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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

Quantum cryptography – secure information transfer is enabled by using quantum key distribution. (Left) The internet’s undersea world. Solving the capacity crunch as well as increasing information transfer security are rapidly becoming important. (Middle) First long-range, quantum cryptography system between a large bank and the Vienna City Hall. (Right) Principles of quantum cryptography – secure information transfer is enabled by using quantum key distribution.

II. Light with Orbital Angular Momentum

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(iθ).

III. Optical Vortex propagation in fibers

The specially designed “vortex fiber” lifts degeneracy in the +1 higher-order mode group, thereby enabling stable propagation of the modes without coupling. (a) Measured refractive index profile (relative to silica index) for fabricated vortex fiber, and corresponding LP01 mode intensity profile. (b) Effective indices for the three vortex fiber modes. (c) Measured grating resonance spectra for coupling from the fundamental LP01 mode to desired higher order mode. Graph represents mode conversion efficiency of 99.8%.

IV. Setup

Schematic of our experimental setup. Narrowband (100kHz) tunable laser (for signal) was combined with a 60m broadband 1550 nm LED source (for characterization) and split 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 ~500µm.

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(iθ).

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 internal 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: