Integrated optics for cluster state generation

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Quantum information science is one of the most promising implications of quantum mechanics [1]. Quantum bits of information (qubits) can be realized by several physical systems. Due to low decoherence, even at room temperature, photonic qubits form a feasible platform for quantum computation via manipulation of degrees of freedom like polarization by conventional beam splitters and wave plates. A quantum circuit for general quantum computation is build up from one-qubit and two-qubits gates; a general quantum circuit can be realized as a set of linear interferometers, single photon sources and single photon detectors, as was showed by Knill, Laflamme, and Milburn (KLM) [2]. For proper operation of such a circuit, the interferometer elements have to be phase stable. Tabletop experiments using bulk optical elements can suffer from phase instability, moreover the size of more complex circuits grows rapidly. The miniaturization and integration of photonic qubit gates into a complex chip is desirable [3]. Our experiments use femtosecond laser direct-writing technique (FLDW) to define these gates via pattering waveguides on glass substrates.

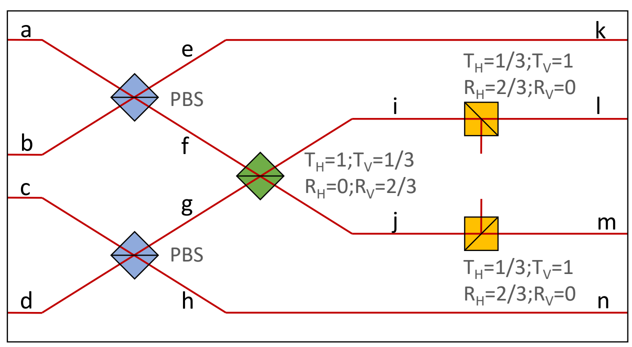

Figure 1: Integrated-optics chip for linear cluster state generation

Here we present the generation of a linear four qubit cluster state $|\psi\rangle=1/2\ [|0000\rangle+|0011\rangle+|1100\rangle-|1111\rangle]$ on a gorilla glass chip. Experimental generation of cluster states is important because the states are a resource for the one-way computational model, which is the preferred paradigm for photonics quantum computation [4,5]. The circuit architecture for the cluster state generation is shown by the Figure 1. For representation of logical “0” and “1” polarization states, $|H\rangle$ and $|V\rangle$ were used. The initial state $|\psi_0\rangle=1/\sqrt{2}\ [|H\rangle+|V\rangle]$ is generated by two free space down-conversion single photon sources based on BBO crystals. Coupling the initial states to the waveguides structures in the chip is done via fibers with thermal expanded core (TEC) to increase the coupling efficiency. The states in modes a, b, c, d (Figure 1) obtain phase shifts before entering to PBSs, though the phase shift is the same for each mode and can be neglected. The states in the modes a, b are projected by the PBS into a Bell state $|\psi_{ef}\rangle=1/\sqrt{2}\ [|H_eH_f\rangle+|V_eV_f\rangle]$ (modes e, f), and the same for the states in modes c, d, which are projected into a Bell state (modes g, h). Finally, the Bell states are fused into the linear cluster state via a C-Phase gate, and we achieve $|\psi_{eklh}\rangle=1/\sqrt{2}\ [|H_eH_kH_lH_h\rangle+1/\sqrt{3}|H_eH_lV_kV_h\rangle+1/\sqrt{3}|V_eV_lH_kH_h\rangle-1/3|V_eV_kV_lV_h\rangle]$. At the end, the amplitudes of the produced cluster state are corrected by unbalanced PBSs in modes k, l and we get the linear cluster state in proper form $|\psi_{emnh}\rangle=1/2\ [|H_eH_mH_nH_h\rangle+|H_eH_nV_mV_h\rangle+|V_eV_nH_mH_h\rangle-|V_eV_mV_nV_h\rangle]$. The experimental setup and first experimental data will be presented.

References

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