

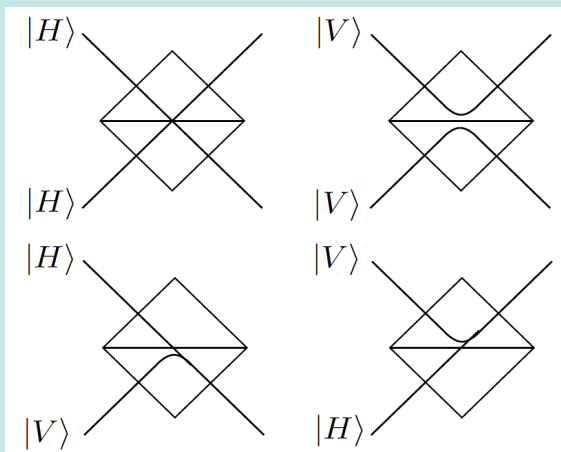
Introduction

One of the most significant challenges facing the experimental realization of linear optics quantum computing¹ (LOQC) is mode-mismatch^{2,3}. Ideally, photons in LOQC circuits should be indistinguishable. Mode-mismatch makes photons distinguishable which undermines circuit operation. This can be introduced, for example, by spatial misalignment, imperfect temporal synchronization, or non-identical photon sources.

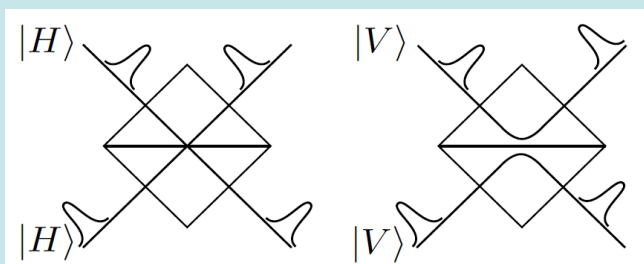
Several recent proposals for LOQC use the *parity gate* (or type-II fusion gate⁴) as the fundamental building block. Here we examine the operation of this gate in the presence of mode-mismatch.

The Parity Gate

The parity gate measures the *parity* of a two-photon state. If both photons have the same polarization they have *even parity*, whereas if they are different they have *odd parity*. The parity gate is constructed using a polarizing beamsplitter (PBS).



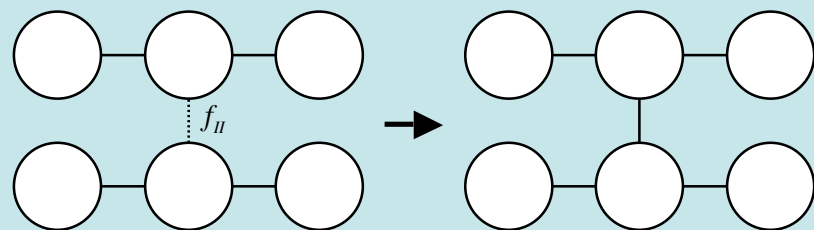
Parity measurement: Two photons are incident on a PBS, which transmits horizontally- and reflects vertically-polarized light. When exactly one photon is measured at each output mode, only *HH* and *VV* terms survive (where *H* and *V* denote horizontal and vertical polarization). Measurement is performed in the diagonal basis, such that these two outcomes cannot be distinguished. Thus, the state is projected into the subspace spanned by *HH* and *VV*, the even-parity subspace.



Parity measurement with mode-mismatch: In the presence of mode-mismatch (represented here as a temporal delay in one of the photons), measurement reveals some information as to whether the incident state was *HH* or *VV*. The input state is still projected into the even-parity subspace, but this will no longer be a coherent process. Instead we are left with a mixture of the two possibilities.

Cluster state quantum computing

Cluster state quantum computing^{5,6} is a model for quantum computing in which an entangled state - known as a *cluster state* - is prepared. Once prepared, a quantum computation can be performed using only a sequence of single qubit measurements. Optical cluster states can be generated efficiently using the parity gate⁴.



Generating optical cluster states: The parity gate (f_{II}) is used to fuse together two smaller clusters to construct a larger one.

Cluster states with mode-mismatch

In the presence of mode-mismatch, an error model can be derived for the cluster state,

$$\hat{\rho}_{\text{out}} = (1-p)|C\rangle\langle C| + p\hat{Z}_i|C\rangle\langle C|\hat{Z}_i$$

where $|C\rangle$ is the desired cluster state, i the fused qubit, and p the error probability. This is a simple dephasing error model, for which error correction techniques exist^{7,8}. Thus, mode-mismatch can be tolerated, provided it is within the bounds of the relevant fault-tolerance threshold.

Acknowledgements

We thank Daniel Browne, Terry Rudolph, Henry Haselgrove and Chris Dawson for helpful discussions. This work was supported by the Australian Research Council.

References

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