

Quantum key distribution with photonic integrated circuits to protect against cyberattacks

Six research and industry partners from Thüringen launch the PIC-PAM project

Erfurt, Germany, 1 June 2026. On 27 May 2026, Thüringen approved funding for the three-year collaborative project “Photonicallly Integrated Polarisation Analysis Module with Single-Photon Processing (PIC-PAM)”, which is co-financed by the European Union. The partners Quantum Optics Jena GmbH, AIM Micro Systems GmbH, X-FAB Global Services GmbH, Fraunhofer Institute for Applied Optics and Precision Engineering IOF, the Institute of Applied Physics at Friedrich Schiller University Jena, and IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH (IMMS GmbH) will work within the project to more closely integrate Thüringen’s competences in optics and photonics with those in microelectronics and sensor technology. The aim is to achieve a significant innovation breakthrough by combining integrated photonics and quantum communications to enhance the cybersecurity of German ICT fibre networks, particularly for data centres and campus networks. Therefore, the six members of Thüringen’s photonics network OptoNet e.V. aim to develop small modules suitable for common network hardware at reduced costs, which can easily be installed at security-critical locations. For this purpose, photonic and microelectronic functions will be integrated on a single silicon chip: a polarisation analysis module for measuring the quantum states of photons, single-photon detectors for highly sensitive signal conversion, and electronics for high-resolution time stamping and evaluation of the detections.

Cybersecurity for future communications infrastructures

Even today, protecting sensitive information from cyber threats is a top priority and requires ever newer and more robust security measures to ensure confidentiality and prevent unauthorised access. “It is foreseeable that quantum computers will be able to break traditional encryption methods in the coming years, thereby jeopardising the security of information,” explains Dr Kevin Füchsel, Managing Director of Quantum Optics Jena GmbH, which is leading the overall project.

According to Füchsel, quantum key distribution based on entanglement is a promising technology for securing future communications infrastructures: “It is possible to generate and distribute cryptographic keys with physically guaranteed security, regardless of an attacker’s computing power.” In quantum communications, it is not electrical signals but photons – individual particles of light – that are transmitted, and these are entangled in their quantum states. Information is encoded via the polarisation of a single photon. Eavesdropping, like any other form of manipulation, alters the state of the photons. This makes attacks detectable and enables targeted protective measures. According to Füchsel, three components are required for quantum key distribution: polarisation analysis to detect the state of a photon, single-photon detectors to ensure that the individual light particles are actually measured, and time stamping to synchronise the transmitter and receiver and filter out noise.

Quantum key distribution – so far, large hardware for tiny photons

To put all these theoretical advantages of quantum key distribution into practice for widespread use in the IT networks of the future, the six partners are working on a miniaturised technology platform. “A glance at the multitude of opto-mechanical components currently used in laboratory setups for quantum communications makes it clear that the miniaturisation and photonic integration of quantum key distribution presents significant challenges, but also opportunities,” states Prof. Dr Andreas Tünnermann, Director of Fraunhofer IOF and of the Institute of Applied Physics at Friedrich Schiller University Jena, characterising the project. He is confident that Thüringen will be able to take a pioneering role in this field: “We have expertise built up over many years in both optics and photonics on the one hand, and microelectronics and sensor technology on the other. By joining forces, we will succeed.”

Dr Andreas Fischer, Managing Director of AIM Micro Systems GmbH, adds: “We are working towards a highly integrated solution that can be easily and flexibly deployed in network devices, much like a small SFP module.” To this end, all partners will contribute to the development of more compact, standardised and industry-ready components. The challenges for assembly and interconnection technology lie in the photonic and electrical connection to the overall system, Fischer continues.

Silicon chip will combine all functions within a few millimetres

In this project, a complete analysis unit will be developed as a monolithic integrated circuit that combines the photonic and electronic functional units on a single chip with a size of just a few millimetres.

“We will further develop our technologies specifically for quantum key distribution and continue to adapt our CMOS processes for the manufacture of photonic-integrated chips,” explains Dr Gabriel Kittler, CEO of X-FAB Global Services GmbH. This would enable photonic and electronic component layers to be processed on a single wafer in future. IMMS and Fraunhofer IOF will use this X-FAB technology platform to develop subsystems for the joint chip.

Fraunhofer IOF will implement all solutions for the silicon-nitride-based photonic components of the chip, such as the micro-optical assemblies, the light processing in the polarisation analysis unit including the beam splitter, and the couplers for connecting the photonic and electronic circuits and for fibre coupling from the chip to external devices. The test setups for characterising all photonic modules will be implemented at University of Jena.

“Everything that is intended to happen in the electronic layer of the chip will be developed at IMMS, and we will integrate as many functions as possible – the variety of individual components of today are to be incorporated into the chip of tomorrow,” explains Martin Eberhardt, Managing Director of IMMS. One focus will be on SPAD-based single-photon detectors, which, like the existing discrete sensors, handle the highly sensitive signal conversion but will be located directly in the chip. These highly sensitive single-photon avalanche photodiodes (SPADs) will, for the first time, be expanded to include the timestamping electronics to be newly developed in PIC-PAM. Eberhardt goes on to say that the transfer of IMMS’ existing SPAD-based solutions to quantum applications with integrated photonics, in collaboration with Fraunhofer IOF, will be particularly promising.

