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Nonlinear modal decomposition of structured light

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Structured light, tailored in its degrees of freedom for specific applications, has recently emerged as a highly topical field driven by advancements in both linear and nonlinear optical techniques. This has led to significant progress in nonlinear structured light, with applications spanning holography, spectroscopy, imaging, and even quantum teleportation. These breakthroughs rely on the ability to create structured light at one wavelength while achieving high-fidelity detection at another. While wavelength conversion techniques for generating structured light are well established, detection tools remain in their infancy. Here, we introduce a modal decomposition technique for structured light using nonlinear crystals, enabling full-field reconstruction at one wavelength by using a basis encoded at a different wavelength. In addition, we propose a faster, single-shot reconstruction approach through a nonlinear extension of off-axis holography. We demonstrate both techniques using representative examples of structured light, including orbital angular momentum (OAM) and Hermite-Gaussian (HG) beams. Our nonlinear approach to modal analysis offers the flexibility to choose efficient detectors, effectively removing wavelength constraints in structured light applications. This technique opens up new possibilities for nonlinear structured light, paving the way for future advancements in communication, imaging, and spectroscopy.

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