Nanoscale Quantum Photonics Laboratory
Chief Scientist: Yuichiro Kato (Ph.D.)

(0) Research field

CPR Subcommittee**:** Engineering
Keywords: condensed matter physics, nanoscale device physics, carbon nanotubes, photonic crystals, microspectroscopy

(1) Long-term goal of laboratory and research background

Control over the quantum nature of photons at the nanoscale opens up unique opportunities in quantum information processing. We study the physics underlying the operation of nanoscale photonic devices to explore new approaches for manipulating quantum states, with focus on devices that make use of individual single-walled carbon nanotubes. By combining microspectroscopy with electronic techniques, we investigate unconventional methods for manipulating the optical properties of nanomaterials within device structures, which should form the basis for future quantum technologies employing integrated quantum photonic circuits.

(2) Current research activities (FY2020) and plan (until Mar. 2025)

<u>Hexagonal boron nitride as an ideal substrate for carbon nanotube photonics</u>

N. Fang, K. Otsuka, A. Ishii, T. Taniguchi, K. Watanabe, K. Nagashio, Y. K. Kato, *ACS Photonics* **7**, 1773 (2020).

The effects of hexagonal boron nitride (*h*-BN) on photoluminescence (PL) of carbon nanotubes (CNTs) are investigated. *h*-BN/CNT heterostructures are constructed by transferring *h*-BN flakes over air-suspended CNTs grown over trenches on SiO_2/Si substrates. PL excitation spectra are compared before and after the transfer. The PL intensity and the linewidth are comparable to as-grown air-suspended CNTs, showing that *h*-BN is an ideal substrate for carbon nanotube photonics. Large redshifts in excitation and emission energies are observed after the transfer of the *h*-BN flake, which is difficult to explain by the dielectric screening effect alone. These findings highlight the superior properties of *h*-BN for 1D/2D hybrid-dimensional photonics and open a new pathway for manipulating excitons in CNTs.

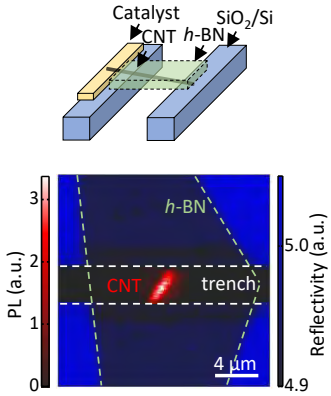


Fig. 1: (Top) Schematic of an *h*-BN/CNT heterostructure. (Bottom) Photoluminescence image overlayed with reflectivity image.

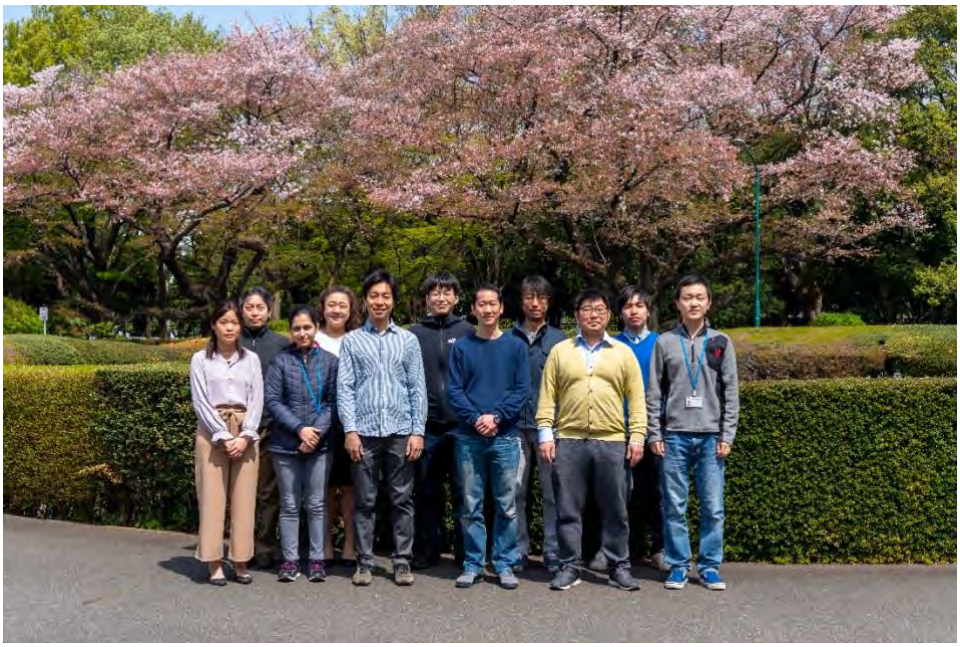
(3) Members as of March, 2021

(Chief Scientist)
Yuichiro Kato
(Research scientist)
Wataru Terashima
(Special Postdoctoral Researcher)
Nan Fang
(Postdoctoral researcher)
Zhen Li, Chee Fai Fong
(Visiting Researcher)
Alka Sharma
(Visiting Scientist)
Keigo Otsuka
(Student Trainee)
Nicolas F. Zorn
(Assistant)
Yoriko Nissaka

(4) Representative research achievements

1. D. Yamashita, H. Machiya, K. Otsuka, A. Ishii, Y. K. Kato, "Waveguide coupled cavity-enhanced light emission from individual carbon nanotubes", APL Photonics **6**, 031302 (2021).
2. N. Fang, K. Otsuka, A. Ishii, T. Taniguchi, K. Watanabe, K. Nagashio, Y. K. Kato, "Hexagonal boron nitride as an ideal substrate for carbon nanotube photonics", ACS Photonics **7**, 1773 (2020).

Group Photo



Group Webpage
https://www.riken.jp/en/research/labs/chief/nanosc_qtm_photon/index.html
http://katogroup.riken.jp/en/