Amplitude damping of vortex modes

Angela Dudley[1,2], Michael Nock[1], Thomas Konrad[1], Filippus Roux[2] and Andrew Forbes[1,2]
[1] *School of Physics, University of KwaZulu-Natal, Private Bag X54001, Durban 4000, South Africa*
[2] *CSIR National Laser Centre, PO Box 395, Pretoria 0001, South Africa*
Author e-mail address: ADudley@csir.co.za

Abstract: An interferometer, mimicking an amplitude damping channel for vortex modes, is presented. Experimentally the action of the channel is in good agreement with that predicted theoretically. Since we can characterize the action of the channel on orbital angular momentum states, we propose using it to investigate the dynamics of entanglement.

1. Introduction

Our approach in designing an amplitude damping channel for vortex modes is an extension of a previously reported orbital angular momentum (OAM) sorting device[1]. The interferometer induces a phase shift, Δϕ, which is proportional to both the OAM of the incoming beam and the relative angle, θ, between the two Dove prisms and is given by: $\Delta\phi=2l\theta$[1]. A phase mask which decreases the OAM by 1ħ is inserted into path B (depicted in Fig. 1).

2. Theoretical Background

When a Gaussian mode (l=0) enters the interferometer, there is no relative phase shift resulting in the mode exiting in path A. However, a vortex mode with l=1 experiences a relative phase shift, $\Delta\phi=2\theta$, and therefore exits in a superposition of paths A and B. Consequently, the vortex mode in path B is reduced by 1ħ. The overall action of the channel, on a general superposition of modes, l=0 and l=1, can be described by a single photon transformation

$$\alpha|l=0\rangle^{A}+\beta|l=1\rangle^{A}\rightarrow\alpha|l=0\rangle^{A}+\beta\left(\sqrt{1-p}|l=1\rangle^{A}+\sqrt{p}|l=0\rangle^{B}\right). \quad (1)$$

This mimics the well-known quantum amplitude damping channel. $\sqrt{1-p}=\cos\theta$ and $\sqrt{p}=\sin\theta$, where θ is the relative angle between the two Dove prisms.

3. Results

The power in each path, exiting the interferometer, is proportional to the square of the electric field, resulting in the same behaviour as the probabilities of single photons. The power in the two exiting paths of the interferometer are monitored for various angles, θ.

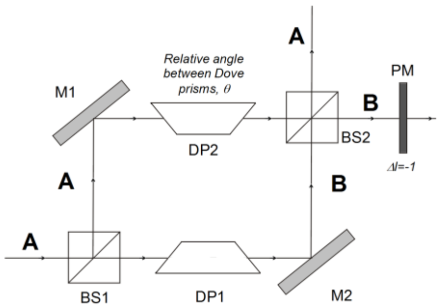

Fig. 1. Schematic of the vortex mode amplitude damping channel. (BS: beam-splitter, M: mirror, DP: Dove prism, PM: phase mask).

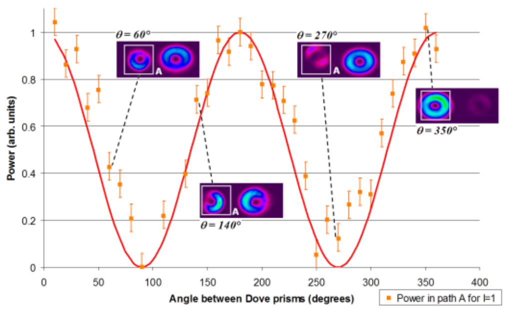

Fig. 2. Plot of the measured power in path A (orange points) for various values of θ.

The measured power in path A (Fig. 2) follows the trend of the theoretical result, $P_A \sim \cos^2\theta$, denoted by the red curve. There is also good agreement between the measured power in path B (not illustrated here) and the theoretical result, $P_B \sim \sin^2\theta$.

4. References

[1] J. Leach, M. J. Padgett, S. M. Barnett, S. Frank-arnold and J. Courtial, "Measuring the orbital angular momentum of a single photon," Phys. Rev. Lett. **88,** 257901-1-4 (2002).