Classical Algorithms for Efficient Approximate Simulation of Quantum-Optical Experiments

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Negativity in phase-space quasiprobability distributions is widely recognized as an essential resource enabling quantum computational speedups. When these distributions are non-negative, quantum circuits can be efficiently simulated on classical computers. We present classical algorithms that enable approximate yet efficient simulation of quantum-optical experiments, even in the presence of negativity. By applying this framework to boson-sampling experiments, we identify fundamental challenges for verifying such experiments under realistic conditions involving noise and loss. In particular, we show that mode mismatch represents a major obstacle to realizing quantum speedups, and introduce a new method for characterizing mode-mismatching effects in linear-optical networks.