Controlling Quantum Light in Integrated Photonic Systems

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Photonic quantum technologies rely on the precise generation, manipulation, and measurement of quantum states of light, with the long-term goal of realizing scalable and application-ready quantum systems. Our research addresses this challenge by developing integrated nonlinear photonic platforms that enable controlled quantum light engineering across multiple levels, from physical devices to complex quantum functionalities.

In this talk, I will present our work along three closely connected directions. First, we develop thin-film lithium niobate (TFLN) as an integrated platform for quantum photonic devices, including sources, circuits, and elementary functionalities. This includes the realization of photon-pair sources based on parametric down-conversion, quantum interference such as Hong–Ou–Mandel effects, and integrated implementations of mode-selective devices such as the quantum pulse gate.

Second, we investigate how spectral engineering can be exploited to access high-dimensional photonic systems. By tailoring parametric processes via dispersion engineering, we achieve fully controlled quantum state preparation in the spectral-temporal domain. This enables encoding in temporal modes and spectral bins, as well as mode-selective operations based on the quantum pulse gate, opening new possibilities for quantum communication, metrology, and network applications.

Third, we explore photonic quantum simulation and computation, with a focus on Gaussian boson sampling using squeezed-light resources. In this context, continuous-variable photonic states combined with photon-number-resolving detection provide a powerful non-Gaussian resource. Building on this framework, we investigate photonic model systems to develop new approaches to quantum simulation and computation, as well as benchmarking strategies and a deeper understanding of complexity in scalable photonic platforms.

Together, these efforts establish a unified approach to controlling quantum light in integrated photonic systems, linking device platforms, high-dimensional encoding, and photonic quantum computing, and paving the way toward programmable, large-scale quantum technologies.