Quantum entanglement, one of the defining features of quantum mechanics, is the process where the outcome of measurements on spatially distant particles cannot be separated. It underlies many important quantum information protocols and goal of loop-hole free test of quantum mechanics, sub diffraction-limit imaging and robust high-data rate quantum key distribution are a few examples that continue to drive forward the field of efficient sorting and detection of quantum states of light.

We demonstrate a scheme which achieves full field quantum correlations by using multi-point detectors placed in the signal and idler arms of a two-photon downconversion system. We separate different spatial modes by the use of different length optical delays which are connected to the outputs of a fibre array. The entry position at the fibre array therefore corresponds to a unique arrival time at the detector allowing us to take advantage of the high timing resolution of the SPADs and resolve the location of the coincidence. We find strong correlations in the position and momentum bases which correspond to the near-field and far-field of the crystal respectively, see figure. Through the use of spatial light modulators in each arm, acting as variable focal length lenses, we show that the correlations persist in intermediate fields provided that geometrical imaging is satisfied. The conditional variance product of the correlations in the near and far-fields is found to be significantly below the bound required for separability.

We also present a method to sort orbital angular momentum (OAM) states of light using two static optical elements [1]. The optical elements perform a Cartesian to log-polar coordinate transformation, converting the helically phased light beam corresponding to OAM states into a beam with a transverse phase gradient. A subsequent lens then focuses each input OAM state to a different lateral position. We demonstrate the concept experimentally by using two spatial light modulators to create the desired optical elements, applying it to the separation of eleven OAM states.

High efficiency multi-point detectors and efficient OAM sorting schemes are important developments when using the position/momentum basis or the angle/OAM basis for implementing high dimensional quantum key distribution.


1 SUPA, University of Glasgow, UK. 2 SUPA, Heriot Watt, UK. 3 University of Leiden, Netherlands. 4 University of Ottawa, Canada.


---

FIG. 1: Experimentally recorded coincidence count rates for different focal lengths of the lenses in the signal and idler arms and corresponding count rates from the fibre arrays for near-field and far-field geometries. The dashed lines correspond to the geometrical imaging conditions, where in the context of a Klyshko picture, the signal detector is imaged to the idler detector.