NEWS AND VIEWS

Journal of Semiconductors
(2022) 43, 050401
doi: 10.1088/1674-4926/43/5/050401

Breaking the symmetry of polarizers

Chengwei Qiu†

Department of Electrical and Computer Engineering, National University of Singapore, Singapore 117583, Singapore

Citation: C W Qiu, Breaking the symmetry of polarizers[J]. *J. Semicond.*, 2022, 43(5), 050401. https://doi.org/10.1088/1674-4926/43/5/050401

In recent years, the properties of parity-time (PT) symmetric system are revealed to realize plenty of counterintuitive phenomena[1]. In particular, encircling the exceptional point (EP) in a PT symmetric system for asymmetric mode switching has caught people's eyes because of its potential in the design of chiral devices. In photonic systems, the dynamical variation of parameters along a loop around an EP was usually realized along the propagation direction of light in the waveguides for asymmetry mode switching[2–5]. This chiral dynamic gives out a novel method for optical mode controlling.

In the field of polarization manipulation, encircling EP for asymmetric polarization switching has already been theoretically verified by Absar U. Hassan and his colleagues[6]. Moreover, they supposed that this phenomenon can be used to realize an optical omnipolarizer and demonstrated a prototype theoretically, in which the parameters variation around EP was supposed to be realized by changing the width of a waveguide with slanted sidewall. As shown in Fig. 1(a), different from a conventional polarizer, the proposed omnipolarizer will rotate the orthogonal polarization state to the transmission axis, and exhibit different transmission axes for forward and backward propagation. This work lays the theoretical foundation of chiral polarization switching. After that, this concept of omnipolarizer has been experimentally demonstrated by Lopez-Galmiche *et al.* based on fiber circuit[7] in 2020. The adjustment of system parameters was realized by making use of the birefringence of modulator. In 2021, Khurgin *et al.* also implemented this omnipolarizer based on spatial optical elements[8]. The encircling EP evolution was realized by adjusting the waveplates and optical attenuators. These successes provide a novel method for polarization manipulation, and encourage people to further exploit the potential of asymmetric polarization switching. Nowadays, integrated photonic system rapidly rises up to be one of the most popular platforms for fields like optical communication[9], calculation[10] and neural network[11]. As a result, it is worthy to find out the on-chip implement of this concept for on-chip polarization manipulation.

Recently, Wei and his colleagues reported on a breakthrough of the asymmetric polarization switching in an anti-PT symmetric system, and applied this phenomenon as an on-chip chiral polarizer[12]. The research group makes use of the asymmetric property of the initiating state in the anti-PT symmetric system[13] (Fig. 1(b)) to realize the chiral switching between TE and TM modes. Moreover, a communication experiment is performed to demonstrate the function of polarization formatting using this chiral polarizer, in which the data encoded on polarization can be formatted into particular states dependent on propagation direction. This work expands the chiral polarization switching to the field of integrated optical system, and apply it in an optical communication experiment.

Considering the rapid development of the future research of PT/anti-PT symmetric systems, as well as the on-chip applied optical systems, the chiral devices could play a significant role. We believe that these chiral polarizers could provide a new method for on-chip polarization manipulation, and trigger a boost on the application of asymmetric mode switching based on encircling EP in PT/anti-PT symmetric systems.

References

[1] Özdemir Ş K, Rotter S, Nori F, et al. Parity–time symmetry and exceptional points in photonics. Nat Mater, 2019, 18, 783

[2] Doppler J, Mailybaev A A, Böhm J, et al. Dynamically encircling an exceptional point for asymmetric mode switching. Nature, 2016, 537, 76

[3] Yoon J W, Choi Y, Hahn C, et al. Time-asymmetric loop around an exceptional point over the full optical communications band. Nature, 2018, 562, 86

[4] Liu Q J, Li S Y, Wang B, et al. Efficient mode transfer on a compact silicon chip by encircling moving exceptional points. Phys Rev Lett, 2020, 124, 153903

[5] Li A D, Dong J J, Wang J, et al. Hamiltonian hopping for efficient chiral mode switching in encircling exceptional points. Phys Rev Lett, 2020, 125, 187403

[6] Hassan A U, Zhen B, Soljačić M, et al. Dynamically encircling exceptional points: Exact evolution and polarization state conversion. Phys Rev Lett, 2017, 118, 093002

[7] Lopez-Galmiche G, Lopez Aviles H E, Hassan A U, et al. Omnipolarizer action via encirclement of exceptional points. Conference on Lasers and Electro-Optics, 2020, FM1A.3

[8] Khurgin J B, Sebbag Y, Edrei E, et al. Emulating exceptional-point encirclements using imperfect (leaky) photonic components: Asymmetric mode-switching and omni-polarizer action. Optica, 2021, 8, 563

[9] Sun S H, He M B, Xu M Y, et al. Hybrid silicon and lithium niobate modulator. IEEE J Sel Top Quantum Electron, 2021, 27, 1

[10] Zhou H L, Zhao Y H, Xu G X, et al. Chip-scale optical matrix computation for PageRank algorithm. IEEE J Sel Top Quantum Electron, 2020, 26, 1

[11] Shen Y, Harris N C, Skirlo S, et al. Deep learning with coherent nanophotonic circuits. Nat Photonics, 2017, 11, 441

[12] Wei Y X, Zhou H L, Chen Y T, et al. Anti-parity-time symmetry en-

Correspondence to: C W Qiu, chengwei.qiu@nus.edu.sg
Received 4 MARCH 2022.

