Perfectly absorbing exceptional points

William R. Sweeney,1 Chia-Wei Hsu,1 Stefan Rotter,2 and A. Douglas Stone1

1Department of Applied Physics and Yale Quantum Institute,
Yale University, New Haven, CT 06520, USA
2Institute for Theoretical Physics, Vienna University of Technology (TU Wien), Vienna A-1040

It is well known that hermitian operators have a complete, orthogonal set of eigenvectors, even when some eigenvalues are degenerate. This is not true for non-hermitian operators, where degeneracy is generally accompanied by a coalescence of eigenvectors. The set of parameters at which this happens is called an exceptional point (EP). For physicists, EPs are relevant for open physical systems, or those with gain or loss. It is therefore a feature that can be leveraged in modern photonic designs with engineerable non-hermitian elements. At an EP of resonances, the lineshape is modified, and the parametric dependence of the resonances acquires a universal, nontrivial topology (right panel in figure). These qualities make resonant EPs interesting for many reasons, such as robust non-reciprocal state transfer, enhanced sensitivity to small perturbations, and inducing chirality of lasing and scattering in an otherwise non-chiral disk resonator. However, due to overall loss, they cannot be directly accessed in steady-state. The addition of gain can remedy this, at the cost of adding noise.

We identify a new kind of EP, degenerate coherent perfect absorption (CPA), which is steady-state, and can occur without any associated noise. Its absorption peak is flatter than for ordinary CPA, and can be used generally to broaden resonant absorption. Another application, analogous to chiral lasing for a resonant EP disk, is chirally-dependent absorption, which couples propagation direction to loss modality (radiative vs dissipative).

We also demonstrate a little-known property of wave-operator EPs: they are not self-orthogonal. The eigenvector of a finite-dimensional symmetric matrix at EP is in a sense orthogonal to itself, and it is often assumed that this generalizes to infinite-dimensional operators, such as the wave-operators of physics. We find that this is not the case.