

Decay-Free Light Radiation from Photonic Grating Enabled by Exceptional Points

Alexander Yulaev,^{1,2} Sangsik Kim,³ Qing Li,⁴ Daron A. Westly,¹ Brian J. Roxworthy,^{1*} Kartik Srinivasan,¹ and Vladimir Aksyuk¹
yulaev@umd.edu

¹*Physical Measurement Laboratory, National Institute of Standards and Technology, Gaithersburg, MD 20899*

²*Department of Chemistry and Biochemistry, University of Maryland, College Park, MD 20742*

³*Department of Electrical and Computer Engineering, Texas Tech University, Lubbock, TX 79409*

⁴*Department of Electrical and Computer Engineering, Carnegie Mellon University, Pittsburgh, PA 15213*

Exceptional points (EPs) observed in non-Hermitian systems where complex eigenvalues become degenerate lead to many unconventional physical phenomena. Recently, EPs have been observed in band diagrams of photonic grating couplers. Here we report a carefully tuned periodic photonic grating with $\approx 50\%$ duty cycle (DC) that projects a decay-free light beam in free space when operating between EPs. This constant-intensity radiated beam can be understood as the uniformly distributed energy loss by the photonic mode entering the grating from one end and propagating across its length. We use the finite element method (FEM) and a coupled-mode theory (CMT) to explain the experimental results.

Figure 1a depicts the fabricated 50% DC photonic grating with an overlaid schematic showing the slab mode propagation. The corresponding band diagram analysis using FEM of infinitely long grating structure demonstrates two EPs where the two modes coalesce and acquire equal complex eigenfrequencies (Figure 1b). When the DC is detuned from 50%, a band gap appears between two modes removing observed degeneracy. The 180 μm long grating is fabricated of SiN_x slab clad in SiO_2 from both sides and is excited from one side (Figure 1c) at the EP frequency. Experimentally observed free-space beam projected from the grating is surface normal and shows no decay in intensity profile till the grating end (Figure 1d).

In summary, we find that tuning operation between EPs in 50% DC photonic grating results in a linear loss of the photonic mode unidirectionally propagating across the device and a decay-free intensity profile of the radiation. The observed unique phenomenon is enabled by exceptional point physics and paves the way for dispersion engineering for generating top-hat light beams.

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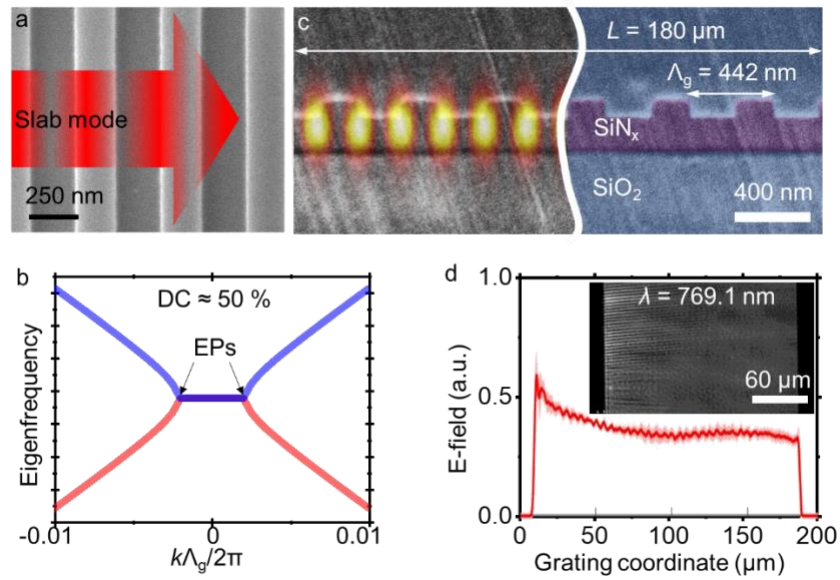


Figure 1: 50 % Photonic grating projecting a decay-free light beam tuned between EPs in the band diagram. a. Scanning electron microscopy image depicting the 50 % grating structure overlaid with a slab mode schematic. b. A band diagram of the 50 % DC photonic grating depicting EPs. c. Cross section SEM of the device and a color map of simulated grating mode tuned between EPs in the band diagram. d. Integrated constant-intensity light profile of the radiated beam outcoupled from the 180 μm long 50 % DC grating based on the experimentally observed free-space light (inset).