

Non-Hermitian Photonics: Parity-Time Symmetry and Exceptional Points

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Abstract:

Whispering-Gallery- Mode (WGM) microresonators have emerged as excellent platforms for exploring basic science and for fabricating functional devices. They have been used for sensing, cavity-QED, optomechanics, low threshold lasing, and most recently for the realization of parity-time (PT) symmetry in optics. Waveguide coupled WGM microresonators represent open physical systems due to optical losses originating from absorption, coupling and radiation, and thus they are characterized by non-Hermitian Hamiltonians. As is the case for any non-Hermitian system, if the system parameters are steered, the WGM-microresonator system can be brought to an exceptional point (EP), which is a non-Hermitian degeneracy at which complex eigenvalues and the corresponding eigenstates of a physical system coalesce. The presence of an EP affects the system significantly, leading to nontrivial physics with interesting counterintuitive features.

In this talk, I will report and discuss the control of optical processes and the flow of light in WGM microresonators by operating them in the vicinity of EPs. I will first show parity-time (PT) symmetry and its breaking in coupled WGM resonators with balanced loss and gain, and then discuss how this system can be utilized for nonlinearity-based nonreciprocal light transmission when it is operated in the broken-PT phase [1]. Next, I will show that modulating the loss contrast between two lossy WGM microresonators can bring the system to an EP which then leads to the counterintuitive observation of loss-induced suppression and revival of optical nonlinearities and lasing [2]. Finally, I will report on dynamical control of the chirality of optical modes of a waveguide-coupled WGM resonator and the emission direction of a WGM microlaser in the vicinity of EPs [3]. I will end the talk discussing some of the the opportunities and challenges in the WGM research, in particular within the framework of exceptional points and PT-symmetry.

[1] B. Peng et al., Parity-time- symmetric whispering-gallery microcavities. *Nat. Phys.* 10, 394-398 (2014).

[2] B. Peng et al., Loss-induced suppression and revival of lasing. *Science* 346, 328 (2014).

[3] B. Peng et al., Chiral modes and directional lasing at exceptional points. *Proc. Natl. Acad. Sci. USA* 113, 6845 (2016).