Quantum logic operations in optical fibers

B.C. Jacobs, M.J. Fitch, T.B. Pittman, and J.D. Franson
Johns Hopkins University, Applied Physics Laboratory, Laurel, MD 20723
Bryan.Jacobs@jhuapl.edu

Abstract: We have recently demonstrated several probabilistic quantum logic operations using linear optics and post selection. Here we show how the fidelity of these devices can be increased using fibers to reduce optical mode mismatch errors. OCIS codes: (270.000) Quantum Optics

Probabilistic quantum logic operations can be implemented using linear optical elements, additional photons (ancilla), and post-selection [1,2]. We have proposed [3] and experimentally demonstrated [4,5] several logic devices of this kind that succeed with an ideal probability of ½. In the demonstrated gates, quantum parity check and destructive controlled not, a non-linear logic operation is performed on a two-photon input state by combining the photons at a polarizing beam splitter and post-selecting one output mode of the beam splitter based on a detection event in the other output mode. The polarization of the accepted output generally relies on a two-photon interference effect and is therefore highly sensitive to the indistinguishability of the photons.

The extent to which the indistinguishability of the photons effect the gate performance depends on the input polarizations; some input combinations do not rely on interference effects at all for successful gate operation. The worst-case errors in the original proof-of-concept experiments were as high as 15% and were largely attributable to optical mode mismatches between the two input photons. These experiments were performed in free space and relied on mirrors to maintain the input beam alignment. We have recently developed an optical fiber version of the experiment, shown in Figure 1, designed to simplify these alignment issues. Preliminary results of the new setup demonstrate average errors of 3% and worst-case errors less than 6%.

Results of the fiber-based version of the quantum parity check and destructive controlled not gates will be presented along with a detailed analysis of the remaining error sources.

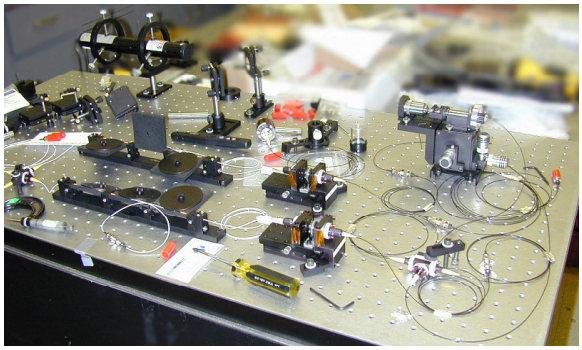

Figure 1. Fiber-based quantum logic experiment.

[1]. E. Knill, R. Laflamme, and G. J. Milburn, Nature **409**, 46 (2001).
[2]. M. Koashi, T. Yamamoto, and N. Imoto, Phys. Rev. A 63, 030301 (2001).
[3]. T. B. Pittman, B. C. Jacobs, and J. D. Franson, Phys. Rev. A 64, 062311 (2001).
[4]. T. B. Pittman, B. C. Jacobs, and J. D. Franson, Phys. Rev. Lett. 88, 257902 (2002).
[5]. T. B. Pittman, B. C. Jacobs, and J. D. Franson, Phys. Rev. A 66, 052305 (2002).