Continuous Variable Sampling from Photon-Added or Photon-Subtracted Squeezed States

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In the recent years we have witnessed an increasing interest in quantum circuits that define sub-universal models of quantum computation [1]. These models lie somewhere in-between classical and universal quantum computing, in the sense that, although not possessing the full computational power of a universal quantum computer, they allow for the outperformance of classical computational capabilities with respect to specific problems. Beyond their conceptual relevance, the reason for this interest is that these models require less experimental resources than universal quantum computers do. Therefore, they may enable experimental demonstration of *quantum advantage*, i.e. the predicted speed-up of quantum devices over classical ones for some computational tasks. These models are often associated with sampling problems for which the task is to draw random numbers according to a specific probability distribution. Some of these probability distributions are likely to be hard to sample for classical computers, assuming widely accepted conjectures in computer science, for example with the celebrated Boson Sampling [1].

In parallel, Continuous-Variable (CV) systems are being recognized as a promising alternative to the use of qubits, as they allow for the deterministic generation of unprecedented large quantum states, of up to one-million elementary systems [2], and also offer detection techniques, such as homodyne detection, with high efficiency and reliability.

We introduce a new family of quantum circuits in continuous variables and we address the corresponding sampling problem, that we call CVS (for Continuous-Variable Sampling) [3]. We show that, relying on the widely accepted conjecture that the polynomial hierarchy of complexity classes does not collapse, their output probability distribution cannot be efficiently simulated by a classical computer. These circuits are composed of input photon-subtracted (or photon-added) squeezed states, passive linear optics evolution, and eight-port homodyne detection. We address the proof of hardness for the exact probability distribution of these quantum circuits by exploiting mappings onto different architectures of sub-universal quantum computers. We obtain both a worst-case and an average-case hardness result in the case of exact sampling. Hardness of Boson Sampling with eight-port homodyne detection is obtained as the zero squeezing limit of our model.

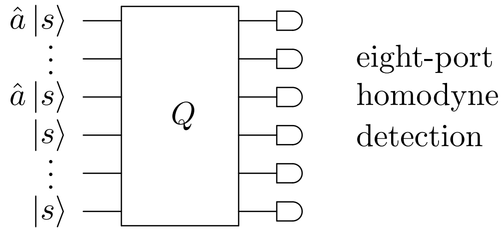

FIG. 1: A representation of a CVS circuit. In input are vacuum squeezed states and photon-subtracted vacuum squeezed states. The passive linear optics evolution is described by a unitary matrix Q. Measurement is performed by eight-port homodyne detection.

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[2] J.-i. Yoshikawa *et al*, APL Photonics **1**, 060801 (2016).
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