Structured Light and Matter

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We discuss fundamental optical phenomena at the interface of singular optics (“structured light”) and metamaterials (“structured media”) [1], including theoretical and experimental studies of linear and nonlinear light-matter interactions of vector and singular optical beams in optical metamaterials. Understanding the physics of the interaction of complex beams with nanostructured “engineered” matter is likely to bring new dimensions to the science and applications of complex light, including novel regimes of spin-orbit interaction, extraordinary possibilities for dispersion engineering, and novel possibilities for nonlinear singular optics.

On the other hand, metamaterials emerge as a fundamentally new platform for studies of basic physics and applications of spin-related effects for electromagnetic waves at optical frequencies.

We report theoretical and experimental studies of linear and nonlinear interactions of complex light beams with orbital angular momentum with fiber-based magnetic and negative-index metamaterials [2]. Figure 1 shows measured intensity profile of the radially polarized vortex beam and interference patterns obtained by interfering this beam with a plane wave (b), resulting in a fork zebra-like (d) pattern and a spherical wave (c), resulting in a spiral pattern. Moreover, our initial theoretical studies predict that vortex-based nonlinear optical processes, such as second harmonic generation or parametric amplification that rely on phase matching, will also be strongly modified in negative index materials.

These studies could find applications for multidimensional information encoding, secure communications, and quantum cryptography as both spin and orbital angular momentum could be used to encode information; dispersion engineering for spontaneous parametric down-conversion; and on-chip optoelectronic signal processing.