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Spatial Eigenmodes of Atmospheric Turbulence

Free space quantum communication can benefit from encoding information into high-dimensional quantum states of light. One possibility of such encoding is to use orbital angular momentum (OAM) of photons. However, the wavefronts of the spatial modes of light endowed with OAM, such as Laguerre-Gauss (LG) modes, are fragile with respect to fluctuations of the refractive index of air. In the present thesis, we explore the potential of alternative encoding high-dimensional states of photons - into spatial eigenmodes of atmospheric turbulence.

Specifically, we study the properties of eigenvalues and eigenvectors of the “turbulence operator”, which describes the action of a single realisation of the atmospheric turbulence on light beams propagated over a distance of 400m in the air and confined to a circular aperture in the receiver plane. This operator takes into account beam diffraction, refraction on the inhomogeneities of the dielectric susceptibility of air, and losses arising from the finite sized aperture and from the finite dimensional basis used to represent the turbulence operator.

We consider two sets of basis modes on a circle: the Zernike polynomials and the LG modes. We show that the former set of functions is rather useless, since it is not possible to accurately represent light beams propagated in vacuum or in turbulence. For the LG basis set, we use a basis dimension limited to 240 mode functions and investigate how the proximity of the eigenvalues to unity depends on the specific choice of the mode functions. We find that the eigenmodes whose eigenvalues are close to unity are highly localized in the transverse plane.