Experimental demonstration of computer reconfigurable multimode entanglement

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Novel quantum communication and computation protocols require an increasing number of entangled modes. Conventionally, the entangled modes are carried by many single mode beams [1]. In our work we demonstrate a set of tools that generate, manipulate and detect multimode entanglement within a single beam of light with the modes being set in the Hermite-Gauss basis. This new method is flexible and computer controlled in the sense that any quantum protocol requiring a finite number of modes can be tested. In our scheme (see Fig. 1), all the entangled modes are carried by a single beam and their correlations are measured with a pair of multipixel homodyne detectors and one single local oscillator. This method takes full advantage of the new degenerate OPAs which can squeeze simultaneously several co-propagating modes. It allows for fully computer controlled entanglement relationships: there is no need for hardware changes to switch from one protocol to another.

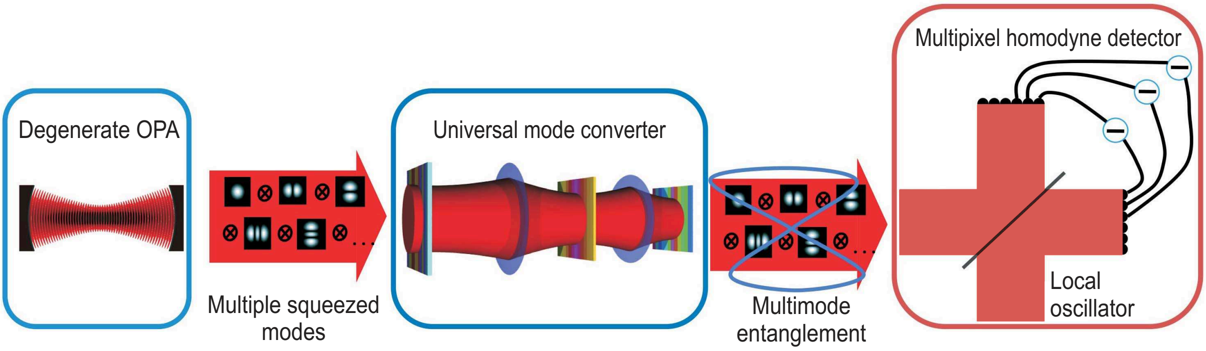

Fig. 1: Overview of the generation and manipulation of entanglement within a single beam of light.

The first step in creating the co-propagating, entangled modes is to generate several squeezed modes within the same beam. This can be done either by using a degenerate OPA cavity [2], which is a cavity capable of squeezing several Hermite-Gauss modes, or by combining orthogonal squeezed modes (produced by several single mode OPAs) with minimum loss using optical cavities. The second step is to mix the different squeezed spatial modes. For this purpose we introduce a unitary mode converter (UMC), which is a succession of spatial Fourier transforms and reflections on computer controlled deformable mirrors. We show that we can in theory perform any kind of spatial basis change provided that there are enough reflections and Fourier transforms [3]. Our experimental results for the performance of the UMC match well to the simulated results and outperform the conventional way of generating higher-order modes using optical cavities. Finally, the third step is a simultaneous detection which utilizes a pair of 8-pixel photodiodes working as a multi-pixel homodyne detector [4]. An 8-channel direct data acquisition card is then used to record the squeezing and determine the quantum correlations.

References

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