Usage Report for Fiscal Year 2022

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 light-matter coupling between the 2D materials and planar air-holes photonic crystals. We aim to design two types of structure namely the H1 photonic crystal cavity and photonic crystal waveguide for coupling with the 2D material. Such structures will be useful for the demonstration of miniaturized, semiconductor optoelectronic devices that could be useful for on-chip classical and quantum applications.

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

Based on the simulation results, we have fabricated the H1 photonic crystal cavity and photonic crystal waveguide with silicon-on-insulator (SOI). We have successfully observed the enhancement of light emission from the 2D material in the infrared regime by coupling it to the photonic crystal structures.

4. Conclusion

The simulations carried out using the HOKUSAI Bigwaterfall have been absolutely crucial to the ideation, development, and the progress of our research project. The experimental results are largely consistent with that from simulations.

5. Schedule and prospect for the future

We are exploring how the choice of 2D material affects the light-matter coupling properties. We have also started performing simulations to design photonic crystal structures for fabrication using gallium nitride (GaN) instead of SOI in order to develop devices that work in the visible light regime.

6. 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 2022 List of Publications Resulting from the Use of the supercomputer

[Conference Proceedings]

[Oral presentation]

C. F. Fong, Y. Ota, Y. Arakawa, S. Iwamoto, Y. K. Kato, “Intrinsically chiral modes near exceptional points in modified H1 photonic crystal cavity modes,” Conference on Lasers and Electro-Optics (CLEO 2022), San Jose, USA (May 16, 2022).

C. F. Fong, D. Yamashita, N. Fang, T. Taniguchi, K. Watanabe and Y. K. Kato, “Formation of heterocavity by deposition of hexagonal boron nitride flake on photonic crystal waveguide,” 83rd JSAP Autumn Meeting, oral 21a-C304-2, September 20-24, 2022, Tohoku University, Sendai, Japan.