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Quantum nonlinear parametric interaction in realistic waveguides: a comprehensive study

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Nonlinear sources of quantum light are foundational to nearly all optical quantum technologies and are actively advancing toward real-world deployment. Achieving this goal requires fabrication capabilities to be scaled to industrial standards, necessitating precise modeling tools that can both guide device design within realistic fabrication constraints and enable accurate post-fabrication characterization. In this talk, we introduce a modeling framework that explicitly integrates the engineering tools used for designing classical properties of integrated waveguides with quantum mechanical theory describing the underlying nonlinear interactions. We analyze the validity and limitations of approximations relevant to this framework and apply it to comprehensively study how typical fabrication errors and deviations from nominal design – common in practical waveguide manufacturing – affect the nonlinear optical response. Our findings highlight, in particular, a critical sensitivity of the framework to group-velocity dispersion, the potentially disruptive role of geometric inhomogeneities in the waveguide, and an upper bound on single-mode squeezed-state generation arising from asymmetric group-velocity matching conditions.

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