Experimental realization of an innovative Phase-Stable Bulk-Optic scheme for Quantum Walks

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Abstract

We present the experimental implementation of a reconfigurable phase-stable bulk-optic scheme for 1-D Quantum Walks (QWs). The scheme is based on two displaced multipass Sagnac Interferometers (Sis) connected through a common Beam Splitter. The Sagnac configuration allows to set stably the QWs' phases for any step of the evolution. One or two photons can be injected in the setup and all output modes can be measured at any step. We show the experimental realization of different kinds of the evolution, for both one photon and two photons configuration.

One dimensional Quantum Walks are a suitable scenario for the simulation of the movement of a particle, also called walker, in a 1-dimensional lattice, representing the surrounding environment with which the particle interacts. Several diffusion processes can be replicated by mean of an appropriate QW and different algorithms are based on 1-D QW [1]. A 1-D QW can be can be realized through a network of Beam Splitters (BSs), each of them representing a particular position site of the 1-D lattice. The movement of the walker inside the network is determined by the interference between all possible paths that the walker can travel. QWs can be realized relying on different platforms [2]. The most direct way to realize a QW is by mean of a network of bulk BSs, but this implementation undergoes phase instability. Here we present the experimental implementation of an innovative phase-stable bulk-optic scheme for 1-D Quantum Walks. The setup is based on two displaced-multipass Sagnac Interferometers (SIs), connected through a common BS. The resulting loop is equivalent to a chain of Mach-Zehnder interferometers (MZIs), for each of them phase-stability is ensured by the Sagnac configuration. A QW can be realized exploring the vertical dimension of the BS as well as the horizontal one. The vertical displacement can be obtained by suitable Beam Displacers (BDs), such that when a beam goes through one of them his height is increased by a fixed value. All possible paths of a QW can be realized placing the BDs along clockwise trajectories of SI1 and along counterclockwise ones of SI2 (see Fig. 1a)). By mean of thin Rotating glass Plates (RPs) phases can be addressed in each mesh of the network. Removable Mirrors (RMs) are used to extract and measure each of the possible paths travelled by the walker. We reproduced experimentally the behaviour of an ordered QW, namely a QW in which each path has the same phase, and a completely disordered QW, in which each path experiences different phases. In Fig. 1b) is reported the variance of the photon position during the evolution inside the QW. Theoretical predictions (OT, DT), predictions obtained with real parameters of the setup (OTR, DTR) and experimental data (OE, DE) are reported as function of the number of step. Data agree with theoretical simulations, showing that the setup is able to reproduce different kinds of 1-D QW.

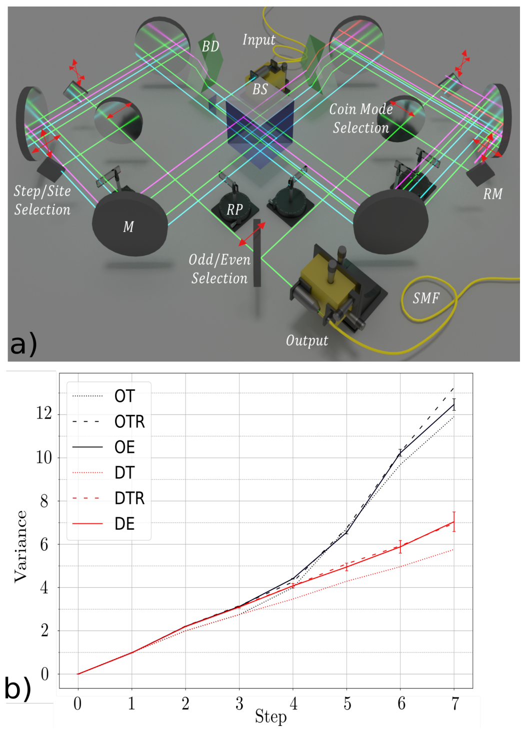

Figure 1: a) Setup realized experimentally. b) Behaviour of position variance for ordered and disordered QW.

[1] Crespi, Andrea et alii, *Anderson localization of entangled photons in an integrated quantum walk*, Nature Photonics **7.4**, 322 (2013).

[2] Sansoni, Linda, et alii, *Two-particle bosonic-fermionic quantum walk via integrated photonics*, Physical review letters **108**, (2012).