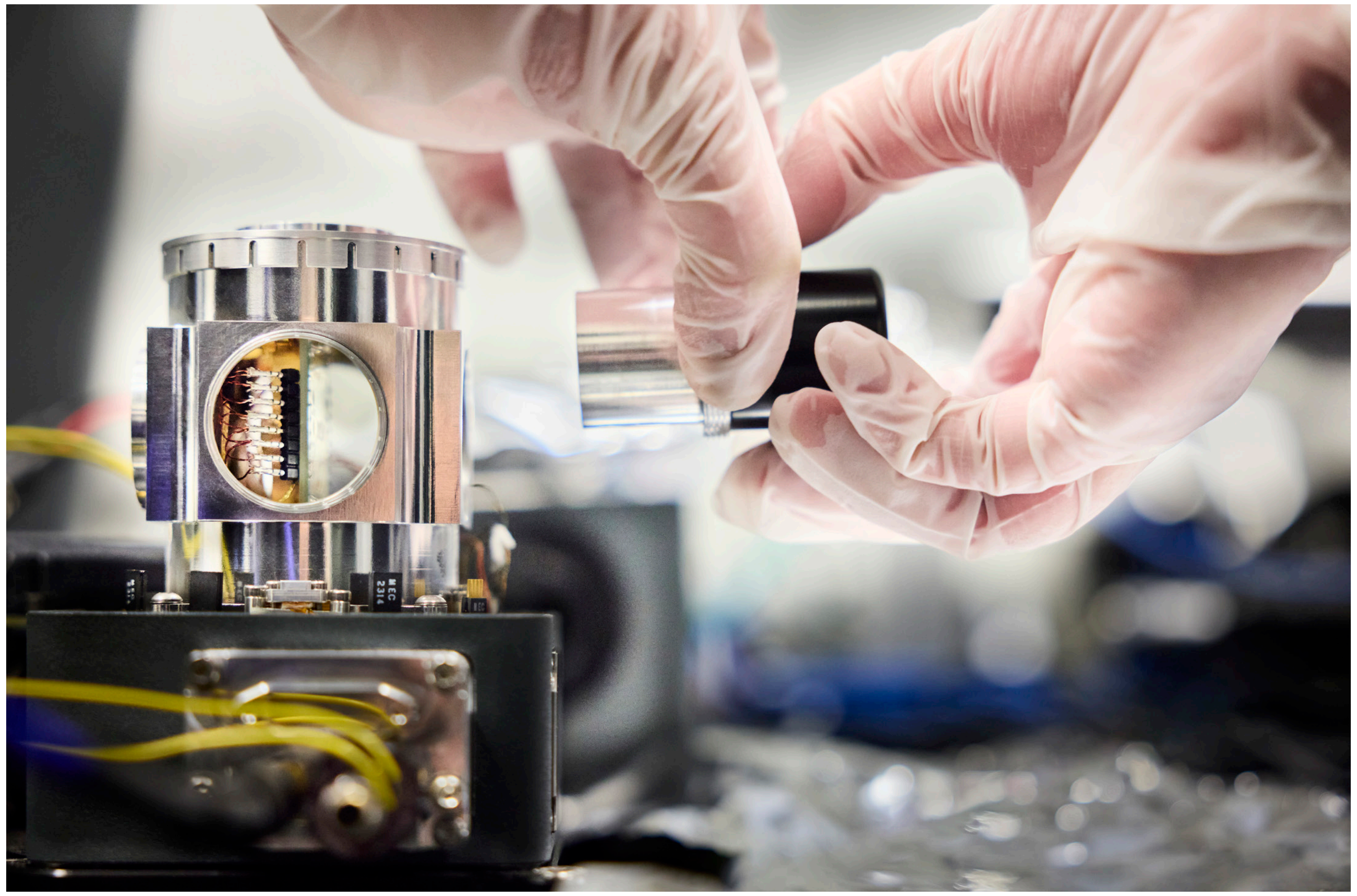

The heat shield, located within the cryostat, where the nitrogen vacancy device is located. © Fraunhofer ILT, Aachen / Ralf Baumgarten

Partners

QuTech

Quantum Delta NL

NANO LABNL

Fraunhofer

QIA QUANTUM INTERNET ALLIANCE

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...and more!

TNO is involved in every aspect of the quantum ecosystem, from quantum sensors to nanofabricated color-center-based diamond devices and the materials that compose them. For more information, please visit tno.nl.

