Compact coherent perfect absorbers based on topological mode-matching method using Jackiw-Rebbi states in metasurfaces

Chan Young Park, Jae Woong Yoon*
Department of Physics, Hanyang University, Seoul, 133-791, Korea
*yoonjw@hanyang.ac.kr

In a resonant system with a lossy medium, electromagnetic radiation field can be completely annihilated by appropriately designing structure geometry and coherent incident-waveform configuration. Such devices, known as coherent perfect absorbers, enable efficient phase-sensitive optical modulation between coherent perfect absorption (CPA) and coherent total scattering (CTS). Toward this end, guided-mode resonance (GMR) absorbers [1] have been studied due to structural simplicity, tunable operational bandwidth, and adjustable Q-factor, but conventional GMR-CPA devices require extremely uniform nanostructures (~1 mm²) and plane-wave-like illumination. Here, as an efficient solution to this problem, we propose a GMR CPA-device structure based on a photonic Jackiw-Rebbi (JR) state at a junction of two topologically distinguished GMR gratings, allowing efficient mode-matching to incident Gaussian beams [2]. Figure 1 shows our topological GMR CPA device's field distribution and performance, compared to a conventional GMR device. With two 14-μm-wide Gaussian beams incident on optimized amorphous-Si (α-Si) structures, conventional GMR achieves incomplete CPA (~50% absorptance), whereas topological-junction GMR structure exhibits no in-plane leakage, achieving improved absorptance (~80%) due to enhanced mode confinement.

An essential condition for ideal CPA is configuring coherent incident beams as exact time-reversals of leakage radiation from localized modes. As demonstrated in Fig. 2, tuning cell-by-cell parameters (e.g., fill factor, period) enables matching leakage radiation profiles $f_{\mathrm{leak}}(x)$ determined by Dirac-mass distributions $m(x)$ to desired incident beam profiles $f_{\mathrm{inc}}(x)$. Consequently, under 10-μm Gaussian-beam illumination, a 30-μm-wide CPA device achieves near-ideal CPA and CTS switching (99% and 1.7% absorptance, respectively), enabled by tight lateral confinement of the JR state and adaptive Dirac-mass shaping.

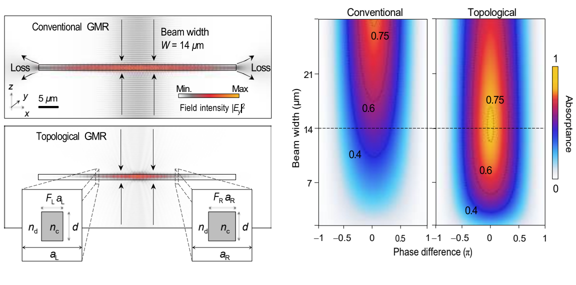

Fig. 1. Concept of a topological GMR CPA device.

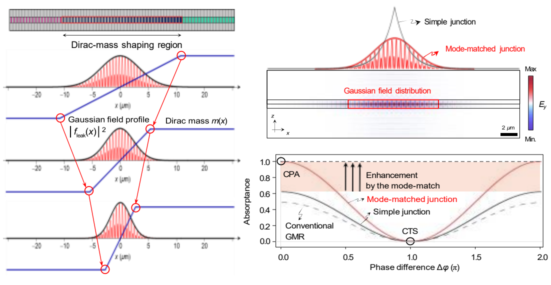

Fig. 2. Topological mode-matching to a Gaussian beam.

This work was supported by the Leader Researcher Program (NRF-2019R1A3B2068083).

References

1. Giese, J. A. et al. Guided-mode resonant coherent light absorbers" Opt. Letters, 39(3), 486–488 (2014).
2. Lee. Ki Young, et al. "Topological beaming of light" Science Advances, 8(49), eadd8349 (2022).