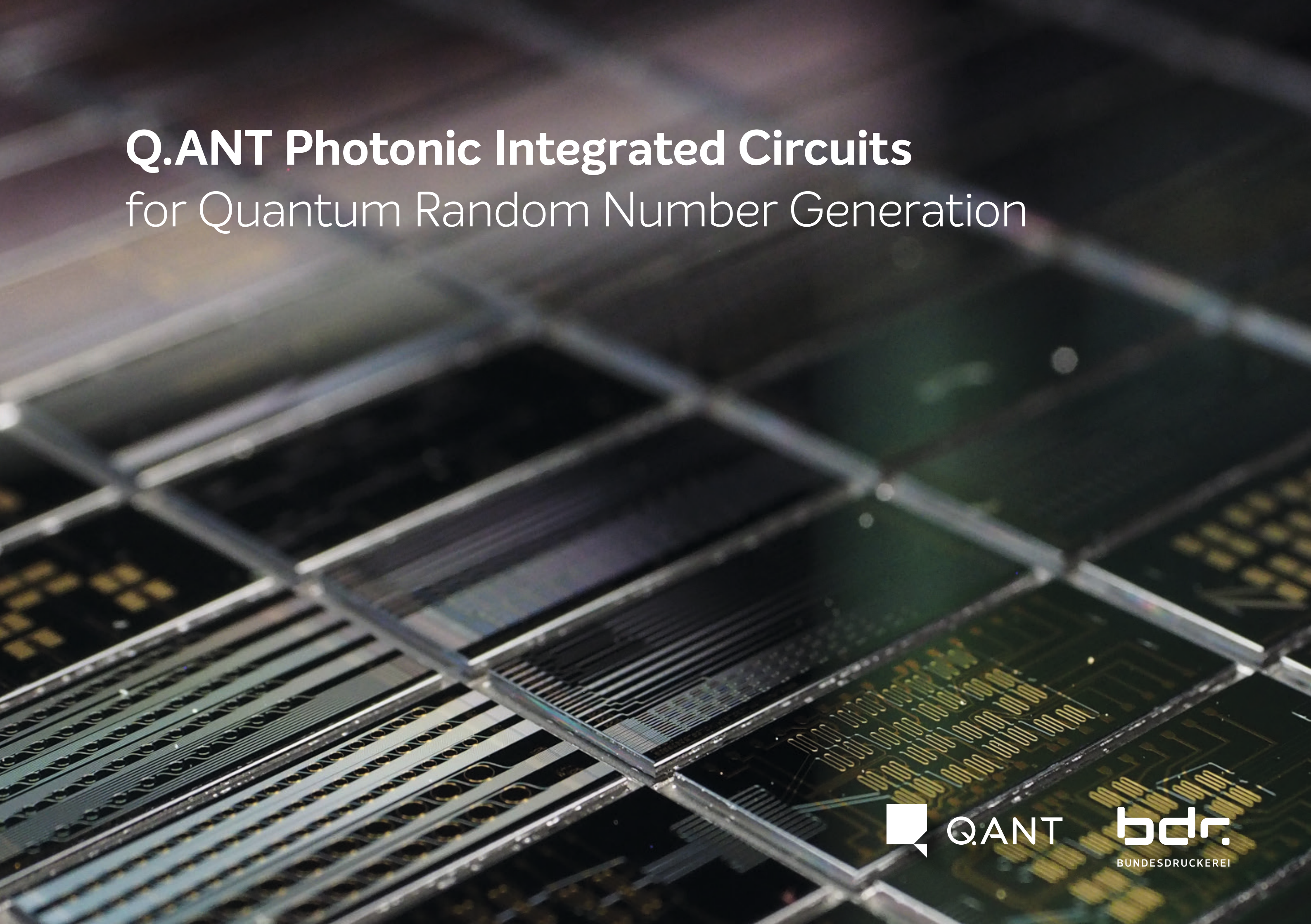
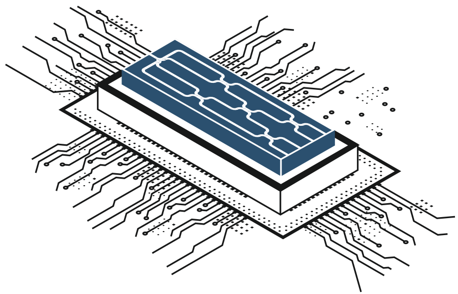
Q.ANT Photonic Integrated Circuits
for Quantum Random Number Generation