Quantum technology at TNO

Enabling the quantum internet of the future

TNO innovation for life

A name you can trust

Since 1932, TNO has been the independent link between academic investigation and real-world application. Our work focuses exclusively on developing the technologies, systems and applications that demonstrate a direct benefit to partner competitiveness and to society as a whole.

Our unique position as a Research and Technology Organisation (RTO) enables us to work at the cutting edge of the most revolutionary technologies, while remaining focused on their practical application and direct value-add for citizens and communities.

The road to the quantum future

Quantum networks promise to unlock many new applications, such as safe communication through QKD, distributed quantum computing and distributed quantum sensing. These applications push beyond what classical technologies can do. They increase the security of our communication, enable more powerful quantum computers, and increase the sensitivity of the sensors. Yet all of these applications require a quantum network that uses single photons to create quantum entanglement between the different points in the network.

TNO is one of the few organisations in the world that is working on all aspects of such a future quantum network. From the color center qubits at the heart of the systems, to the development and testing of the complete quantum end node and repeater. We support the design, nanofabrication and characterisation of components and subsystems, but also offer full system design, prototyping, and demonstrators

Technologies we work with

- NV-based devices (End nodes, Repeaters)
- Full system integration (End nodes, Repeaters)
- Microelectromechanical systems (MEMS)
- Photonics Integrated Circuits (PICs)
- Superconducting MW lines
- Diamond device manufacturing

How we work with them

- Prototyping and demonstration platforms
- Development and manufacturing of sub-systems
- Quantum repeater design and characterisation
- Consulting on engineering/development of quantum internet systems and subsystems
- Characterisation of quantum chips in both room and cryogenic temperatures
- Development, integration, and interfacing of various components and systems in the quantum communication stack
- Full system design of quantum end nodes and repeaters, including in-depth systems architecture and component design

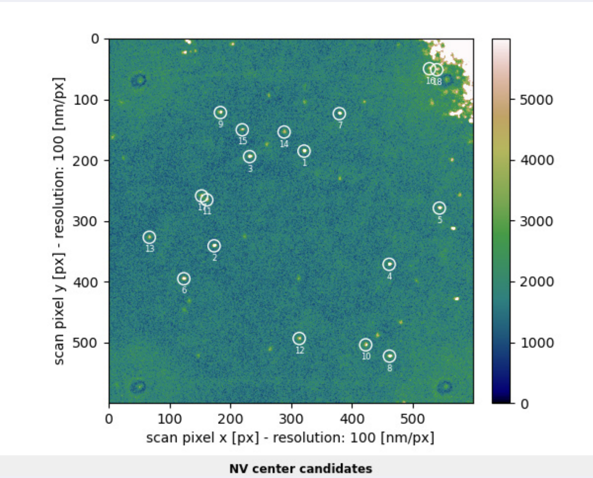
In-depth quantum chip testing

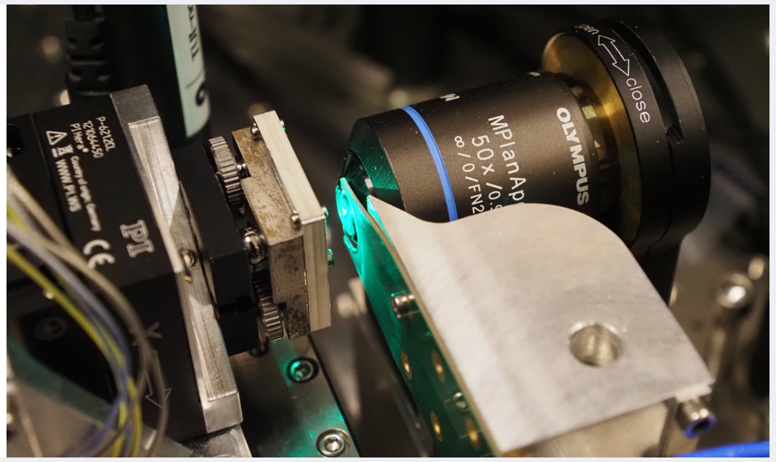
TNO validates the operation of both our own devices and systems, and those of our partners, to enable accelerated and targeted improvement. All to enable the development of the future quantum network and to validate current quantum sensor innovations.

Room-temperature characterisation setup (RTCS)

The optical room-temperature characterisation setup (RTCS) is suitable for the precise spatial mapping and characterisation of NV centers in diamond at room temperature.

