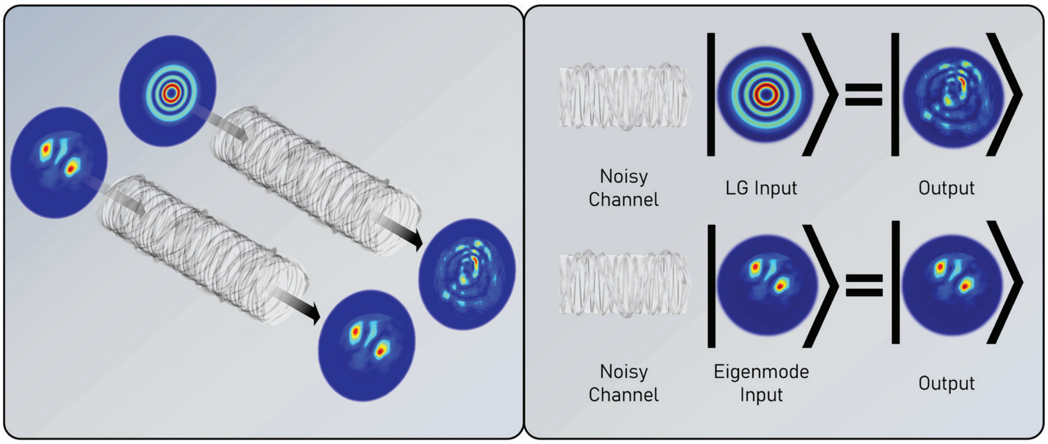
Distortion-Free Forms of Structured Light

An exciting prospect in modern optics is the exploitation of structured light,[1] such that each light pattern could form an encoding alphabet for optical communications or might be used in manufacturing to enhance performance and productivity. Unfortunately, patterns of light get distorted when they pass through noisy channels and can deteriorate to the point that the output pattern looks nothing like the input, negating the benefit. Now, using atmospheric turbulence as an example, we have shown how to find invariant forms of light that come out of a turbulent channel the same as they were put in—distortion-free.[2]

Passing light through the atmosphere is crucial in many applications, such as free-space optics, sensing and energy delivery, but doing so efficiently has proved challenging. Traditionally, a trial-and-error approach has been used to find the most robust forms of light to some particular noisy channel, but to date, all forms of familiar structured light (such as light carrying orbital angular momentum) have become distorted as the medium gets progressively noisier. But is it possible to create light that doesn't see the distortion, passing through as if it weren't there? In other words, can we make forms of light that are the true eigenmodes of the channel? By treating the channel (our medium) as a mathematical operator, we were able to create forms of light that were unrecognizable but nevertheless completely robust to the medium,[2] an idea that can be extended to find general invariances in structured light.[3] To demonstrate its impact in real-world applications, information was encoded into such an invariant and used for free-space optical (FSO) communication, showing that indeed the channel itself imparts negligible noise. The result was a new encoding state-of-the-art of 50 spatial modes in an FSO communication link.[4]

Although atmospheric turbulence was used as a practical and severe example, the approach is valid for more general problems of complex light in complex systems. It could be useful, for instance, in transporting classical and quantum light through optical fiber, underwater channels, living tissue and other highly aberrated systems. Because of the nature of eigenmodes, it doesn't matter how thick this medium is, nor how strong the perturbation. This method should work well even in regimes where traditional corrective procedures, such as adaptive optics, fail. Maintaining the integrity of structured light in complex media will pave the way for future work in imaging and communicating through noisy channels, which is particularly relevant when the structured forms of light are fragile quantum states. OPN



Left: Input Laguerre-Gaussian (LG) modes get distorted when passed through a noisy channel, but the true eigenmodes remain distortion free. Right: The LG modes and eigenmodes depicted as a graphical operator equation.

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