INTERVIEW

Fraunhofer ILT coordinates NRW quantum roadmap

At a kick-off meeting in Cologne on January 30, 2024, a group of innovative minds gave the starting signal for a roadmap that will bundle the ongoing activities in the field of quantum technologies at universities, research institutes, start-ups and companies in the federal state of North Rhine-Westphalia (NRW). The two leading state ministries – for culture and science (MKW) and for economy, industry, climate protection and energy (MWIKE) – have commissioned the coordination office QT.NMWP.NRW and Forschungszentrum Jülich with implementing the roadmap. The Fraunhofer Institute for Laser Technology ILT in Aachen is responsible for coordinating it.

North Rhine-Westphalia has a vibrant quantum ecosystem. Across the state, universities and research institutions, start-ups and established companies as well as supporting initiatives are driving the development of quantum technology into a future market. The state government of NRW is initiating a quantum technology roadmap to bundle these activities, analyze opportunities and potential and make optimal use of existing strengths and locational advantages. Its kick-off meeting took place in Cologne on January 30, 2024. In the following interview, Dr. Bernd Jungbluth, who coordinates the Quantum Roadmap NRW on behalf of Fraunhofer ILT in Aachen, talks about technological potential and wow effects in quantum technology, research activities in the state, the strategic quantum technologies program at the Fraunhofer ILT and about his plans and goals for developing the ongoing roadmap.

"Strategic approach to the future market of quantum technologies"

Dr. Bernd Jungbluth leads the Strategic Mission Initiative Quantum Technologies at Fraunhofer ILT and coordinates the NRW quantum roadmap.

Dr. Jungbluth, what makes quantum technologies a strategic, promising field?

What is currently unfolding under the generic term "Quantum Technology 2.0" is a systematic continuation of the technological progress R&D has made in the past 100 years. We are now able to control the smallest microscopic systems and can prepare,

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control and read out individual atoms, ions and photons. One of the key tools for this is the laser: It gives us access to the laws of quantum mechanics, which are generally counter-intuitive, but create real wow effects. This leads us to set new standards in areas such as sensor technology, imaging, computing and secure communication. In short: Quantum Technology 2.0 enriches our engineering toolbox immensely!

What is the part of the Fraunhofer ILT in this field of technology?

Quantum technology is on a threshold, moving from knowledge-driven basic research to application-oriented technology development. The Fraunhofer-Gesellschaft has set itself up to boost the transfer of quantum technologies to industry. As Fraunhofer ILT, we were involved right from the beginnings in 2016. After all, lasers are the ultimate tool for high-precision processing on the micro- and nanometer scale, but also for the preparation and control of quantum systems. What's more, photons, which we have always worked with, are themselves carriers of quantum information. In an internal ILT task force, we systematically analyzed the opportunities and needs arising from quantum technologies, what skills we already have and where we need to build on them. On that basis we are able to apply very specifically and successfully for publicly funded projects, to which we are now contributing our expertise. We regard ourselves as pioneers in the laser industry and are taking our partners from the photonics sector with us on this journey – especially the companies, of course.

Which applications are in the spotlight?

Current projects funded by the Federal Ministry of Education and Research (BMBF) are dedicated to quantum optical coherence tomography (OCT). This allows us to gain precise insight into ceramics or tissue, the latter of which is very promising for medical diagnostics. The highlight here is that we can entangle photons of different wavelengths with each other. Thanks to this entanglement – which Einstein once called "spooky" – the properties of these photon pairs remain so closely correlated despite spatial separation that the measurement of one photon is sufficient to know the state of the second. We generate these pairs using lasers and non-linear optics. The process is interesting for measuring in wavelength ranges where detection has so far been complicated.

Where does this lead to?

In a BMBF-funded "Lighthouse project for quantum-based measurement technology," we are part of a large consortium that aims to make OCT technology usable for tumor detection. ILT is contributing a line spectrometer and algorithms. Basic photonic

technologies are also important, such as selective laser etching (SLE), which we use to introduce micrometer-fine structures into vitreous bodies. We use this to produce ion traps for photonic quantum computers. Another important project is our Rydberg Tweezer Array, which optimally distributes beams in a Rydberg computer. Light from four outputs is split into 2,000 individual beamlets to provide 2,000 qubits.

