Integrated photonic quantum systems

Michael Kues
Institute of Photonics, Leibniz University Hannover, Nienburgerstr 17, 30167, Germany

For more than 100 years, researchers explore quantum physics, which led to major breakthroughs, such as the laser, being today in daily use. With the increased control that is gained in recent years over quantum systems, the current advances in quantum technologies allow the exploitation and distinct control of quantum phenomena such as superposition and entanglement. These quantum phenomena enable fundamental performance advantages over normal classical procedures. They can be used for example to realize quantum-enhanced metrology, where quantum systems show the increase in sensitivity for metrological tasks, such as length measurements, as it will be exploited in the next generation of gravitational wave detection systems. Moreover, quantum physics is foreseen to enable quantum computing which could accelerate computational tasks for certain specific problems and enable entirely novel solutions with applications in drug development, material design or climate change. However current quantum computing technology is still in a prove-of-concept demonstration phase as it requires to prove scalability to large-scale quantum systems. More conceptually and technologically advanced is the use of quantum phenomena in order to realize future-prove communication systems, that means communication techniques which cannot be decrypted by future advances in mathematical concepts or computing resources. Here prove-of-concept systems in optical fiber as well as in satellite configurations and even commercial devices already exist, which require however advances with respect to multi-user operation increased transmission rates and reduced complexity.

Among other quantum systems, such as trapped ions or superconducting systems, photons come with the advantage that they are very robust to decoherence, i.e., they preserve the quantum state over long time and distances. Moreover, systems can mainly work at room-temperature which avoids the need for complex cryogenic cooling systems. Photons are also directly compatible with today’s optical fiber communications networks that are usually used for transmitting information via classical laser pulses.

In order to realize the aforementioned applications in real-world scenarios, practical, scalable, mass-producible, system aproaches are required to transform them out of lab into industry grade systems. In this context, integrated photonic chip systems have seen tremendous advancements in recent years, and can be exploited to form stable quantum systems with the potential for scalability. In this lecture, I will give an introduction into the topic of integrated photonic quantum systems, revising the on-chip realization of quantum states and their integrated/fiber-based processing with dedicated application scenarios.