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Fault-Tolerant Blind Quantum Computation with Communication Qubits under Photon Loss

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Blind quantum computation (BQC) enables a client with limited quantum capabilities to delegate quantum tasks to a more powerful quantum server without revealing the details of the calculations. This secure delegation is especially relevant in distributed quantum architectures, where clients and servers are connected via photonic links[1]. Recent advances propose fault-tolerant protocols that leverage entanglement between matter-based communication qubits and photonic qubits to implement blind quantum gates through teleportation.
We analyze two fault-tolerant schemes for realizing a blind gate based on photonic communication. The first[2] uses two matter qubits on the server side: a communication qubit, which receives the teleported blind gate from the client, and a computation qubit, which stores and evolves the quantum state. In this scheme, repeated photon transmissions are required until a successful measurement by the client occurs. In contrast, our alternative approach incorporates error correction directly on the communication qubit, enabling gate operations without a separate computation qubit and significantly reducing matter qubit requirements.
We present a comparative analysis of both protocols under varying photon loss rates, evaluating their performance. The results highlight key trade-offs between photonic redundancy and matter qubit requirements, offering guidance for future implementations of scalable and secure quantum computing platforms.

[1] P. Drmota et al., Phys. Rev. Lett. 132, 150604 (2024). https://doi.org/10.1103/PhysRevLett.132.150604
[2] G. Baranes et al., arXiv:2505.21621 [quant-ph] (2025). https://arxiv.org/abs/2505.21621

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