Investigations on Turbulence Impacted Structured Laser Beams for Free-Space Optical Communications

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ABSTRACT

There is a renewed interest in wave propagation analysis through turbulent and turbid media because of its wide range of applications ranging from astronomical to biomedical imaging. Researchers have been constantly trying to optimise the free space optical communication systems without or with the minimal use of adaptive optics system. Many attempts have been made to optimize the transmitting beams to improve communication efficiency. Such optimization of transmitting beams consists of many methods like altering their degree of coherence, and degree of polarization, or using different classes of beam shapes.In this thesis, different classes of beams are analysed after passing through a laboratory level turbulence simulator to see their potential to be used in free space communication systems.

The main objective of the thesis is to investigate the effect of atmospheric turbulence when different structured laser beams are propagated through it. We considered different classes of beams in different coherence regimes and their resilience to the impact of dynamic turbulence is thoroughly studied.

In the first section, the Fried coherence length of the rotating pseudo random phase plate is calculated. This work describes a new approach for determining the Fried's coherence length of a dynamic Kolmogorov type turbulence in a laboratory setting. The autocorrelation function generated from the quantitative properties of a rotating PRPP in one of the arms of a Mach-Zehnder interferometer is used in this method and the Fried parameter is found out with a better accuracy.

The next session of the thesis deals with the wave propagation analysis of partially coherent Gaussian-Schell model beams, zero order Bessel-Gaussian beams and partially coherent Gaussian vortex beams through a rotating pseudo random phase plate. The effect of turbulence is quantitively characterized by calculating their scintillation index, beam wandering and Zernike polynomials and qualitatively by finding the intensity line profiles at the laboratory level. The experimental results are further extended and verified using simulations. It was found that certain classes of beams under certain criteria show more resilience to the impact of turbulence making them desirable for free space optical communication purposes.

Towards the end of the thesis, the phenomenon of enhanced backscattering is studied using Laguerre Gaussian and Bessel-Gaussian beams. These beams are focused onto a detector after passing through a rotating dynamic turbulence twice. The backscattered rays are examined. When a beam is reflected off a retroreflector, it exhibits enhanced backscattering. When we employ a typical Gaussian beam, the amplification factor approaches two, and it decreases as the topological charge increases. The BG beam also exhibits enhanced backscattering, with an enhancement factor comparable to that of Gaussian beam. Along with the increased backscatter, the endurance of the BG beams is preserved as compared to the other incident beams.