Harnessing OAM Diversity for Robust FSO Propagation

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Abstract: There have been numerous demonstrations of high speed Free Space Optical (FSO) communication using mode division multiplexing, however, the range of these systems remains severely limited. In this work we present the results of several different experimental approaches using spatial modes such as OAM to increase the range of FSO links.

1. Introduction

Free Space Optical (FSO) communication is an exciting technology that is able to sustain extremely high data rates using technologies such as Mode Division Multiplexing with Orbital Angular Momentum (OAM) [1]. FSO may also prove to be a viable alternative to optical fiber in places where massive geographical distances and resulting costs are prohibitive [2]. Unfortunately, the range of high speed FSO links is currently very limited, with commercial products only achieving ranges of less than about two kilometers.

Atmospheric turbulence is one of the major issues with long range FSO communication, and MDM in particular because it degrades the orthogonality of the modes. There are two major avenues whereby the effects of turbulence can be mitigated: signal processing (such as MIMO, forward error correction and optimized modulation schemes) and optically (adaptive optics, optimized mode sets and diversity). In this work we will briefly review our research into optimal mode sets and modal diversity.

2. Optimal Modes and Diversity for FSO

Vector vortex modes, which are Laguerre-Gauss (LG) or OAM modes with a spatially varying polarization, were believed to be more robust to atmospheric turbulence than their scalar counterparts. We have experimentally shown, however, that due to the fact that the atmosphere is not birefringent, vector modes offer no improvement over scalar vortex modes [3]. Since a vector mode inherently makes use of both polarization states, they may in fact be sub-optimal for FSO because the polarization degree of freedom cannot be used for other purposes.

Hermite-Gauss (HG) modes are similar to LG modes except that they are rectangular rather than circular and can be created using super-positions of OAM modes. This difference in symmetry appears to provide an opportunity: we have shown that certain HG modes are significantly more robust than OAM modes in atmospheric turbulence [4]. One of the major effects of turbulence are tip and tilt aberrations, and HG modes that are symmetric about one axis are robust against this whereas OAM modes are not. Importantly, this resilience is maintained in the presence of higher order aberrations.

This difference in the effect of turbulence can be harnessed for something called modal diversity. Diversity is a common technique used in radio where multiple antennas are used to decrease the probability of errors. Optically, diversity is possible using an r_0 (atmospheric coherence length) separation of transmit or receive apertures. We have shown that since turbulence affects different spatial modes differently, using co-propagating LG (or OAM) and HG modes, there is in fact a diversity gain even without the conventionally required r_0 separation [5].

3. Summary

Here we present two possible techniques for improving the range of FSO links. Firstly, we show that HG modes are more resilient to turbulence than OAM modes. Secondly, we show that the performance of a FSO link can be significantly improved by harnessing a combination of OAM and HG modes to create modal diversity.

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