- Accurate 3D location of NV centers and density approximation
- NV orientation in crystal lattice
- Photon count-rate under excitation saturation
- ESR, T1, T2*, G2 characterisation with external microwave application
- High degree of automation resulting in short measurement rounds
- Rabi measurement by varying the pulse length to measure the rabi-oscillation for a set MW power





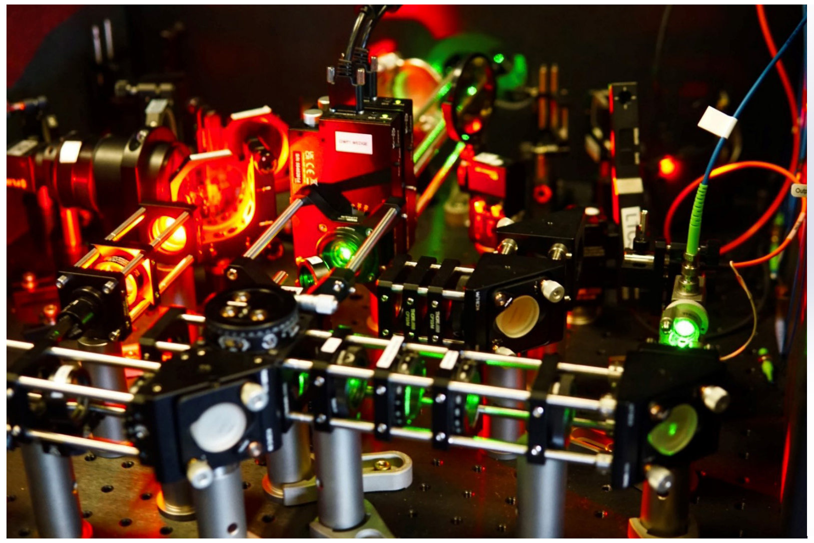
Identification of single nitrogen-vacancy (NV) centers in diamond. (Left) Confocal image of a diamond. The circled bright spots indicate NV centers. (Middle) Image of the room-temperature characterisation setup.

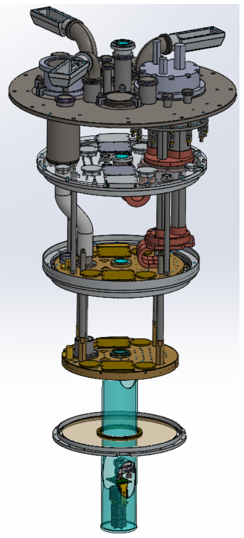
Low-temperature characterisation setup (LTCS)

The optical low-temperature characterisation setup (LTCS) is suitable for the characterisation of color centers and related components within various material platforms.

- <1 Kelvin base temperature
- Up to 1 Telsa magnetic fields in all directions
- Various laser wavelengths available, amongst others: 532 nm and 618 – 640 nm
- 16 Optical fibers to the device
- Optical free-space sample access with a photoluminescence spectroscopy setup specially designed for color centers in diamond
- Microwave control up to 12.5 GHz
- DC voltages for device control
- Automated control of characterization measurements

Figure left: The optical system used for the free-space experiment. Figure right: A CAD model of the cryostat system including lenses and sample holder.





