Exceptional Points in Lasing Systems: From Loss-Induced Lasing to Laser Mode Braiding

L Yang[1]

[1] *Department of Electrical & Systems Engineering, Washington University in St. Louis, One Brookings Drive, Campus Box 1042, Green Hall 1101, St. Louis MO, USA. Contact Phone: +13149359543*
Contact Email: yang@seas.wustl.edu

In the past years, various interesting phenomena have been demonstrated in laser systems operated at or around exceptional points (EPs), non-Hermitian degeneracies at which both eigenvalues and eigenvectors coalesce. Initially regarded as mathematical singularities of open systems, EPs are now recognized as practical resources for engineering laser dynamics and uncovering new regimes of light generation. In this talk, I will review a series of experiments demonstrating how exceptional points can fundamentally reshape laser behavior. I will begin with the observation of loss-induced lasing [1], where increasing loss drives a system through an exceptional point, redistributing optical power and restoring laser emission. I will then discuss the chiral nature of exceptional points and its manifestation in whispering-gallery-mode lasers, giving rise to directional laser emission [2].

Next, I will present studies revealing how laser linewidth evolves in the vicinity of exceptional points, highlighting the influence of non-Hermitian singularities on the coherence properties of laser systems [3]. Finally, I will describe our recent realization of laser mode braiding in a programmable chip-scale platform based on coupled self-injection-locked lasers [4]. By controlling gain and frequency detuning, the system can be guided around multiple exceptional points, generating topological braids that are directly visualized through the laser output spectrum. This approach enables the observation of linked and knotted eigenvalue trajectories, including Hopf links, trefoil knots, and Solomon links, transforming abstract topological structures into measurable physical phenomena. Together, these results illustrate how exceptional points have evolved from fundamental concepts in non-Hermitian physics into versatile tools for controlling, visualizing, and exploiting complex laser dynamics. They establish laser systems as a unique platform for exploring the interplay of topology, dissipation, and light generation in modern photonics.

References

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