Usage Report for Fiscal Year 2021

Project Title:

Non-hermitian physics in photonic crystal cavity

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1. Background and purpose of the project, relationship of the project with other projects

Our group investigates the interaction between nanoscale light emitters – such as carbon nanotubes and 2D layered transition metal dichalcogenide – and photonic structures. In this project, we focus on the H1-type 2D planar air-holes photonic crystal cavity. Based on non-Hermitian interactions between the cavity modes, we aim to design a symmetry broken H1 photonic crystal cavity with an intrinsic chirality by modifying the parameters of the air holes near the cavity. The photonic cavity field of such a chiral structure is expected to support circular polarization. Such a structure will be useful for the investigation of chiral-light-matter coupling effects. In this fiscal year, we also started investigating the formation of a heterocavity by placing a flake of 2D material on a photonic crystal waveguide.

2. Specific usage status of the system and calculation method

Finite-difference time-domain (FDTD) simulations are performed on the supercomputer. The FDTD method is widely used for computational electromagnetics. In this method, space is divided into a discrete grid and the fields are evolved in time using discrete time steps when solving the Maxwell's equation. We make use of an open source FDTD package called MEEP [1]. The FDTD simulations can be split into a number of parts and the calculation for each part can be run in parallel, as such the supercomputer is ideal for performing fast parallel simulations.

3. Results & Conclusions

Based on the simulation results, we confirmed that by careful modifications of selected air holes in a H1 photonic crystal cavity, we could indeed obtain optical modes with intrinsic chirality which is characterized by the circular polarization of the optical fields. Also, we confirmed that high quality factor heterocavities can be formed by placing a flake of 2D material on a photonic crystal waveguide.

4. Schedule and prospect for the future

We are currently preparing the H1 photonic crystal samples as well as the photonic crystal waveguide samples in order to verify the findings in our simulations. We are also carrying out further simulations to optimize different sample parameters, as well as to understand the origins/mechanisms of the formation of the chiral cavities and heterocavities.

5. Reference

[1] A.F. Oskooi, D. Roundy, M. Ibanescu, P. Bermel, J.D. Joannopoulos, and S.G. Johnson, MEEP: A flexible free-software package for electromagnetic simulations by the FDTD method, Comput. Phys. Commun. 181, 687 (2010).

Fiscal Year 2021 List of Publications Resulting from the Use of the supercomputer

[Paper accepted by a journal]

C. F. Fong, Y. Ota, Y. Arakawa, S. Iwamoto and Y. K. Kato, “Chiral modes near exceptional points in symmetry broken H1 photonic crystal cavities” Phys. Rev. Research 3, 043096 (2021).

[Oral presentation]

C. F. Fong, Y. Ota, Y. Arakawa, S. Iwamoto, Y. K. Kato, “Intrinsic circularly polarized H1 photonic crystal cavity modes near exceptional points”, 82nd JSAP Autumn Meeting, oral 10p-N404-7, September 10-13, 2021, Japan (Online)