Dynamic properties of optical near-field excitation transfer system consisted of randomly distributed quantum dots

Wataru Nomura
Graduate School of Engineering, the University of Tokyo,
2-11-16 Yayoi, Bunkyo-ku, Tokyo 113-8656, Japan,
Email: nomura@nanophotonics.t.u-tokyo.ac.jp

As optical energy and signal transfer device in nanophotonics, we have proposed and developed an optical near-field excitation transfer system which consists of a randomly distributed quantum dot (QD) array. An optical signal is transferred as an optical excitation between neighboring QDs via an optical near-field coupling in this system. We have already confirmed the optical excitation transfer efficiency and destination selectivity owing to resonant energy levels theoretically and experimentally [1,2]. In this talk, we report the signal velocity and its dispersion in the optical near-field excitation transfer system.

Two types of resonant CdSe/ZnS core–shell QDs, called QD1 and QD2, were used for the experiments. Since the diameter of QD2 is about 1.43 times larger than that of QD1, the optical excitation transfers from QD1 to QD2 unidirectionally via an optical near-field interaction [3]. The samples were fabricated on a silica substrate using e-beam lithography and lift-off technique, as shown in Fig. 1. In this sample, QD2s were randomly dispersed in a circular region with 2 μm diameter inside a film of widely dispersed QD1s. Samples A, B and C were prepared with different thicknesses, H, of the QD1 film: H = 10 nm, 25 nm and 70 nm, respectively. We evaluated the time evolution of the emission from QD2 while exciting QD1 located a distance L away from QD2 using time-correlated single photon counting method and a Ti:sapphire laser with a wavelength of 360 nm, a pulse frequency of 80 MHz, and a pulse duration of 2 ps. The acquired time-evolved emission curves were approximated using an integration of a Gaussian function and a single exponential decay. We obtained the signal velocities v and its dispersions d from the L dependency of peak and width of the Gaussian functions, respectively. As a result, the obtained value of v and d in samples A, B and C were $v = 1.2 \times 10^5$, 1.7×10^5, and 3.2×10^5 m/s and d = 1.84, 1.35, and 1.30 ps/μm, respectively. As shown in Fig. 2, v monotonically increases with increase of H. This trend agrees with the previously measured energy transfer efficiency of randomly distributed QDs. On the other hand, d decreases with increase of H. This trend is considered to originate from optical near-field interactions between randomly distributed QDs.

A part of this work was supported by the “Development of Next-generation High-performance Technology for Photovoltaic Power Generation System” Program, NEDO,

Japan.

Reference

[1] W. Nomura, T. Yatsui, T. Kawazoe, M. Naruse, and M. Ohtsu, Appl. Phys. B **100**, 181 (2010)

[2] W. Nomura, T. Yatsui, T. Kawazoe, E. Runge, and C. Lienau, and M. Ohtsu, Appl. Phys. B **107**, 257 (2012)

[3] N. Sakakura, Y. Masumoto, Phys. Rev. B **56**, 4051 (1997)

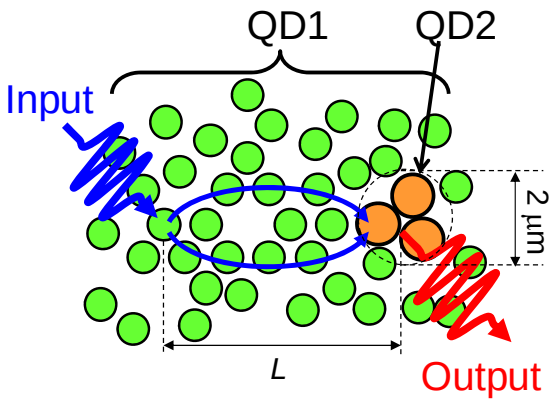

Fig.1 Schematic image of fabricated samples.

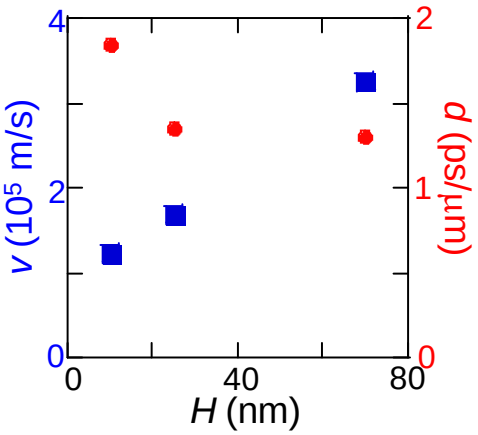

Fig.2 Signal velocities *v* (blue squares) and its dispersions *d* (red circles) versus height of QD1 film *H*.

Wataru Nomura

Project Researcher, Department of Electrical Engineering and Information Systems and Nanophotonics Research Center, Graduate School of Engineering, The University of Tokyo

He received the B.E. and M.E. degrees from Tokyo Institute of Technology in 2002 and 2004, respectively, and the Dr. Eng. degree from The University of Tokyo in 2007. Since 2007, he has been a Project Assistant Professor at the University of Tokyo. He received the JSAP Incentive Award for Excellent Presentation from the Japan Society of Applied Physics in 2009, the 6th Optics & Photonics Japan Best Presentation Award in 2010, and Prize of the Promotion of Engineering Research in 2013.