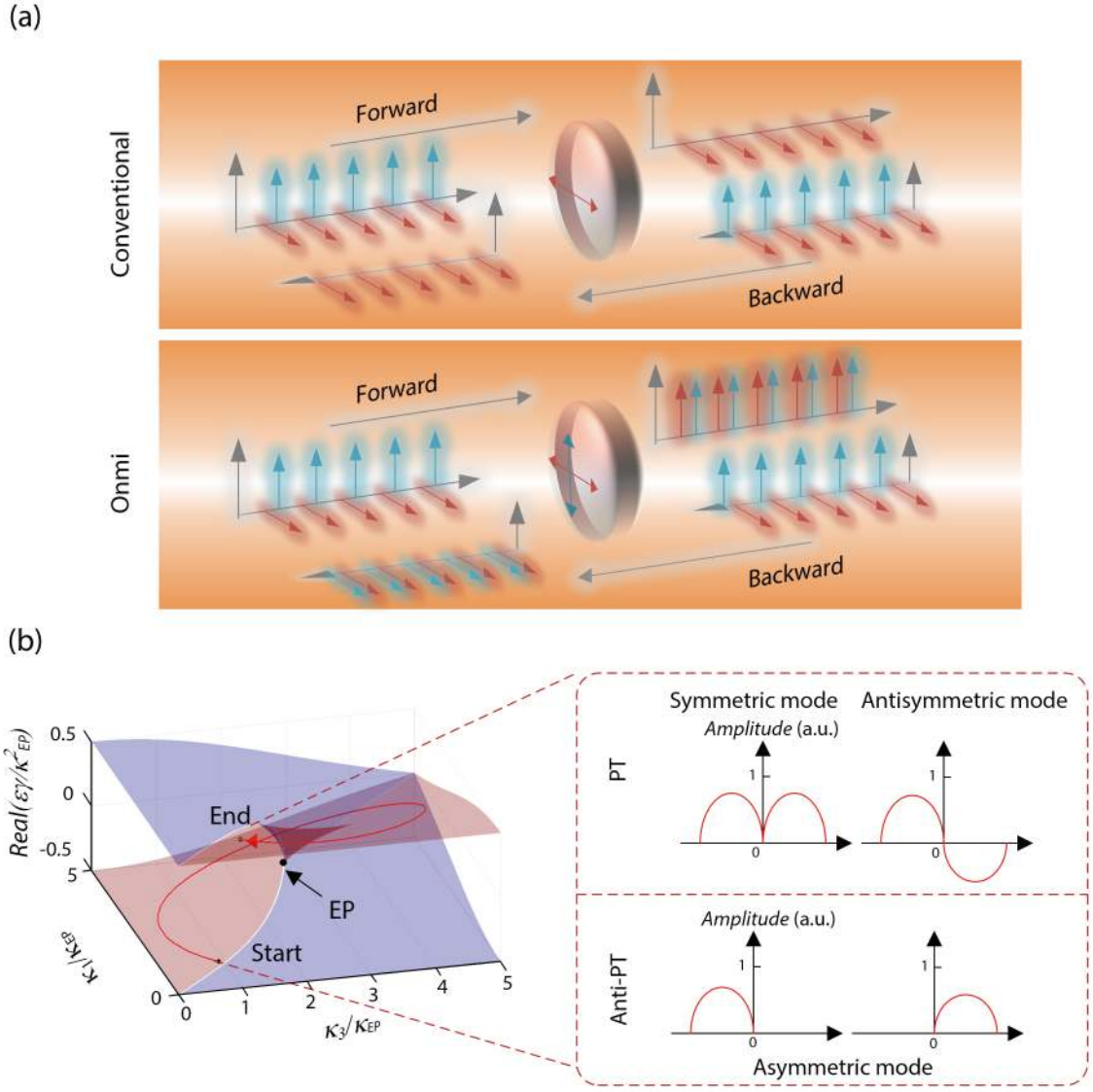

Fig. 1. (Color online) (a) The difference of mode distribution between PT symmetric and anti-PT symmetric system. (b) The compare between conventional polarizer and chiral polarizer.

abled on-chip chiral polarizer. Photon Res, 2021, 10, 76

[13] Zhang X L, Jiang T, Chan C T. Dynamically encircling an exceptional point in anti-parity-time symmetric systems: Asymmetric mode switching for symmetry-broken modes. Light Sci Appl, 2019, 8, 88

Chengwei Qiu currently holds Dean's Chair Professor in National University of Singapore. He has received many awards like MIT TR35@Singapore Award, Young Scientist Award by Singapore National Academy of Science, Faculty Young Research Award in NUS, SPIE Rising Researcher Award, Young Engineering Research Award, Engineering Researcher Award in NUS, World Scientific Medal by Institute of Physics, Singapore, etc. He is known for metasurfacess and optical manipulation. He has published over 380 peer-reviewed journal papers. He was Highly Cited Researchers in 2019, 2020, 2021 by Web of Science, and a Fellow of The Electromagnetics Academy, US. He has been serving in Associate Editor for various journals such as JOSA B, PhotoniX, Photonics Research, and Editor-in-Chief for eLight. He is in Editorial Advisory Board for Laser and Photonics Review, Advanced Optical Materials, and ACS Photonics.