Efficient simulatability of Continuous-Variable circuits with large Wigner negativity

Laura García-Álvarez[1], Cameron Calcluth[1], Alessandro Ferraro[2], and Giulia Ferrini[1]

[1] *Department of Microtechnology and Nanoscience (MC2), Chalmers University of Technology, SE-412 96 Göteborg, Sweden.*
[2] *Centre for Theoretical Atomic, Molecular and Optical Physics, Queen's University Belfast, Belfast BT7 1NN, United Kingdom.*

Abstract. Wigner negativity is known to be a necessary resource for computational advantage in several quantum-computing architectures, including those based on continuous variables (CVs) [1,2]. However, it is not a sufficient resource, and it is an open question under which conditions CV circuits displaying Wigner negativity offer the potential for quantum advantage. In this work, we identify large families of circuits that display large Wigner negativity, and yet are classically efficiently simulatable, although they were not recognized as such by previously available theorems.

Keywords: Wigner negativity, Continuous-Variable quantum computing, Bosonic codes

The families of circuits with large negativity identified as simulatable use bosonic codes, such as the GKP code [3], or codes based on rotational symmetry [4]. In these encodings, the computational basis states are described by intrinsically negative Wigner functions, even though they are stabilizer states for qubits. We derive our results by establishing a link between simulatability of high dimension discrete-variable (DV) quantum computers and bosonic codes.

Our method is based on the embedding of encoded qubit states into encoded qudit (namely, a DV system of generic dimension larger than 2) states, where some of the CV operations that are not defined in the logical qubit space, now become Clifford operations in a higher-dimensional qudit space.

References

[1] A. Mari and J. Eisert, Physical Review Letters **109,** 230503 (2012).
[2] V. Veitch, N. Wiebe, C. Ferrie, and J. Emerson, New Journal of Physics **15,** 013037 (2013).
[3] D. Gottesman, A. Kitaev, and J. Preskill, Physical Review A **64,** 012310 (2001).
[4] A. L. Grimsmo, J. Combes, and B. Q. Baragiola, Phys. Rev. X **10,** 011058 (2020).
[5] L. García-Álvarez, C. Calcluth, A. Ferraro, and G. Ferrini, arXiv:2005.12026 (2020).