Linear optics quantum logic gates in the real world

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Quantum information (QI) offers capabilities in both communication and computation that are not achievable using classical physics alone. The fundamental unit of QI is the quantum bit (qubit), which is a two-state quantum system analogous to the classical bit. The implementation of QI protocols requires the use of qubits that: are well isolated; are efficiently controllable; can interact nonlinearly with each other. Recent proposals suggest that this is achievable using linear optics alone [1], with the required strong, nonlinear interactions between two photons occurring without any nonlinear optical materials at all.

The controlled-NOT (CNOT) gate is one of the elements required in quantum computation. In the original linear optics design, a CNOT gate [1] was realised via four photons and several interferometers. Subsequent simplifications [2, 3], such as reducing the number of photons, or the number of interferometers, should make the optical CNOT easier to demonstrate. However, some of these schemes [1, 2] have assumed that the system consists entirely of ideal components and perfectly controlled experimental conditions. This is unlikely to be practically achievable; therefore we must more realistically model the gates.

We investigate the practical issues which are likely to arise in experiments we are currently performing. In particular, we model the effects of beamsplitter imbalance, imperfect spatial mode matching, and timing considerations, in order to determine which elements most significantly impede the correct optical CNOT operation. We have already shown that mode matching is a critical factor, with relatively small mismatches leading to notable output state corruption.

References

[1] E. Knill, R. Laflamme & G. J. Milburn, Nature **409**, 46 (2001).

[2] T. C. Ralph, A. G. White, W. J. Munro, and G. J. Milburn, Phys. Rev. A **65**, 012314 (2001).

[3] T. C. Ralph, N. K. Langford, T. B. Bell, A. G. White, arXiv:quant-ph/0112088, Phys. Rev. A., to appear (2002).