Generating true random numbers from quantum noise



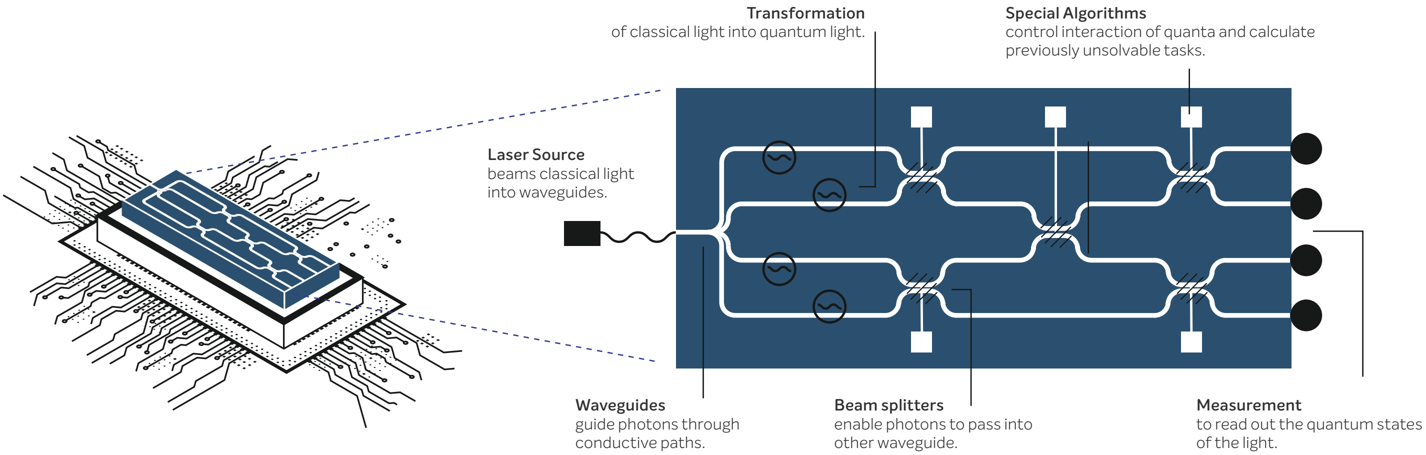
In this joint project, Q.ANT developed a photonic integrated circuit (PIC) for the generation of quantum random numbers for the Bundesdruckerei. Random numbers are applied in cryptography, secure communication or lottery as well as for scientific calculations and financial portfolio simulations. However, it is not trivial to generate true randomness. A promising way to generate true random numbers is to access the true randomness of the intrinsic quantum uncertainty.

Our photonic integrated chip does exactly this: It takes the quantum noise of the vacuum state as input and massively amplifies the fluctuations by using a special detection scheme. This makes quantum noise accessible for the generation of true random numbers.
The generation of random numbers is only one showcase out of a wide range of applications of the Q.ANT photonic integrated circuits.

How the Q.ANT Photonic Integrated Circuits work

The Q.ANT Photonic Framework
For Q.ANT, light is the essential resource for exploiting the potential of quantum technologies. The photonic quantum technology is therefore at the center of product development at Q.ANT. The expertise lies in mastering and controlling the entire optical and electronic process chain up to data processing. This includes the conversion of electrons into photons, the generation and exploitation of optical quantum effects and the reconversion of photonic quantum information into electrical signals and data.

The Q.ANT Lithium Niobate Platform
Q.ANT is developing its own process design kit for producing photonic integrated circuits in lithium niobate. This material platform was specifically chosen for its favorable properties for quantum computing. The benefits of integrations are a high stability as well as a scalable and reproducible production. Lithium niobate enables the creation of fast switches as well as high non-linearities for efficient generation of quantum resource states, while allowing for low loss at the same time.



