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Long-Range Fiber Transmission of Optical Vortices

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Abstract

We use specialty fiber (“vortex fiber”), to create and propagate orbital angular momentum states over ~kilometer lengths in telecom band (~1550nm). The spiral phase structure of the vortex beams was confirmed by interference with a Gaussian reference. This result is an important step toward achieving long-range classical and quantum communication links using orbital angular momentum of light.

I. Quantum cryptography

One application: optical tweezer use OAM light to rotate particles.

II. Light with Orbital Angular Momentum

Orbital angular momentum of light.

Problem: Intermodal coupling in conventional fibers

Solution: “Vortex fiber”

The specially designed “vortex fiber” lifts degeneracy in the higher-order mode group, thus enabling stable propagation of the modes without coupling.

IV. Setup

Schematic of our experimental setup. Narrowband (100Hz) tunable laser (for signal) was combined with a 60nm broadband 1550 nm LED source (for characterization) and applied to the input of the vortex fiber. Conversion from the fundamental mode into the optical vortex modes was achieved using microbend-induced fiber grating with period of ~90 µm [10]. Using a polarization controller before the microbend grating, we ensured that the left or right circular polarization state at the grating output effectively excites optical vortex modes. The LED source was used to characterize the grating spectrum (inset a), and a mode conversion efficiency of ~99% was obtained. After long (>0.9km) propagation in the fiber, the mode was imaged or interfered with a reference beam on a camera (InSaa SWIR) in order to obtain information about mode’s intensity or phase respectively (insets b and c).

V. Results

Using the “vortex fiber”, we were able to create and propagate optical vortices over more than 0.9 kilometers in the telecom band (~1550nm). Optical vortex mode intensity is shown in (a), along with its azimuthal line profile (b) that reveals exceptional mode purity (~20dB) after long length propagation. When interfered collinearly with a fundamental mode as a reference, a spiral pattern was observed (c, d), confirming the OV mode phase profile of exp(θi). In the case of angled interference well-known fork holograms have been observed (e, f). High visibility of the fork hologram also reveals high mode purity (~99%).

VI. Conclusion

In summary, light with orbital angular momentum can be used as means of improving throughput and security in classical and quantum communication links. One of the biggest challenges this, potentially revolutionary, concept faces is instability due to atmospheric scintillation (in free space) or intermodal coupling (in fibers). We have used specially designed vortex fiber to demonstrate the fiber propagation of optical vortices at distances relevant to metropolitan links of the order of kilometers. Cross talk levels were below 20dB, and our length scale limitation was due to availability of fiber rather than any fundamental constraint. Our demonstration represents a thousand fold improvement in the length over which OAM states have been transmitted to date. This result can find immediate applications in long-range quantum communications, and in the longer run has the potential to impact classical communication systems used in every day life.

References: