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Enhancing the Robustness of Structured Light Communication via Skyrme Number in Complex Medium

Structured light, owing to its ability to carry orbital angular momentum (OAM) as an additional degree of freedom for information encoding, has attracted significant attention in optical communication and information processing. However, in practical applications, the helical phase structure of structured light is inevitably distorted by turbulence effects during propagation through complex medium, leading to a significant decline in the accuracy of OAM mode recognition and subsequent information loss. In this study, we propose a robustness-enhancing scheme based on the Skyrme number to improve mode recognition accuracy in turbulent environments. We further experimentally validate the feasibility of this approach by transmitting vector beams through turbulence simulated by a digital micromirror device (DMD) multiple times. The experimental results demonstrate that, even after three turbulence-induced distortions, the Skyrme number can still be accurately identified. These findings suggest that the Skyrme number, as a more resilient topological degree of freedom, provides a solid foundation for the development of large-scale, stable free-space optical communication systems.

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