Small module for easy use in network devices

To ensure that these innovative chips can ultimately be used in a small, SFP-like module within network devices, AIM Micro Systems will implement the necessary assembly and interconnection technology: AIM will assemble the chips, fit them with housings and implement suitable connections for optical and electronic components, taking into account industrial suitability and manufacturing technologies.

At Quantum Optics Jena, work will be done to create a photon source that enables quantum key distribution to be carried out using photons visible to SPADs. In addition, the company will build the overall demonstrator for the project based on the developments made by all partners to demonstrate the functionality of the results.

Innovation made in Thüringen

“Thüringen is one of Germany’s leading centres for microelectronics and photonics. We are delighted that six highly innovative photonics companies from our membership are working on this significant innovation in the integration of integrated photonics and quantum communications, all based in Thüringen,” says Anke Siegmeier, Managing Director of OptoNet e.V.

Furthermore, the close collaboration with X-FAB as a regional semiconductor manufacturing partner and the involvement of local research institutions will generate significant benefits for Thüringen. The region will benefit from the transfer of technology and know-how to local suppliers and start-ups, from the strengthening of the value chain, and from the transferability of the results to cross-sector applications – even beyond Thüringen.

Funding



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Images

Image 1:

https://www.imms.de/fileadmin/redaktion/projekte/PIC-PAM/20260421_PIC-PAM_Kick-off_IMG_20260421_164241_1920x1280.jpg

Caption: Representatives of the PIC-PAM project partners Quantum Optics Jena GmbH, AIM Micro Systems GmbH, X-FAB Global Services GmbH, Fraunhofer Institute for Applied Optics and Precision Engineering IOF, the Institute of Applied Physics at Friedrich Schiller University Jena, and IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH (IMMS GmbH) at the first working meeting in Erfurt. Photograph: IMMS.

Image 2:

https://www.imms.de/fileadmin/redaktion/projekte/PIC-PAM/Integrierte_optische_Schaltung_1_Copyright_Fraunhofer_IOF_1920x1280.jpg

Caption: Integrated optical circuit with fibre-optic connections (top and bottom), developed at Fraunhofer IOF in Jena. © Fraunhofer IOF.

Background information

Quantum Optics Jena GmbH

Today's information security relies on complex cryptography. Quantum computers will challenge these methods in the future. Quantum Optics Jena GmbH is developing quantum key distribution (QKD) based on entangled photons to enable secure communications on a physical basis. The company covers the entire process chain – from sources and analysis to key management. Solutions are available for fibre-optic networks as well as for future QKD satellite systems. <https://qo-jena.com/>

AIM Micro Systems GmbH

AIM Micro Systems GmbH, based in Triptis, specialises in the development and manufacture of high-precision micro-optical and optoelectronic systems. As a technology-oriented partner, the company supports customers in demanding sectors such as medical technology and sensor technology throughout the entire process chain – from design and industrialisation through to series production. The company has particular expertise in the integration of complex optoelectronic and photonic components under cleanroom conditions, as well as in the implementation of customised solutions with a high degree of vertical integration. <https://www.aim-micro-systems.de>

X-FAB Global Services GmbH

X-FAB is a global foundry group providing a comprehensive set of specialty technologies and design IP to enable its customers to develop world-leading semiconductor products that are manufactured at X-FAB's six wafer fabs located in Malaysia, Germany, France, and the United States. With its expertise in analog/mixed-signal technologies, microsystems/MEMS, Photonics and silicon carbide (SiC), X-FAB is the development and manufacturing partner for its customers, primarily serving the automotive, industrial and medical end markets. X-FAB has approximately 4,300 employees and has been listed on Euronext Paris since April 2017 (XFAB). <https://www.xfab.com/>

Fraunhofer Institute for Applied Optics and Precision Engineering IOF

The Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena conducts application-oriented research in the field of photonics and develops innovative optical systems for controlling light – from its generation and manipulation through to its application. The institute's range of services covers the entire photonic process chain, from opto-mechanical and opto-electronic system design to the manufacture of customised solutions and prototypes. At Fraunhofer IOF, around 500 staff members generate an annual research budget of 40 million euros. <https://www.iof.fraunhofer.de>

Friedrich Schiller University Jena, Institute of Applied Physics

The Institute of Applied Physics (IAP) at Friedrich Schiller University Jena has a long-standing tradition and expertise in the design, manufacture and application of active and passive optical and photonic components. It is also particularly known for its developments in the field of ultrashort-pulse laser development and application, as well as quantum optics. Collaborative projects with industry ensure practical relevance and feasibility. In the Experimental Quantum Information research group, the focus is on the development and experimental implementation of innovative methods for the generation, manipulation and detection of complex quantum states of light. <https://www.physik.uni-jena.de/en/iap/16984/institute-of-applied-physics>

IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH (IMMS GmbH)

IMMS supports companies in launching internationally successful innovations for health, the environment and industry. It supports them from the feasibility study to series production with application-oriented research and development in microelectronics, systems engineering and mechatronics, and transfers the results of basic research into applications and products. IMMS was founded in 1995 as a Land-owned company of Thüringen and is an affiliated institute of Technische Universität Ilmenau. Around 90 people work at the Ilmenau headquarters and at the Erfurt branch office. <https://www.imms.de/>

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