近接場光学顕微鏡による励起子波動関数マッピング

Real-space mapping of exciton wavefunctions using near-field scanning optical microscopy

Objectives

10～30nm の空間分解能をもつ近接場光学顕微鏡は、量子ドットに閉じ込められた励起子波動関数の実空間マッピングを可能にする。相互作用をする量子ドット系における量子操作に向けて、結晶構造の乱れや外部電場・磁場による局所摂動を、励起子と励起子複合体の波動関数マッピングを通して可視化することに取り組んでいる。

A near-field scanning optical microscope with a spatial resolution of 10-30 nm, which is smaller than the typical size of semiconductor quantum dots (QDs), allows direct mapping of the exciton wavefunction confined in a QD. Through quantum manipulation of interacting QD systems, local perturbations in QDs caused by disorder and an external field can be visualized by means of wavefunction mapping of the exciton and exciton complex states.

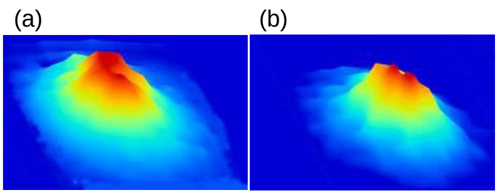

Fig. 1

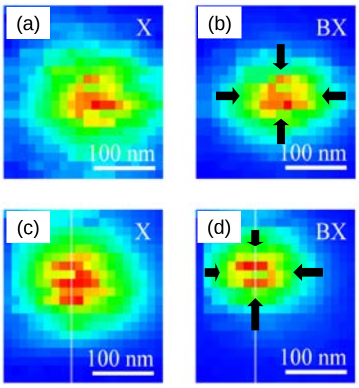

Fig. 2

Achievements

- GaAs 量子ドットに閉じ込められた励起子、励起子分子の発光分布を高空間分解能下でマッピングし、それらの違いを分極場の空間分布（波動関数）によって説明できることを示した。
- 励起子・励起子分子波動関数マッピングを通して、量子ドット内に形成された浅い局在ポテンシャルの存在を明らかにした。
- 励起子・荷電励起子波動関数マッピングを通して、トラップ電子を起源とする電場による波動関数の歪みを可視化した。

- The exciton and biexciton PL emissions from GaAs QDs were mapped out and their difference was quantitatively explained in terms of different distributions in the polarization field.
- The exciton and biexciton wavefunction mapping revealed weak localization of excitons due to a shallow potential formed in a QD.
- The exciton and charged-exciton wavefunction mapping was used to visualize distortion of the exciton wavefunction due to the local electric field generated by a nearby trapped electron.

Fig. 3

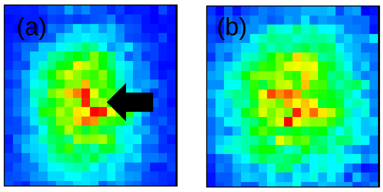

Fig. 1: Near-field optical mapping of the exciton and biexciton wavefucntions in a GaAs QD.
Fig. 2: (a), (b) Isotropic shrinkage of the biexciton (BX) wavefunction with respect to the exciton (X) wavefunction. (c), (d) Anisotropic shrinkage of the biexciton wavefunction due to a shallow potential formed in the QD.
Fig. 3: Distortion of the exciton wavefunction (a) with respect to the charged-exciton wavefunction, and (b) due to a local electric field.

References

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2) Y. Sugimoto, S. Nomura, and T. Saiki, “Visualization of weak confinement potentials by near-field optical imaging spectroscopy of exciton and biexciton in a single quantum dot”, Appl. Phys. Lett. 93, 083116 (2008).
3) Y. Sugimoto, N. Tsumori, S. Nomura, and T. Saiki, “Visualization of Space Charge Field Effect on Excitons in a GaAs Quantum Dot by Near-Field Optical Wavefunction Mapping”, Opt. Rev. 16, 269 (2009).