High Efficiency Dark-to-Bright Exciton Conversion in Carbon Nanotubes

○Akihiro Ishii[1,2], Hidenori Machiya [1,3], Yuichiro K. Kato [1,2]

[1] *Nanoscale Quantum Photonics Laboratory, RIKEN Cluster for Pioneering Research, Saitama 351-0198, Japan*

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

[3] *Department of Electrical Engineering, The University of Tokyo, Tokyo 113-8656, Japan*

E-mail: akihiro.ishii@riken.jp

We report that dark excitons can have a large contribution to the emission intensity in carbon nanotubes due to an efficient exciton conversion from a dark state to a bright state. Time-resolved photoluminescence measurements are used to investigate decay dynamics and diffusion properties of excitons [Fig. 1], and we obtain intrinsic lifetimes and diffusion lengths of bright excitons as well as diffusion coefficients for both bright and dark excitons. We find that the dark-to-bright transition rates can be considerably high, and that more than half of the dark excitons can be transformed into the bright excitons. The state transition rates have a large chirality dependence with a family pattern, and the conversion efficiency is found to be significantly enhanced by adsorbed air molecules on the surface of the nanotubes. Our findings show the nontrivial significance of the dark excitons on the emission kinetics in low dimensional materials, and demonstrate the potential for engineering the dark-to-bright conversion process by using surface interactions.

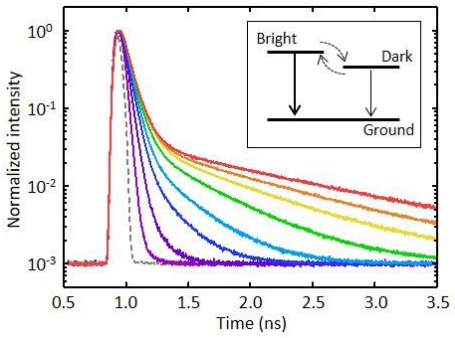

FIG. 1 Emission decay curves obtained from (9,8) nanotubes with various lengths ranging from 0.5 μm (purple) to 4.2 μm (red). The gray line is the instrument response. (inset) Schematic of the three-level model for exciton decay dynamics.

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