Parity-Time (PT) Symmetric Photonics

Objective

Optical systems with balanced loss and gain provide a unique platform to implement classical analogues of quantum systems described by non-Hermitian parity–time (PT)-symmetric Hamiltonians. Such systems can be used to create synthetic materials with properties that cannot be attained in materials having only loss or only gain. Our results could lead to a new generation of synthetic optical systems enabling on-chip manipulation and control of light propagation.

Summary of Research Activities

We report PT-symmetry breaking in coupled optical resonators. We observed non-reciprocity in the PT-symmetry-breaking phase due to strong field localization, which significantly enhances nonlinearity. We show [1] that in one direction there is a complete absence of resonance peaks whereas in the other direction the transmission is resonantly enhanced. Our results [1] could lead to a new generation of synthetic optical systems enabling on-chip manipulation and control of light propagation.

We show [2] how to turn losses into gain by steering the parameters of a system to the vicinity of an exceptional point (EP), which occurs when the eigenvalues and the corresponding eigenstates of a system coalesce. In our system of coupled microresonators, EPs are manifested as the loss-induced suppression and revival of lasing. Below a critical value, adding loss annihilates an existing Raman laser. Beyond this critical threshold, lasing recovers despite the increasing loss, in stark contrast to what would be expected from conventional laser theory. Our results exemplify the counterintuitive features of EPs and present an innovative method for reversing the effect of loss. We also studied electromagnetically induced transparency in whispering-gallery microcavities [3] and PT-Symmetric phonon lasers [4].

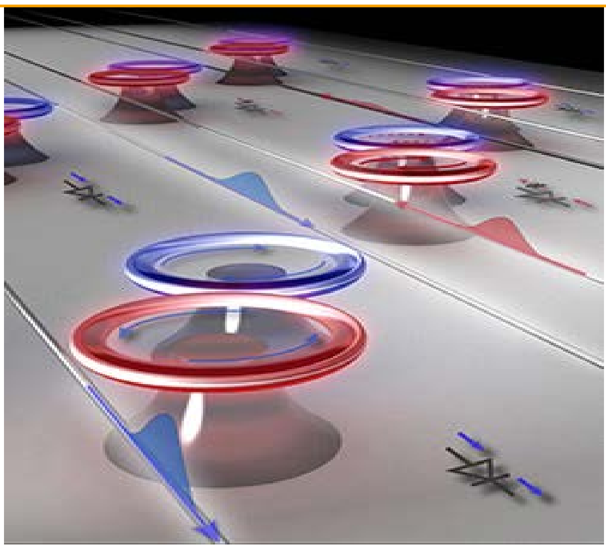

Fig. 1: Our optical diode enables on-chip control of light propagation [1].

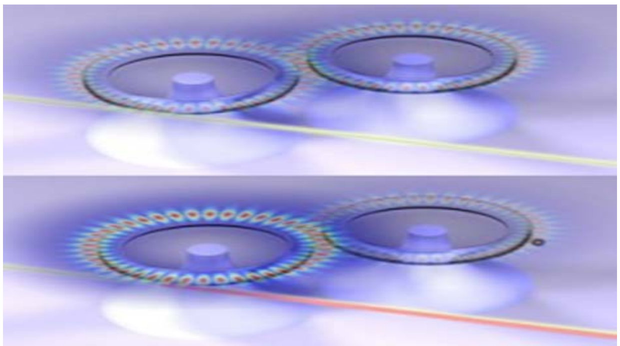

Fig. 2: Extraordinary lasing by increasing energy loss. [2]

Publications

[1] B. Peng, S. K. Ozdemir, F. Lei, F. Monifi, M. Gianfreda, G. L. Long, S. Fan, F. Nori, C. M. Bender, L. Yang, “Parity-time-symmetric whispering-gallery microcavities”, Nature Physics 10, 394-398 (2014). Featured in a Nature Physics "News & Views". Listed as Highly Cited.

[2] B. Peng, S. K. Ozdemir, S. Rotter, H. Yilmaz, M. Liertzer, F. Monifi, C. M. Bender, F. Nori, L. Yang, “Loss-induced suppression and revival of lasing”, Science 346, 328-332 (2014). Featured in a "Perspective" Science 346, 304 (2014).

[3] B. Peng, S.K. Ozdemir, W. Chen, F. Nori, L. Yang, “What is and what is not electromagnetically induced transparency in whispering-gallery microcavities”, Nature Communications 5, 5082 (2014).

[4] H. Jing, S.K. Ozdemir, X.Y. Lu, J. Zhang, L. Yang, F. Nori, PT-Symmetric Phonon Laser, Phys. Rev. Lett. 113, 053604 (2014).