Quantum Random Walks with a Stress-Engineered Optic

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Abstract: We present an analysis of how a stress-engineered optic (SEO) can be used in a quantum random walk (QRW) process. Here, the walker and coin states are represented by orbital angular momentum (OAM) and polarization, respectively. In comparison to previous work done with Q-plates on QRW demonstrations, the SEO offers novel and interesting OAM distributions along with the possibility of implementing multi-path random walks with OAM.

1. Introduction

QRWs are markedly different from classical random walks through the resulting probability density that describes the distribution of the walker state following N steps [1-3]. In the past, Q-plates have been used to demonstrate various types of QRWs in elegant ways since their Jones matrices introduce a very clean interaction between OAM and polarization [1,3]. In this work, we introduce how an SEO can be used instead [4].

2. SEO properties and its role in QRWs

The Jones matrix for the SEO is given by

$$\hat{J}_{\mathrm{SEO}} = \begin{bmatrix} cos[\Delta(\rho)] & ie^{i\phi}\, sin[\Delta(\rho)] \\ ie^{-i\phi}\, sin[\Delta(\rho)] & cos[\Delta(\rho)] \end{bmatrix}, \qquad (1)$$

where ρ is the radial (normalized by the SEO aperture radius) coordinate. Also, $\Delta(\rho) = c\rho/2$ is twice the phase retardance due to the SEO, whose magnitude is governed by c, the stress parameter. In addition to the SEO, it is also necessary to introduce a waveplate [typically either a quarter-wave plate (QWP) or half-wave plate (HWP)] in the system. We will use $\hat{J}_{WP}(\theta)$ to represent the Jones matrix of any wave-plate element. The QRW operator (for one step in the process) is then given by the composition $\hat{Z} = \hat{J}_{WP}(\theta)\hat{J}_{SEO}$. Hence, after N steps, the QRW process is given by $\hat{Z}^{N}$. This operator acts on an initial electric field $\vec{E_i}$ to give a final electric field $\vec{E_f} = \hat{Z}^{N}\vec{E_i}$.

To demonstrate how an SEO generates novel and interesting OAM distributions, we first define two types of QRW. First: the *identity* QRW, where the wave-plate Jones matrix is given by $\hat{J}_{\mathrm{HWP}}(0)$. Seocnd: the *Hadamard* QRW, where the wave-plate Jones matrix is given by $\hat{J}_{\mathrm{QWP}}(\pi/4)$. Identity QRW simulations are shown in Fig. 1.

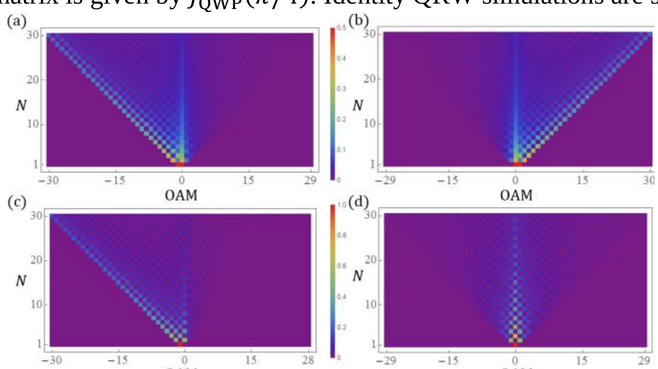

Fig. 1. Probability density plots for the value of OAM after N iterations of the identity QRW process, with $c = 4\pi$. Parts (a) and (b) correspond to the LHC and RHC components of $\vec{E_f}$ for a symmetric input field of $\vec{E_i} = E_0(1\ 1)$. Parts (c) and (d) correspond to the LHC and RHC of $\vec{E_f}$ for an asymmetric input field given by $\vec{E_i} = E_0(1\ 0)$.

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