Optical Recombination in Semiconductor Nanostructures

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Two of the key current challenges in photonics are the development of entangled photon sources and the development of lasers and efficient light sources across the full visible spectrum. There is considerable interest in the use of semiconductor quantum dots (QDs) to achieve both these aims. Here we discuss the issues involved to investigate the piezoelectric potential and electronic structure of III-N wurtzite and of site-controlled (111)-oriented zinc-blende dots. We investigate the single-particle electronic structure of (111)-oriented InGaAs/GaAs QDs by means of an 8-band $k \cdot p$ model. We then discuss how this model needs to be extended in order to identify how best to engineer the dots to give orthogonally polarized exciton states that are degenerate (zero fine structure splitting), thereby supporting the emission of entangled photons. This requires both to treat dots where there are only a few confined electron but many confined hole states, as well as to incorporate the effects of disorder into the system. We highlight that accurate knowledge of physical parameters remains an issue for such dots [1]. We then turn to consider the influence of the built-in potential in wurtzite structures. We first compare the elastic and the first-order piezoelectric tensor of the (111)-zinc-blende systems with the corresponding quantities in a wurtzite structure and point out similarities and differences [2]. We then turn to consider the analysis of the built-in potential and its consequences for polar and for non-polar III-N QDs [3]. We propose that the growth of InGaN/GaN QD structures can lead to a significant reduction in the built-in potential compared to InGaN/GaN quantum well structures, allowing efficient optical emission to longer wavelengths [4]. We also highlight that the calculated field values and their effects are very sensitive to details of the dot shape and composition in such heterostructures.

References

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