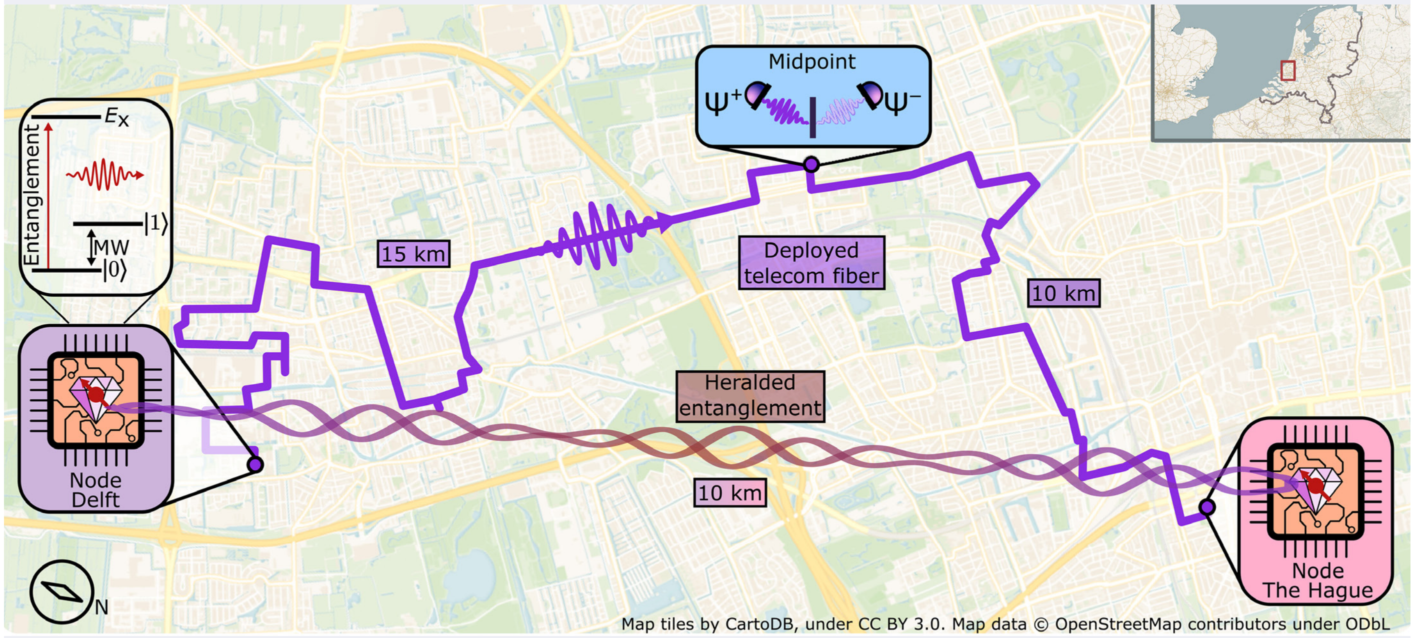
Successful projects

Qlink

Within the QuTech collaboration, TNO contributed to the successful entanglement of two nodes over metropolitan distance, and the technology is scalable to many nodes.

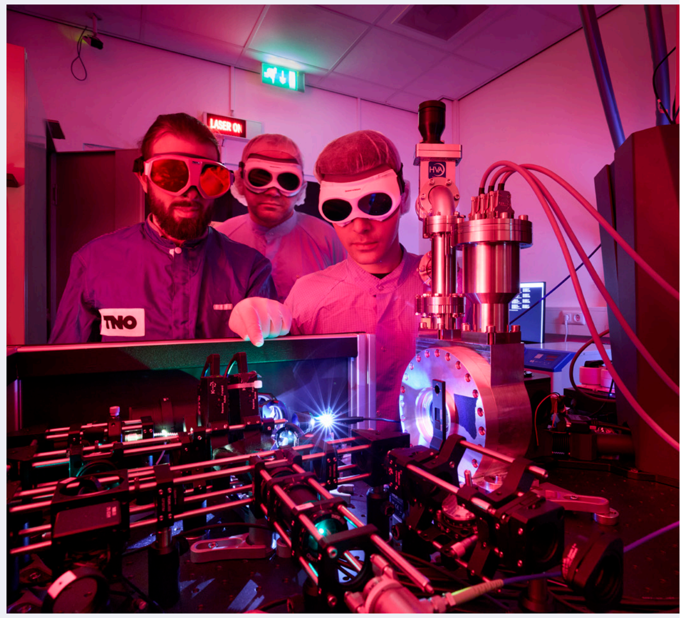
- End-to-end phase stability of single photon channels <15 degrees over 15 km metropolitan fiber link
- Extensive experience with the design and MAIT of color center-based nodes
- Extensive experience with color center-based measurements
- Track record of entanglement generation between distant NV centers in diamond.

Figure below: The overview of the experiment: In purple, the actual route of the fibers from the quantum nodes to the midpoint heralding station. The distance between the nodes is 10 km.



Fraunhofer ILT

To support the Fraunhofer ILT institute in their development for quantum frequency conversion, TNO designed, built, and tested an NV center-based quantum node. It contains all required functional layers: from the diamond device containing the NV and gates to photons in a fiber, ready for entanglement generation with a second NV center quantum node. The node is utilising all the latest developments, such as optical phase stabilisation of the single photon path, Stark tuning of NV centers under various angles, and NV center SIL devices.



Scientists working on the NV-based quantum node, now located at Fraunhofer ILT in Aachen.© Fraunhofer ILT, Aachen / Ralf Baumgarten