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Multi-qubit gates for bosonic logical qubits in trapped ions

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Bosonic codes comprise a paradigm for quantum computing and quantum error correction where quantum information is encoded in continuous degrees of freedom such as modes of radiation or motion. In particular, Gottesman-Kitaev-Preskill (GKP) codes [1] are promising candidates for bosonic quantum information processing, in which quantum error correction has recently been demonstrated both in superconducting circuits [2] and trapped ions [3]. In order to embed such encodings into larger systems, gates between multiple encoded qubits are required.
We present techniques for the realization of two-qubit gates on GKP codes with finite energy [4]. Here we observe that operations designed for ideal infinite-energy codes create undesired effects when applied to physically realistic states. We demonstrate that these can be mitigated using local error-correction protocols. In addition, we propose finite-energy gate implementations which largely avoid the need for further correction.

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[2] P. Campagne-Ibarcq et. al, Nature **584**, 368 (2020).
[3] C. Flühmann et al., Nature **566**, 513 (2019).
[4] I. Rojkov, P. M. Röggla, M. Wagener, M. Fontboté-Schmidt, S. Welte, J. Home, and F. Reiter, arXiv:2305.05262 (2023).

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