

Engineering Non-Hermitian States of Light in Photonic Crystals: From Fundamentals to Applications

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Tailoring resonances has always been at heart of modern photonics: nurturing photons for cavity-quantum electrodynamics, minimizing attenuation of guided light in integrated circuit and optical fiber, sharpening photonic resonances for low-threshold lasing and high-sensitivity optical sensing, engineering emission pattern of light-emitting diodes via radiation-mode out-coupling, to cite a few examples. Most photonic resonances are dictated by the complex energy-momentum dispersion characteristic of which the imaginary-part corresponds to system losses and the real-part corresponds to light frequency.

In this tutorial, we will discuss different novel concepts to harness the complex dispersion characteristics of photonic resonances in sub-wavelength scale via molding periodic arrangement of materials with different permittivity and geometry. To illustrate the engineering of the real-part, we show that the same photonic band can transform continuously from Dirac dispersion to flatband in a simple photonic structure, or undergo a series of magic flatband configurations in moiré superlattice. Moreover, when taking into account the losses in open system, the complex energy-momentum dispersions, theoretically described by non-Hermitian Hamiltonians, reveal unique features with no Hermitian counterparts such as the complex degeneracy at exceptional points, and the destructive interference of losses at bound states in the continuum. All of these concepts will be illustrated by experimental demonstrations in various platforms (III-V nanophotonics, perovskite metasurface, silicon photonics . . .) with different photonic species (dielectric guided resonances, Bloch surface waves, Tamm plasmon, exciton polaritons . . .). Finally, for applications, we will present some proof-of-concepts of original micro-lasers and optical trappings based-on non-Hermitian singularity.

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[3] *Unveiling the Enhancement of Spontaneous Emission at Exceptional Points*, PRL **129**, 083602 (2022)

[4] *Taming Friedrich-Wintgen interference in resonant metasurface: vortex laser emitting at on-demand tilted-angle*, Nano Letters **23**, 10, 4152–4159 (2023)

[5] *Super Bound States in the Continuum on Photonic Flatbands: Concept, Experimental Realization, and Optical Trapping Demonstration*, arXiv:1905.00215