A node for the quantum internet is currently being built in Aachen. What is it all about?

In our development of quantum networks, we are working very closely with QuTech in Delft, the Netherlands, as part of a strategic partnership and are, therefore, at the forefront internationally in this field. This partnership is a prime example of how we, as a photonics and laser institute, can contribute important technological building blocks for quantum technologies and transfer established methods from developing laser-optical systems – from our expertise in optical design and high-precision components to packaging and algorithms. For the quantum internet, we at ILT have developed a virtually noise-free quantum frequency converter based on non-linear optics, which has now been used to successfully exchange entanglement over existing telecom fibers between Delft and The Hague. According to QuTech, this is only possible thanks to laser technology from Fraunhofer ILT. Changing the wavelengths or frequencies of lasers is nothing new in itself, but here we are talking about individual photons that transport quantum information through a conventional fiber optic network between nodes in Delft and The Hague. In the next step, we are now working with QuTech to set up such a node here in Aachen. This will initially serve as a platform for testing and continuing to develop photonic components. The further integration of such nodes is also an exciting development and ultimately, of course, we want to become part of a global network here on site as early as possible. Just as we are doing with our European partners in the Quantum Internet Alliance.

Apart from its technological fascination, how should this project be assessed strategically?

Participation in this globally influential experiment is fantastic for our institute on many levels. It creates visibility for our activities in the future field of quantum technologies, confirms our strategic orientation and shows that we are at the forefront of technology. Our partners are signaling to us that our technological contributions are indispensable. And there are other aspects too: By concretely implementing the quantum internet, we are learning every day and are forced to find solutions to problems that we didn't know existed when we set out. This practical aspect also attracts talent, which is rare in this demanding field of technology. The shortage of

skilled workers is one of the main limitations for quantum technologies. With us, talented people can shape the future instead of getting stuck in an ivory tower.

What role do networks play in opening up the quantum worlds?

We are receiving funding from the state of North Rhine-Westphalia to set up the Internet node. Without the scientific standing that we have acquired in this cooperation, this would hardly be conceivable. We are very grateful to our Dutch colleagues for their trust in us and the many insights they have given us into their research. They are also playing a key role in the construction of our Internet node, which we are jointly assembling, setting up and testing in Delft before we bring it to Aachen and put it into operation here. Networking and networked thinking are key. Our institute has also found its current strength because we bring together the entire spectrum of laser technology, from beam source development to specific applications in a wide range of industries, under one roof. Insight into the challenges and problems of our industrial customers and suppliers has sharpened our focus on what solutions the market actually needs. We are now following this example in quantum technology. We remain an institute for laser technology that strives to closely cooperate with the players in this young field of technology. This is the only way we can make optimum use of the problem-solving expertise we have built up over 40 years. In this context, the North Rhine-Westphalia Quantum Competence Network is just as important to us as the coordination of the quantum roadmap for the state, which was recently taken over by Fraunhofer ILT.

How do you rate the current state of R&D?

In fact, we already have a very fertile quantum ecosystem in NRW with chairs at ten universities, including Siegen, Paderborn, Bonn and Aachen, the German Aerospace Center (DLR), Forschungszentrum Jülich, various Fraunhofer Institutes and a wealth of innovative small and medium-sized enterprises as well as spin-offs and start-ups. The spectrum ranges from the development of scalable semiconductor-based quantum computers at the young Aachen-based ARQUE Systems GmbH, to ion trap-based quantum computers at eleQtron GmbH from Siegen, to Pixel Photonics GmbH from Münster, which is advancing single-photon detection with superconducting nanowires and photonic integrated circuits (PICs). Many of the players are based in the LASER.region.AACHEN. For that reason, we have many lighthouses that need to be synergistically linked in order to make more out of the individual parts. The state is supporting the process with the Ministries for Culture and Science (MKW) and for Economic Affairs, Industry, Climate Protection and Energy (MWIKE). We are not early starters, but we have a very solid scientific and industrial basis. We would like to use our strategic experience to bundle these strengths in the best possible way. We can

create an environment here in which spin-offs and start-ups can develop into relevant players in this future market.

