Parity-time-symmetric waveguides with a chiral gap

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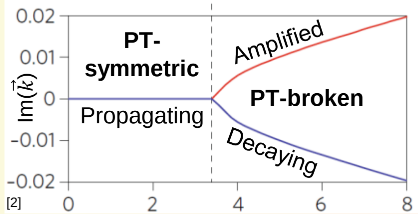
Abbreviated abstract: Chiral sensing is highly researched due to its applications and can be enhanced by Parity-Time (PT) symmetry in a scattering scheme. [1] PT-symmetry can be obtained in coupled waveguides with balanced gain and loss. [2] We numerically study how PT guided modes are impacted by inserting a chiral material in the gap between the waveguides. We observe a strong chiral impact at degeneracies, with various avoided crossings depending on the nature of the interacting modes. Additionally, we extend the existing coupling equations model to include chiral couplings.

Related publications: (up to 2 references)
[1] M. Picardi et al, Phys. Rev. Lett. (120), 117402 (2018)
[2] L. Feng et al, Nat. Photonics (11), 752-762 (2017)

Concepts

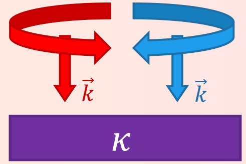
PT-symmetry in coupled waveguides:



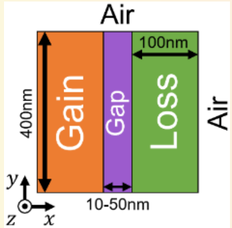
Material chirality: contrast between RCP and LCP

Chiral

$$D = \varepsilon E - i\frac{\kappa}{c}H$$
$$B = \mu H + i\frac{\kappa}{c}E$$



Structure simulation

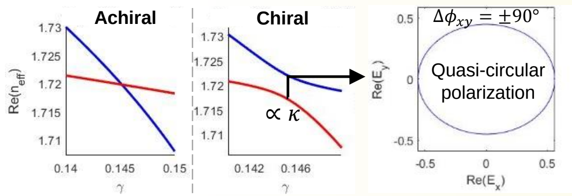


- PT-symmetric 2D waveguides: $n = 2 - i\gamma$ or $2 + i\gamma$
- Gap: achiral or chiral material, variable size
- Finite element method:
  SimPhotonics, developed at Lab. Charles Fabry

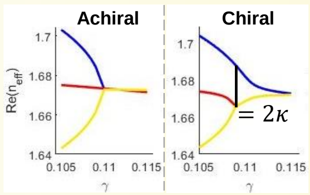
bePOM

Results

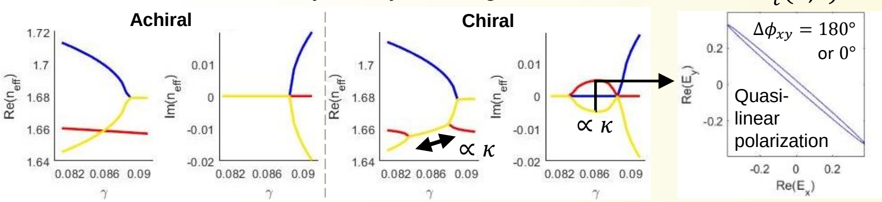
Small gap: TE_{sym}- TM_{sym} crossing
⇒ Chiral anticrossing



Medium gap: crossing at TE EP
⇒ Chiral trimodal anticrossing



Large gap: achiral TE_{anti}-TM_{sym} crossing
⇒ Chiral local symmetry breaking

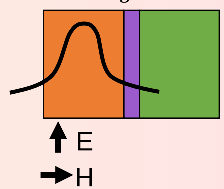


Chiral coupled-mode model

For isolated waveguide modes:

$$\frac{i}{k_0}\frac{d}{dz}\begin{pmatrix}TE_g\\TE_l\\TM_g\\TM_l\end{pmatrix} = \begin{pmatrix} n_{TE}-i\gamma & C_{TE} & \beta & \alpha \\ C_{TE} & n_{TE}+i\gamma & \alpha & \beta \\ \beta^* & \alpha^* & n_{TM}-i\gamma & C_{TM} \\ \alpha^* & \beta^* & C_{TM} & n_{TM}+i\gamma \end{pmatrix}\begin{pmatrix}TE_g\\TE_l\\TM_g\\TM_l\end{pmatrix}$$

Ex: TE_g



C = classical coupling, α, β=chiral couplings

All simulated **avoided crossings** are **recreated with the model**.

Conclusion

- Chirality induces various avoided crossings at TE-TM degeneracy.
- Chiral coupled-mode model gives insight on the interactions at work.

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Acknowledgment