Tomography and Verification of Large-Scale Quantum Systems: Scalable Methods for Photonic Platforms

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As quantum technologies scale up, the need for efficient and reliable verification of large entangled states becomes increasingly pressing. Full quantum state tomography, while comprehensive, faces exponential resource demands in both data acquisition and post-processing—making it impractical for systems beyond a modest number of qubits. This limitation is particularly acute in photonic platforms, where loss and probabilistic gates constrain the number of available state copies.

In this talk, we present a suite of scalable verification and tomography techniques designed for large-scale quantum systems under realistic experimental constraints. These methods combine tools from quantum information theory, probabilistic modeling, and post-processing optimization to make quantum verification and tomography feasible even in systems of arbitrary Hilbert space dimension. Our methods enable few-copy and even single-copy entanglement detection, sample-efficient and device-independent quantum state certification, and targeted tomography focused on physically-relevant observables. Particular emphasis is placed on their practical deployment in photonic quantum technologies, where challenges such as low detection efficiencies and limited data rates demand resource-efficient solutions to support the development of reliable quantum networks and processors and advancing photonic platforms toward real-world applications of quantum information processing.

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