Single-carbon-nanotube photonics and optoelectronics

Yuichiro K. Kato[1,2]

[1]*Nanoscale Quantum Photonics Laboratory, RIKEN, Saitama 351-0198, Japan*
[2]*Quantum Optoelectronics Research Team, RIKEN Center for Advanced Photonics, Saitama 351-0198, Japan*

Single-walled carbon nanotubes have unique optical properties as a result of their one-dimensional structure. Reduced screening leads to large exciton binding energies which allow for room-temperature excitonic luminescence, while enhanced interactions give rise to a variety of exciton processes that may be utilized for modulating the emission properties. Furthermore, their luminescence is in the telecom-wavelengths and they can be directly synthesized on silicon substrates, providing new opportunities for nanoscale quantum photonics and optoelectronics.

Here we discuss the use of individual single-walled carbon nanotubes for generation, manipulation, and detection of photons on a chip. Strong exciton-exciton annihilation process [1] leads to antibunching at room temperature, opening up a pathway to single photon sources. Specially-designed air-mode photonic crystal cavities allow for efficient coupling to nanotube emission [2], while the coupling can be readily tuned by large spectral shifts induced by molecular desorption. Such spectral changes due to the adsorbed molecules give rise to optical bistability, which can be utilized for all-optical memory operations. Gate control over carrier density can be used to generate trions that are also stable at room temperature [3], and efficient carrier-exciton interactions can be used to produce optical pulse trains [4]. By monitoring the photoconductivity in transistor devices, dissociation processes and fine structures of excitonic states can be investigated [5,6]. Narrow linewidth electroluminescence can be obtained in split-gate devices [7]. Ultimately, these results may be combined to achieve further control over photons at the nanoscale.

Work supported by KAKENHI (JP16H05962, JP16K13613) as well as the Nanotechnology Platform and Photon Frontier Network Program of MEXT, Japan.

References

[1] A. Ishii, M. Yoshida, Y. K. Kato, Phys. Rev. B **91**, 125427 (2015).
[2] R. Miura, S. Imamura, R. Ohta, A. Ishii, X. Liu, T. Shimada, S. Iwamoto, Y. Arakawa, Y. K. Kato, Nature Commun. **5**, 5580 (2014).
[3] M. Yoshida, A. Popert, Y. K. Kato, Phys. Rev. B **93**, 041402(R) (2016).
[4] M. Jiang, Y. Kumamoto, A. Ishii, M. Yoshida, T. Shimada, Y. K. Kato, Nature Commun. **6**, 6335 (2015).
[5] Y. Kumamoto, M. Yoshida, A. Ishii, A. Yokoyama, T. Shimada, Y. K. Kato, Phys. Rev. Lett. **112**, 117401 (2014).
[6] T. Uda, M. Yoshida, A. Ishii, Y. K. Kato, Nano Lett. **16**, 2278 (2016).
[7] N. Higashide, M. Yoshida, T. Uda, A. Ishii, Y. K. Kato, Appl. Phys. Lett. **110**, 191101 (2017).