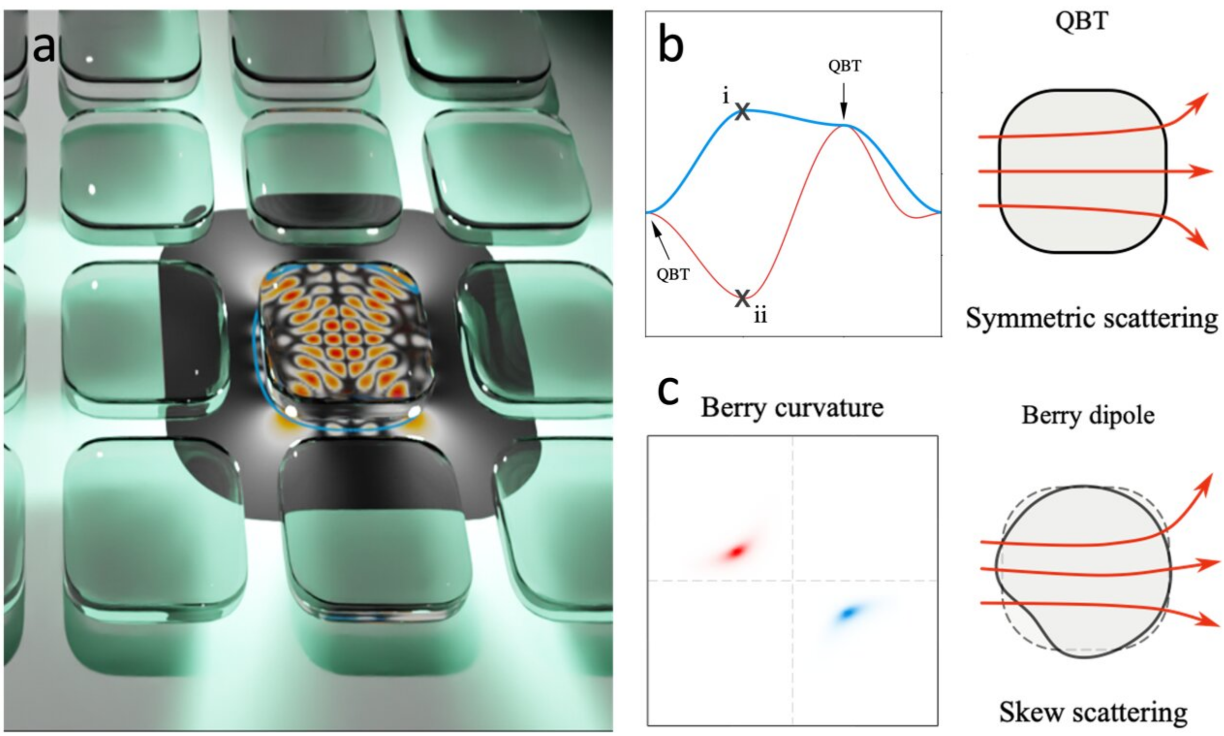
Breakthrough in dynamical localization transitions and Berry curvature-induced transport

May 9 2023



a, Conceptual illustration of a photonic crystal consisting of deformed dielectric microcavities. b, Energy bands as a function of the crystalline momentum (k_x,k_y) for a fixed cavity deformation ε = 0.05, including Quadradic Band Touching (QBT). Cross points (X) i and ii indicate the even parity mode (ψ_E) in a unit-cell for (k_x,k_y)=(π,0) and the odd parity mode (ψ_O), respectively. The right schematic illustration shows the symmetric scattering of light in the original C_4-symmetric boundary with QBT. c Distribution of non-zero Berry curvature in the momentum space induced by scar states in the C_4-breaking boundary. C_4-breaking boundary perturbation splits the single QBT into a pair of Dirac cones. Subsequently, C_2-breaking boundary perturbation gaps out the Dirac cones and induces the Berry curvature dipole. The Berry curvature dipole induces the skew scattering depending on the incident momentum, kinc, as shown in the right schematic illustration. Credit: by Chang-Hwan Yi, Hee Chul Park, and Moon Jip Park

The way light moves around inside an optical microcavity provides an exciting opportunity to explore the connection between classical and quantum physics. This field of research is known as quantum chaos, and it has the potential to spawn many new technologies that bridge the gap between these two fundamental branches of physics.

But even more fascinating is that the strange and unpredictable behavior we observe in microcavities is quite similar to what we see in many other chaotic physical systems, like atoms, quantum dots, and even large groups of particles. Studying the topological properties of microcavities can give us valuable insights into the behavior of different chaotic systems, helping us better understand the universe we live in.

In a new paper published in *Light: Science & Applications*, a team of scientists led by Dr. Chang-Hwan Yi from the Center for Theoretical Physics of Complex Systems, Institute for Basic Science (IBS), Republic of Korea, Prof. Hee Chul Park from the Department of Physics, Pukyong National University (PKNU), Republic of Korea, and Prof. Moon Jip Park from the Department of Physics, Hanyang University (HYU), Republic of Korea has made a significant breakthrough in the field of wave chaos research. Their recent study unveils a new platform for studying dynamical localization transitions in periodic cavity arrays. The research team explored the wave chaos of deformed optical microcavities coupled to crystalline momentum in a periodic cavity array, i.e., scar-momentum locking.

By controlling the crystalline momentum, they observed dynamical localization transitions and found that the Bloch momentum can substitute the role of boundary shape deformation. The team also proposed the possibility of realizing Berry curvature-induced transport phenomena that utilize the intrinsic wave property of chaotic states. The crossover between Rayleigh and Mie regimes of Berry curvature-induced transport could pioneer a new aspect of wave-particle correspondence in wave chaos.

The recent breakthrough in studying wave chaos phenomena provides a valuable tool for manipulating the behavior of light waves in periodic structures. Dr. Chang-Hwan Yi notes, "Our work offers a new avenue for studying wave chaos phenomena and opens up possibilities for discoveries in the field."

With potential implications in quantum information and communication, as well as the development of new optoelectronic devices, this breakthrough could provide the way for future technological advancements. In addition, the study could lead to further exploration of crystal momentum-induced dynamical tunneling, expanding our understanding of wave chaos phenomena.

As the world continues to rely on new technologies, fundamental research breakthroughs like this offer a glimpse into new possibilities in science and engineering. The collaboration among IBS, PKNU, and HYU has provided a promising platform for exploring wave chaos phenomena and the properties of light waves.

More information: Chang-Hwan Yi et al, Bloch theorem dictated wave chaos in microcavity crystals, *Light: Science & Applications* (2023). DOI: 10.1038/s41377-023-01156-9

Provided by Light Publishing Center, Changchun Institute of Optics, Fine Mechanics And Physics, CAS