Holographic optical tweezers with multiple vector beams

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Abstract: Complex vector states of light have demonstrated to be a powerful tool in a great variety of applications. Here we present new approaches for the creation of such optical fields, including multiple scalar and vector states multiplexed from a single hologram and a new approach to generate free-space propagation-invariant vector beams. We also outline a quantum toolkit for the quantitative analysis of such beams. Finally, we combine these advances into an optical trapping and tweezing setup to demonstrate a holographic trap containing multiple vector vortex and scalar orbital angular momentum modes.

1. Introduction

Structured light is a highly topical field that captures the ability to tailor light in amplitude, phase and polarization [1]. Amongst the many structured light fields are vector beams, characterized by spatially variant polarization patterns. They have found a myriad of applications to date, which have been recently reviewed [2,3]. Here we present new approaches for the creation of such optical fields, including the simultaneous generation or multiplexing, from a single hologram, of multiple scalar and vector states with arbitrary polarization distribution. We also present a new approach to generate free-space propagation-variant vector beams which exploit the polarization dependence of spatial light modulators. Moreover, we outline a quantum toolkit for the analysis of such beams. Finally, we combine these advances into an optical trapping and tweezing setup to demonstrate a vector holographic trap with customized arrays of beams comprising scalar orbital angular momentum and cylindrical vector beams generated by a single hologram.

2. Summary of results

We outline new approaches to the creation of vector beams. We point out that it is possible to create multiplexed vector beams from a single hologram by combining interferometric and holographic approaches, demonstrating all Higher-Order Poincare Sphere beams simultaneously from one device [4]. We also show that a common path approach can be used to create propagation invariant flat-top beams by exploiting the efficiency issues of SLMs, combining an undiffracted Gaussian mode with a vortex mode [5]. After the creation step we are able to show accurate analysis of the vector beams by employing quantum tools to form a vector beam analyser. This allows the degree of vectorness to be analysed during propagation. Finally, we deliver these beams into an optical trap and show simultaneous optical trapping and tweezing of scalar and vector beams [6]. We use this to test the trapping efficiency of cylindrical vector vortex beams, including radially and azimuthally polarized beams in the same trap. We believe that this constitutes the first demonstration of a vector holographic optical trap (HOT), extending the functionality of previous scalar HOTs.

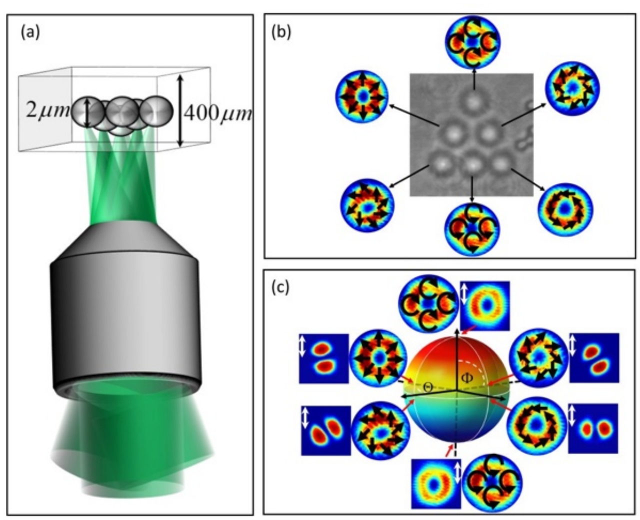

Fig. 1. An example of a vector holographic trap for the delivery of scalar and vector beams.

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