A short story about Photonic Integrated Circuits for novel information processing

Our photonic integrated circuits in lithium niobate are a novel technology platform, which will open new paths for quantum information processing. Currently, promising architectures, algorithms and applications are:

Photonic computing

Light can be used to speed up classical matrix multiplication. This has a great potential to accelerate Artificial Intelligence (AI) applications as these operations form the basis of deep neural networks. Other architectures are suitable to solve quadratic unconstrained binary optimization (QUBO) problems, which address relevant industrial use cases, like logistical optimization.

Quantum sampling algorithms

In quantum sampling, one taps into the intrinsic quantum property of wave functions collapsing into probability distributions upon measurement. As shown above, it can be used to generate true random numbers from the intrinsic probabilistic nature of quantum. This can be done by the optical amplification of the quantum uncertainty of the vacuum state via balanced homodyne detection. True random numbers are important for cryptography, quantum communication, or Monte-Carlo methods for scientific or financial simulations.
Other applications of quantum sampling are based on a protocol called Gaussian Boson Sampling. Photonic integrated circuits in lithium niobate are very suitable for this, as they allow the efficient generation of the required quantum input states, called squeezed states. Applications thereof are chemical simulations, e.g. vibrational spectra of molecules or molecular docking in drug research. Alternatively, one can map graph optimization problems, like logistical scheduling, onto the photonic chips for finding the optimal solution.

Quantum machine learning

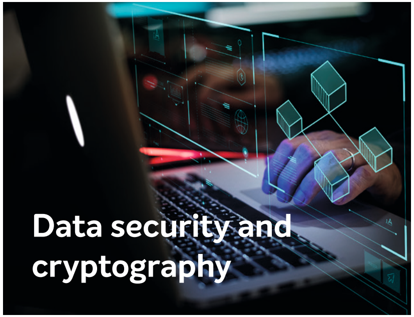
Algorithms in the domain of quantum machine learning typically make use of the huge dimension of the Hilbert space of quantum systems to perform machine learning tasks more efficiently due to larger available resources. Additionally, for squeezed photonic states in photonic integrated waveguides, there exists a rather direct correspondence to classical neural networks while giving access to quantum effects.

Universal photonic quantum computing

In our opinion, the most feasible approach to universal photonic quantum computing is measurement-based, cluster-state quantum computing. This approach makes use of distinct photonic properties, like their mobility and that new qubits can be generated on demand. The gate operations are implemented via feed-forward measurements. Lithium niobate, with its fast-switching capability, is essential for this. As this is a universal computational model, one can access all the well-known quantum algorithms, like prime number factoring via Shor's algorithm, Grover search algorithms or solving linear equation systems via the HHL algorithm.

QANT

Quantum Computing
real and relevant today and tomorrow



Q.ANT is pioneering in Quantum Sensing and Quantum Computing

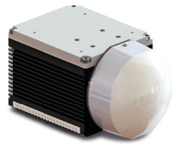
Q.ANT is a high-tech startup driving photonic quantum technology. Founded in 2018, Q.ANT currently employs more than 60 people at its site in Stuttgart/Southern Germany. The vision of Q.ANT is to improve the quality of how machines analyze their environment, how humans process information, and how we think. Focusing on four product lines – Particle Metrology, Atomic Gyroscopes, Magnetic Sensing and Photonic Computing – the company engages with a broad array of industries and applications ranging all the way from medical technology and autonomous vehicles to aerospace, machinery, and the process industry.

Particle Metrology
Sensor for analyzing finest particles in gases, liquids and as powders.

- Chemistry, pharma and food processing
- Algae and bacteria analysis
- Material Characterization

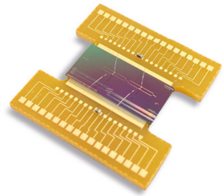
Atomic Gyroscope
Sensor for stabilization and localization of systems.

