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Generation of LG and HG beams using Computer Generated Hologram

The generation of higher-order optical modes has become an important area of research owing to their unique phase and intensity distributions, which enable advanced applications in optical trapping, high-capacity communication systems, and quantum information processing. Among these, Laguerre–Gaussian (LG) and Hermite–Gaussian (HG) beams represent two fundamental families of structured light, characterized by orbital angular momentum and Cartesian nodal line structures, respectively. The present work focuses on the design and implementation of Computer-Generated Holograms (CGHs) for the efficient generation of LG and HG beams.

The objective of this study is to demonstrate a cost-effective and flexible approach for producing such beams by encoding the required phase profiles onto digitally synthesized holograms. The methodology involves calculating the analytical phase functions corresponding to LG and HG modes and embedding them into hologram masks using Fourier optics principles. These holograms, when displayed on a spatial light modulator (SLM) or printed onto diffractive optical elements, are illuminated by a fundamental Gaussian laser beam. Upon diffraction, the encoded phase distribution reconstructs the targeted beam profile at the detector plane. The LG modes exhibit azimuthal phase variations with characteristic doughnut-shaped intensity distributions, while the HG modes display rectangular symmetry with well-defined nodal lines along orthogonal axes.

Simulation studies confirm that the CGH-based approach can accurately reproduce both the amplitude and phase characteristics of the desired modes. Numerical Fourier transforms of the designed holograms yield intensity profiles consistent with theoretical expectations for a wide range of LG indices (radial and azimuthal) and HG orders. Experimental verification further validates the approach: by projecting the CGHs onto a liquid crystal SLM and illuminating with a He–Ne laser beam, we successfully obtained high-quality LG and HG modes. The generated LG beams exhibited clear phase singularities and orbital angular momentum features, whereas the HG beams showed distinct orthogonal nodal structures. Minor discrepancies between simulation and experiment were attributed to pixel resolution limits and alignment errors, but overall beam quality and mode purity remained high.

The results demonstrate that CGHs provide a versatile platform for generating structured light modes without the need for complex optical arrangements such as mode converters or interferometric setups. Compared to conventional methods, this technique offers enhanced flexibility, scalability, and cost-effectiveness, as holograms for arbitrary modes can be designed computationally and rapidly reconfigured in real time using programmable SLMs.

In conclusion, this work establishes a simple yet powerful method for generating LG and HG beams using computer generated holography. The combination of numerical design and experimental realization highlights the robustness and practicality of the approach, making it a valuable tool for applications in modern optics, particularly in optical manipulation, laser mode engineering, optical communication, and quantum technologies.

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