How do you go about developing the quantum roadmap?

The state government entrusted Fraunhofer ILT with coordinating the process, in which we are closely collaborating with the EIN Quantum NRW office and the Forschungszentrum Jülich. Ultimately, however, our aim is to involve as many players in the state as possible. Now, after the kick-off, things will really get going. We have an integrative process in mind. All interested parties who would like to contribute their expertise and ideas are invited. So far, 70 companies, universities and research institutes are on board. It is an exciting task to integrate them all appropriately, manage their heterogeneity and reach agreement on a joint roadmap. It is about using limited resources wisely and creating suitable framework conditions. A Center for Quantum Science and Engineering (QSE) could also become a central anchor point. When the final funding decisions are made, we can start almost immediately in transitional areas on the Digital Photonic Production (DPP) research campus in Aachen. Many relevant players from the quantum ecosystem in North Rhine-Westphalia are already rubbing shoulders with each other today. Regardless of this, we are convinced that quantum technologies can – and will – make an important contribution to structural change in our region.

Quantum technology at the AKL'24

FORUM - QUANTUM TECHNOLOGY & PHOTONICS is an all-day forum that will take place at the International Laser Technology Congress AKL'24 in Aachen on Wednesday, April 17, 2024. In three sessions, it will cover current approaches in quantum computing, the implementation of quantum networks and the latest hardware developments for quantum frequency conversion and single photon detection. Dr. Bernd Jungbluth and Florian Elsen (both Fraunhofer ILT) will moderate the sessions. Click here or the complete AKL'24 program.

Image 1:
Dr. Bernd Jungbluth, group leader NLO and Tunable Lasers at Fraunhofer ILT, is coordinating the NRW Quantum Roadmap on behalf of Fraunhofer ILT in Aachen.
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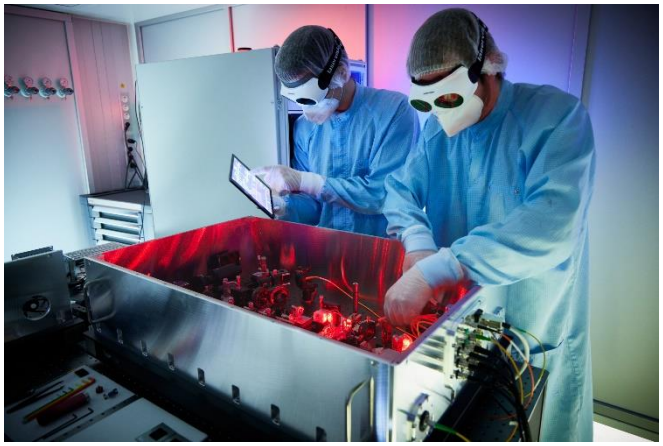

Image 2:
With QuTech, Fraunhofer ILT is developing key components for the quantum internet (shown here: laboratory prototype for a low-noise quantum frequency converter).
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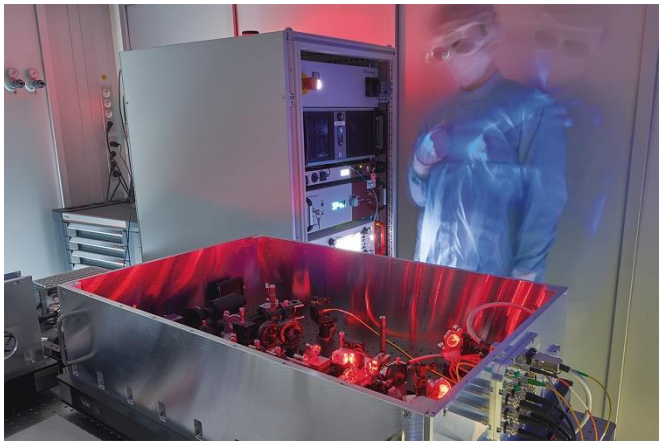

Image 3:
Quantum technology is full of wow effects: Quantum frequency converters for individual photons that transport information.
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