- Satellite leveling
- Indoor Automated Guided Vehicle (AGV) Localization



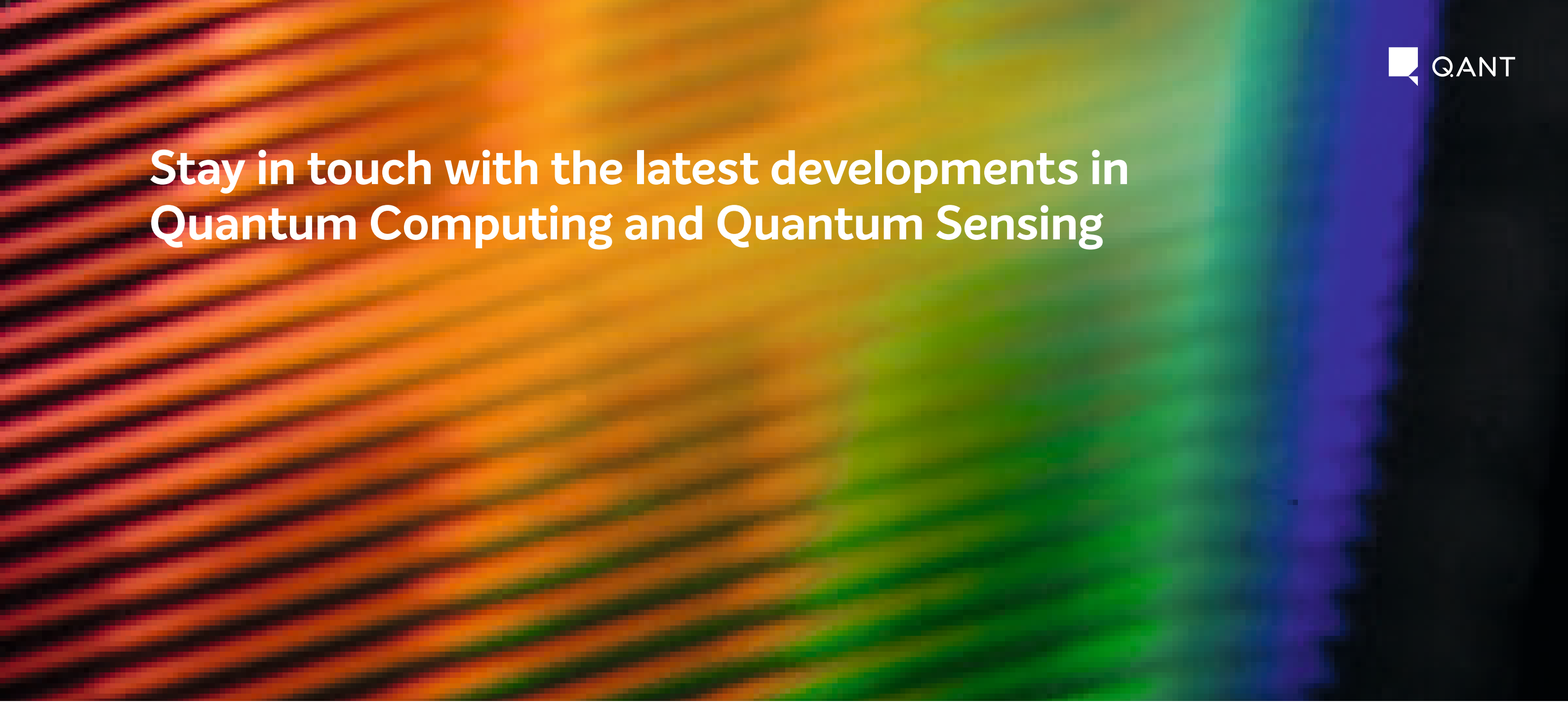
Magnetic Sensing
Sensor for measuring finest signals in magnetic fields.

- Prosthesis control by neuronal signals
- Outdoor Automated Robotic Localization
- Human-Machine Interface



Photonic Computing
Photonic integrated chips for solving complex problems.

- Quantum Computing
- Complex Optimization
- Neuromorphic Computing



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