Quantum Photonics using Structured Photons

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Spatially structured photons have found many fruitful applications in quantum photonics due the possibility of encoding high-dimensional quantum states.

In one study, we use this enlarged Hilbert space to encode up to four qubits on a single photon and implement a quantum version of a finite automaton (FA), i.e. a fundamental computational device making binary decisions using finite states (see Fig. 1a). We demonstrate its advantage over a classical FA in terms of resource efficiency, by solving the prime number promise problem with less states than classically possible [1].

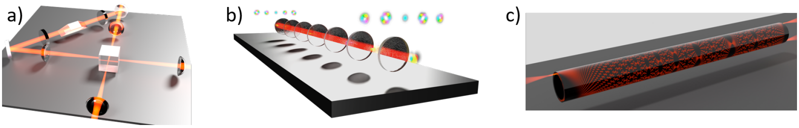

Fig. 1: Simplified sketches of the implementations of a quantum FA (a), a spatial mode multiport (b), and the cylindrical Talbot effect (c).

We further study more complex quantum state operations by implementing general unitary mode transformations for structured photons using multi-plane light-conversion techniques (see Fig. 1b). Using this high-dimensional multiport scheme, we observe two-photon interferences between multiple spatial modes along a single beamline [2]. Interestingly, this two-photon bunching leads to novel spatial-mode N00N-states, for which the known phase super-sensitivity of N00N-states translates to a super-resolution in angular and longitudinal displacement [3]. Finally, we investigate the propagation of photons that are confined to a cylindrical geometry using ring-core fibers and study the effect of interferometric self-imaging known as the Talbot effect (see Fig. 1c). We show that ring-core fibers act as controllable high-order optical beamsplitters for single photons and demonstrate two-photon interference within this complex self-imaging effect [4].

The presented schemes show novel approaches to complex quantum information tasks using structured photons and new ways to implement linear optical networks for applications in quantum photonics.

References

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