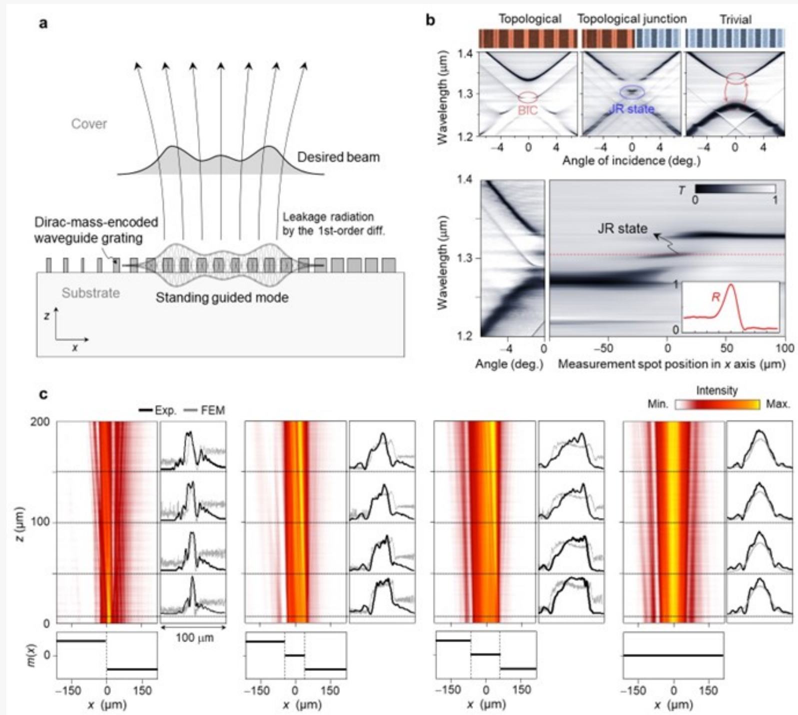
Topological beaming of light: A new approach to precision beam shaping

GA, UNITED STATES, March 13, 2025 /EINPresswire.com/ -- A novel approach to optical beam shaping based on topological physics effect experimentally demonstrated for the first time. By fabricating thin-film dielectric structures with precisely engineered properties, this new technique allows systematic control over beam profiles as opposed to conventional approaches involving tedious numerical optimization procedures. This experimental realization establishes an innovative mechanism for beam control rooted in topological physics and offers an efficient strategy for nanophotonic design, with applications ranging from optical communications to quantum technologies.



Optical beam shaping by a topological effect

Precise control and shaping of light beams are crucial for a wide range of applications, including laser machining, laser therapy, optical communications, and emerging quantum technologies. Traditionally, beam shaping has relied on optical elements such as refractive and diffractive optical elements and spatial light modulators. Although these methods are effective, they generally involve heuristic optimization algorithms, substantially limiting their adaptability particularly for intricate nanophotonic structures.

In a new paper published in The Light: Science & Applications, a team of scientists led by Jae Woong Yoon and Yu Sung Choi from the Department of Physics at Hanyang University in South Korea has experimentally demonstrated a novel approach to topological beam shaping using Jackiw-Rebbi states on metasurfaces.

"Our approach fundamentally differs from traditional beam shaping methods," Professor Yoon explains. "Instead of relying on complex optimization algorithms, we leverage principles from topological physics to create precisely controlled beam profiles in a systematic and efficient manner."

The researchers fabricated thin-film dielectric structures with engineered Dirac-mass distributions, creating domain walls that allow precise control over beam profiles. Their experimental results confirmed the emergence of Jackiw-Rebbi states and their localized characteristics. Most notably, they achieved a flat-top beam profile by locally tailoring the Dirac-mass distribution, highlighting the potential of this method for customized beam shaping.

"A particularly exciting achievement was our demonstration of flat-top beam profiles with controlled widths," Yu Sung Choi, one of the lead authors of the study, says. "This is just one example of many possible beam shapes we can create. Our approach offers versatility for a wide range of applications requiring specialized beam profiles, from Gaussian to flat-top and potentially more complex distributions."

The experimental realization establishes this approach as a new mechanism for beam control, rooted in topological physics, and offers an efficient strategy for nanophotonic design. The researchers note that while their current implementation shows good agreement with theoretical predictions, they've identified an improved method for further development using compound unit-cell structures.

This breakthrough has significant implications for various fields that rely on precise light manipulation, from telecommunications to quantum computing. The method enables the creation of customized beam shapes without complex optimization procedures, potentially accelerating the development of advanced photonic devices.

DOI
10.1038/s41377-025-01799-w

Original Source URL
https://doi.org/10.1038/s41377-025-01799-w

Funding information
This research was supported by the Leader Researcher Program (NRF-2019R1A3B2068083), The National Research Facilities and Equipment Center (NFEC) at the Ministry of Science and ICT, and the quantum computing technology development program of the Quantum Information Research Support Center, funded through the National research foundation of Korea.

Lucy Wang
BioDesign Research
email us here