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A bivariate bicycle code architecture for quantum communication using ion traps

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In the not-too-distant past, reliable transfer of data was largely done with small portable memories. This method is ideal for quantum communication in which the required resource for protocols such as quantum key distribution and quantum teleportation is distributed Bell pairs, as these can be distributed ahead of time using quantum memories [1410.3224].

Quantum low-density parity-check (qLDPC) codes are promising quantum-memory candidates because the distance and number of logical qubits of each qLDPC code 'module' increases with physical qubit count, unlike a surface code module in which only the distance increases. Additionally, intra-module [2410.03628, 2503.10390] and inter-module [2407.18393, 2410.03628] logical operations in qLDPC codes are possible, enabling the preparation of logical Bell states. The disadvantage of qLDPC codes is that they require long-range, rather than just nearest-neighbour, qubit connections, opening up many possibilities as to the ideal layouts and architectures to realise them with.

A popular family of qLDPC codes are the Bivariate Bicycle (BB) codes [2308.07915], for which proposed architectures include long chains of trapped ions [2503.22071, 2508.01879] and tiered superconductors [2507.23011]. Already-realised architectures include superconductors using air bridges [2507.00254].

Ion traps are ideal quantum memories due to their long coherence times and slow gate times. They additionally can be made portable enough to be used in technologies such as atomic clocks [2112.06816]. Consequently, we propose and benchmark an ion-trap architecture for realising a specific BB code memory with 6-12 months memory time. Being specific to quantum communication allows a fixed chip size and a tailored layout without needing to consider extra connections required for universal quantum computation. We benchmark our architectures with simulations implementing an ion trap noise model and a BPOSD decoder. We further benchmark the process of creating distributed logical Bell pairs in our architecture for the purposes of quantum communication.

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