Two-qubit encoding strategy for a continuous quantum system

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Bosonic codes employ particular states of an infinite-dimensional Hilbert space to encode a qubit within a continuous quantum system. Despite the enormous resources available in a continuous quantum system [1], typical encodings only exist for single qubits [2]. Here we go one step further and present an encoding scheme for two qubits (four states), which protects against errors in small shifts of the canonical variables position q and momentum p. Furthermore, we present a universal set of single and two-qubit operations, based on particular symmetry operations for continuous quantum states represented by a square lattice in phase space.

To provide support for numerical calculations we present a self-built simulation package that can simulate quantum operations for a huge variety of continuous quantum systems on powerful HPC hardware as well as on a local pc. Our software does support many well-known codes like GKP or cat codes. Moreover it offers several predefined gates for simulating operations acting on single and composed quantum systems and allows, in particular, the coupling of discrete to continuous systems.

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[1] Lloyd, S. and Braunstein, S., Quantum Computation over Continuous Variables, Phys. Rev. Lett. 82, 1784-1787 (1999).

[2] Gottesman, D., Kitaev, A., and Preskill, J., Encoding a qubit in an oscillator, Phys. Rev. A 64:012310 (2001).