# 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 [1,2,3]. 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 [4]. 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 polartions…). Finally, for applications, we will present some proof-of-concepts of original micro-lasers [5,6] and optical trappings based-on non-Hermitian singularity [7].

[1] Symmetry breaking in photonic crystals: On-demand dispersion from flatband to Dirac cones, **Physical Review Letters** 120 (6), 066102 (2018)

[2] Magic configurations in moiré superlattice of bilayer photonic crystals: Almost-perfect flatbands, and unconventional localization, **Physical Review Research** 4, L032031 (2022)

[3] *Tailoring Flatband Dispersion in Bilayer Moiré Photonic Crystals,* **Laser & Photonics Review** e01038(2025)

[4] *Unveiling the Enhancement of Spontaneous Emission at Exceptional Points,* **Physical Review Letters** 129, 083602 (2022)

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

[6] *Room-Temperature Lasing at Flatband Bound States in the Continuum,* **ACS Nano** 19, 20, 19287–19296 (2025)

[7] *Super Bound States in the Continuum on Photonic Flatbands: Concept, Experimental Realization, and Optical Trapping Demonstration,* **Physical Review Letters**