P33

Controlled Generation of Bessel Beam Braids with Complex Topological Structure

Klemensas Laurinavičius[1]

[1]State Research Institute Center for Physical Sciences and Technology. Saulėtekio al. 3, Vilnius, Lithuania.

Email: Klemensas.laurinavicius@ftmc.lt

The controlled generation of structured light fields with complex topologies has become an important frontier in modern optics. Bessel beams provide a versatile platform due to their nondiffracting behavior and well-defined transverse structure [1]. In this work, we investigate the formation of Bessel beam braids - field configurations created through the superposition of multiple Bessel beams with carefully engineered cone angles and topological charge relationships. We develop a theoretical framework that describes how interference between constituent beams gives rise to braided intensity channels with robust propagation invariance. The influence of parameters such as topological charge combinations and cone angles is analyzed to determine their role in braid formation and controllability. Numerical simulations reveal a wide range of braid geometries, including helical, multi-strand, and dynamically evolving topologies, all maintaining nondiffracting characteristics over extended propagation distances. Our results demonstrate a practical route for generating and tailoring optical braids, opening opportunities for advanced optical manipulation, robust information encoding, and the study of topological phenomena in structured light fields [2].

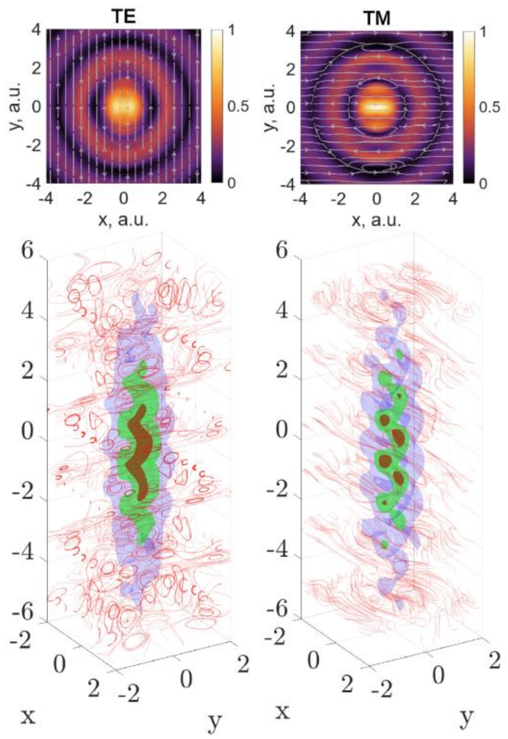

Fig. 1 Field distributions of transverse electric (TE, left) and transverse magnetic (TM, right) polarizations for a topological-charge pair $m_1 = 0$ and $m_2 = 1$.

From a theoretical standpoint, the rotation frequency is governed by the difference between the longitudinal propagation constants of the two contributing beams and by the number of strands composing the braid. The resulting axial phase difference grows linearly with propagation distance, producing a constant azimuthal rotation rate of the interference pattern. This rotation is distributed among the $N_{braids} = \Delta m$ intensity strands, yielding a characteristic braid rotation speed that depends only on the cone angle difference $\Delta\theta$ and the topological charge difference Δm.

REFERENCES

[1] P. Saari and H. Sonajalg. Pulsed bessel beams. Laser Physics, 7(1):32–39, 1997.
[2] Gabrielius Kontenis, Darius Gailevičius, Vytautas Jukna, and Kestutis Staliūnas. Terahertz rate rotating helical intensity beams. Optics & Laser Technology, 182:112036, 2025.