Looping and twisting bright light on a quantum walk

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Abstract: Quantum walks have become a topic of avid research due to its potential to further development in quantum computation as well as complex quantum simulations. Actualization requires implementation of a scalable and versatile physical system which can manipulate this phenomenon to achieve desired outputs. We experimentally demonstrate such a versatile system for free-space actualization using a scalable loop design and orbital angular momentum.

1. Introduction

Quantum walks (QWs) follow from the analogous random walk where a ‘walker’ moves according to the random outcome of a ‘coin flip’ [1]. Each iteration forms a step in the walk which leads to interference of the walker with itself. Physical implementation of the phenomenon holds potential for furthering development of quantum computers and complex quantum system analyses. Many systems that have been investigated, however, hold scalability and fagility issues. Exploiting the wave nature of classical light in a fiber loop architecture to overcome this has shown promise with up to 200 steps achieved [2]. This precedent may be utilized to physically implement a free-space QW in orbital angular momentum (OAM) space with bright classical light [3]. Here we implement this by exploiting the non-separability of classical vector beams such that the walker journey is in contained within a single beam of twisted light [4]. Polarization forms the coin states with a waveplate (WP) acting as a coin operator and a q-plate (QP) evolving the light beam in OAM space by laddering the OAM values according to the polarization [3,4].

2. Experiment setup and results

Figure 1 shows the conceptual setup for physically implementing a QW in free-space with OAM. Here the coin state is initialized by a WP before entering the beamsplitter (BS) and circulating in a loop, through a QP (evolving the light beam in OAM space according to the polarization state) and WP (flipping the coin state), and heading back towards the BS where some light is reflected for another round trip. The transmitted light passes to a mode sorter (MS) where the OAM spectrum is mapped in real time to an array of lateral spots binned on a gated ICCD. Results are given for the 4th step of varying types of QWs as determined by the type of WP (coin) used in the evolution of the walker.

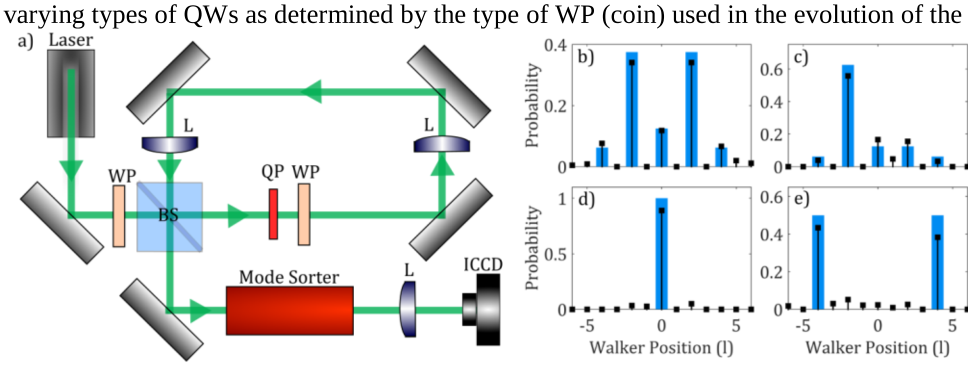

Fig. 1: a) Conceptual diagram of experimental setup. Experimental results (black) with simulated values (blue) are given for step 4 of a b) symmetrical and c) asymmetrical Hadamard QW as well as d) Not and e) Identity coin QWs.

Accordingly, we experimentally demonstrate the versatility and potential scalability of the scheme, paving the way for developing effective quantum walk systems in free-space.

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