Spectral-Temporal Engineering of Photon Pairs in Integrated Nonlinear Photonics

Ch. Silberhorn
Integrated Quantum Optics, Department of Physics, Institute for Photonic Quantum Systems (PhoQS), Paderborn University, 33098 Paderborn, Germany

Single photons and photon pairs are fundamental resources for photonic quantum technologies. Their usefulness, however, is not determined by photon number alone, but increasingly by the degree of control over their spectral, temporal, and modal properties. Parametric down-conversion provides a versatile route towards such tailored quantum states of light, enabling heralded single photons, strongly non-degenerate photon pairs, and deliberately multimode spectral-temporal states.

In this talk, I will discuss recent progress in integrated nonlinear quantum photonics, with a particular focus on thin-film lithium niobate as an emerging platform. Its strong second-order nonlinearity, tight optical confinement, and opportunities for dispersion engineering make it attractive for compact and efficient quantum light sources. These capabilities enable photon-pair generation across widely separated wavelength regimes and provide a basis for connecting different photonic platforms, for example in quantum networks and hybrid quantum architectures.

The second part of the talk will address how parametric down-conversion can be engineered in the spectral-temporal domain. Depending on the design objective, spectral correlations can be suppressed to produce high-purity heralded photons, or deliberately shaped to access multimode and high-dimensional quantum states. This perspective highlights spectral-temporal structure as both a design parameter and a resource for quantum state engineering.

I will further discuss how engineered nonlinear processes extend this toolbox beyond photon-pair generation, including mode-selective operations such as quantum pulse gates, which provide access to individual temporal modes and form an interface between source engineering, state manipulation, and measurement. Together, these approaches support scalable and programmable photonic quantum technologies for future applications.