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Light correcting light with nonlinear optics

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Abstract: Structured light is a growing resource for applications from imaging to quantum communication. We show light can correct distorted structured states at the speed of light using nonlinear optics and without knowledge of the distortion.

Spatially structured light has become a fast-growing resource in both the classical and quantum regimes with applications spanning many fields, such as quantum communication where it affords higher dimensionality [1]. Unfortunately, such states are sensitive to the environment which cause distortions, adversely affecting their performance such as increased cross-talk in quantum key distribution or quantum information transport. Current approaches to correct this range from either applying the inverse after measurement [2,3] and characterization of the aberrations to non-linear reversal techniques where the conjugation of the distortion is undone by resending the light back through the aberrating medium [4].

We will discuss a new approach [5] as illustrated in Fig. 1 (a), where exploiting difference-frequency generation in a non-linear crystal, restores the spatial structure of light without requiring knowledge or reintroduction of the distortions. Using a variety of aberrations, we demonstrate excellent restoration over a range of spatial modes, such as shown in Fig. 1 (b). Furthermore, a proof-of-principle orbital angular momentum communications link will highlight the effectiveness of this approach, where even a highly aberrated channel can be corrected to give minimal cross-talk. Our demonstration of light correcting light can also be extended to alternative experimental modalities and opens a new way to measurement-free error correction for classical and quantum structured light, with direct applications in imaging, sensing and communication.

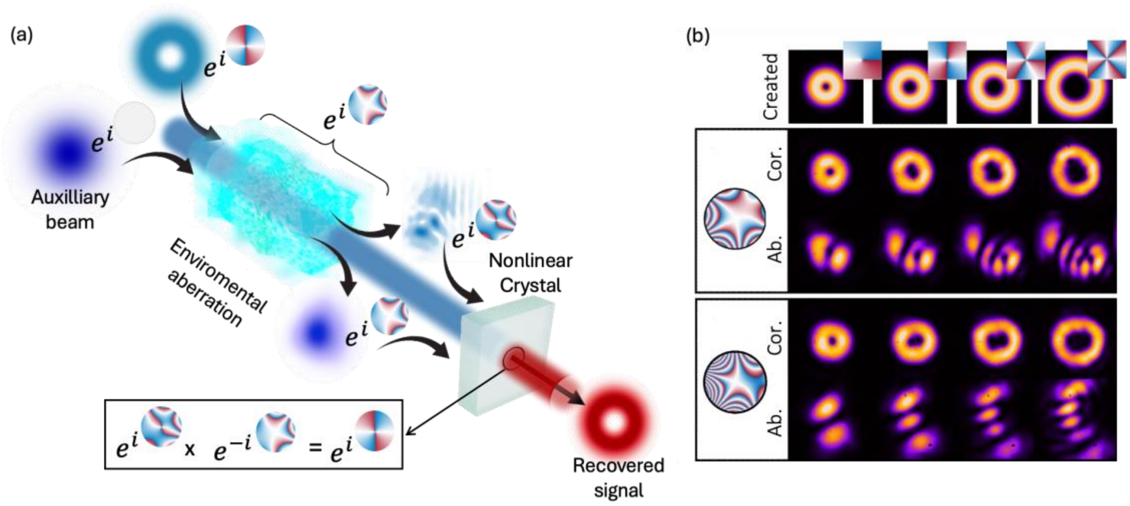

Fig. 1 (a) Conceptual illustration showing that structured light passing through a noisy environment gets distorted (top modes), but if another unstructured (auxiliary) beam also gains the same distortion, the effect can be undone by mixing them in a nonlinear crystal where the original signal is recovered. (b) Proof of principal results showing the distortions (left) give rise to aberrated (Ab.) modes, with significant distortion from the original (created) modes. These are then corrected (Cor.) by sending an auxiliary beam to experience the same distortion, without the need for any knowledge of the aberration, for a nonlinear form of adaptive optics that works at the speed of light.

Example References

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