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The behaviour of vectorial structured light through real-world atmospheric turbulence

Vectorial structured light has demonstrated numerous advantages of scalar light fields in various contexts, including communications, imaging and sensing. Their analogous mathematical structure to entangled biphoton states has allowed for the investigation of new physics in a more accessible manner. Recent work, inspired by the quantum metric commonly called the concurrence, has shown that the non-separability and homogeneity of vectorial structured light can be quantified using this metric. Furthermore, because this measure is defined in terms of inner products, it has been shown to be invariant through any unitary channel. Such findings have substantial implications for free-space optical communication (FSOC), where even the many advantages of structured light have reached their limits due to the deleterious effects of atmospheric turbulence. The concurrence of vectorial structured light, - how "vector"it is - will remain unchanged –including through atmospheric turbulent channels. This is despite distortions to its amplitude, phase and polarization structured which would normally be detrimental to the use of structured modes for communication. Here we report the first demonstration of this phenomenon through real-world atmospheric turbulence. We see that the non-separability remains invariant through a 270 m real-world turbulent channel over a period of 2 hours for encoded concurrence values of 0.25, 0.5, 0.75 and 1. Such a result demonstrates the potential to use this quantity as an encoding scheme in free space optical links. It cares solely about the unitary nature of the channel, thus providing a reliable, distortion-free basis with which to communicate. Consequently, we have also shown strong evidence that atmospheric turbulence is unitary, encouraging the exploitation of this property for exotic, invariant forms of structured light.

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