Usage Report for Fiscal Year 2023

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 aim to enhance the light-matter coupling between the 2D materials with planar air-hole photonic crystal waveguides and cavities. 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 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. Result

Based on the simulation results, we have fabricated the photonic crystal waveguides with silicon-on-insulator (SOI) chips. We then transfer 2D material flakes of suitable thicknesses and shapes onto the photonic crystal waveguides. We have successfully observed light-matter coupling effects between the silicon waveguide and various 2D materials including hexagonal boron nitride (hBN), tungsten diselenide (WSe_2) and molybdenum ditelluride ($MoTe_2$).

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, particularly in determining the parameters of the crystal waveguides for nanofabrication, as well as the choice of 2D materials to couple to the waveguides. The experimental results are largely consistent with that from simulations.

5. Schedule and prospect for the future

We are exploring how the stacks of different 2D material affects the light-matter coupling properties with the waveguides.

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).

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Fiscal Year 2023 List of Publications Resulting from the Use of the supercomputer

[Oral presentation]

1. C. F. Fong, D. Yamashita, N. Fang, S. Fujii, Y.-R. Chang, T. Taniguchi, K. Watanabe, Y. K. Kato, "Nanocavity induced by atomically thin transition metal dichalcogenide in photonic crystal waveguide," *JSAP-Optica Joint Symposia, the 84th JSAP Autumn Meeting 2023*, Kumamoto, Japan (September 19, 2023).
2. C. F. Fong, Y. Ota, Y. Arakawa, S. Iwamoto, Y. K. Kato, "Intrinsically Circularly Polarized Modes Near Exceptional Points due to Symmetry Breaking in a H1 Photonic Crystal Cavity," *International Conference on Nano-photonics and Nano-electronics (ICNN2023)*, Yokohama, Japan (April 21, 2023).