Reconstructing the Quantum State of Photon Propagating Through Atmospheric Turbulence Simulator

Noah S Everett, Keith A Wyman, and Anil K Patnaik

Air Force Institute of Technology, AFIT/ENP, 2950 Hobson Way, Wright-Patterson AFB, USA

In striving for realization of a quantum-based internet and ground-to-space communication, propagation of photonic qubit through atmospheric turbulence is an inevitable requirement for global quantum network [1-4]. To enable development of robust quantum networks with higher fidelity, it is critical that we learn how the state of the qubit is transformed while propagating through the atmosphere [2]. In aiming at this goal, we are building up a laboratory based atmospheric turbulence simulator (ATS) at AFIT to characterize the effects of different scales of atmospheric turbulence on an entangled pair of photons as a function of statistical quantities of turbulence, such as the Fried parameter and scintillation index for long-distance communication.

The simulated turbulence is constructed using two afocal optical systems with a phase plate inserted in each to mimic both weak and strong atmospheric turbulence respectively. The qubit to propagate through the system was a polarization-entangled photon-pair source, produced using spontaneous parametric down-conversion. After propagation, the two beams are modified to be projected onto a specified component of polarization and quantum state tomography are performed on the photons to analyze the effects of the turbulence on the original state once reconstructed [5]. In characterization of the simulated turbulence, we were able to reach strengths up to a D/r_0 of 18.2, which approached the strong turbulence regime. We will discuss the results of the quantum state tomography and other quantum interoferic measurements.

[1] A. K. Patnaik, Proc. SPIE PC12016, Optical and Quantum Sensing and Precision Metrology II, PC1201638 (2022).

[2] K. A. Wyman, N. S. Everett, R. J. Von-Holle, V. I. Ramesh, M. W. Hyde, A. K. Patnaik, Proc SPIE Photonics West, Quantum Computing, Communication, and Simulation IV, PC1291108 (2024).

[3] B. V. DeLuca, A. K. Patnaik, Fourier transfer function for generic light pulse storage and retrieval using EIT. Eur. Phys. J. Spec. Top. 232 (2023) 3369; Y. Rostovtsev, J. Emerick, and A. K. Patnaik, Results in Optics 13 (2023) 100568.

[4] N. S. Everett, K. A. Wyman, R. Lanning and A. K. Patnaik (to be submitted, 2024).