

Error correction for Rydberg blockade-based maximum weighted independent set embedding

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The Rydberg blockade [1] naturally maps the information of the unit ball maximum weighted independent set (MWIS) [2], which corresponds to the solution of a specific NP-complete graph-coloring problem, onto an optical-tweezer-arranged neutral-atom system. Because the Rydberg blockade is a distance-dependent feature, it imposes strong limitations on the graph geometry. Therefore, realizing arbitrary connectivity between atoms requires an additional process known as embedding [3]. By introducing gadgets, sets of auxiliary atoms, embedding strategies can effectively mediate interactions between arbitrary pairs of atoms. Recently, three embedding schemes have been proposed: parity-architecture [4], crossing-lattice [5], and quantum-wire embeddings [6]. These embeddings encode each logical atom in the joint state of several physical atoms using the Rydberg blockade, providing intrinsic protection against local noise. However, error correction remains challenging. To address this, we develop an error correction algorithm for Rydberg-blockade-based embeddings. Our decoding algorithm leverages superatoms, Rydberg-blockaded clusters allowing only one excitation. By counting excitations, the algorithm detects local error clusters and applies corrections when a unique solution exists; otherwise, it expands the clusters to ensure global consistency. Under an independent and identically distributed (i.i.d.) noise model, our cluster-based error correction algorithm exhibits a critical threshold. Moreover, it outperforms the previous post-processing approach, the Ebadi22 greedy algorithm [7]. Unlike conventional error correction methods, our approach leverages the intrinsic properties of the Rydberg platform and provides hardware-friendly insights that help bridge the existing gap between quantum hardware and software.

References

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