Exciton physics and cavity quantum electrodynamics in air-suspended carbon nanotubes

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Electron-hole pairs form tightly-bound excitons in carbon nanotubes due to limited screening of the Coulomb interaction, and these stable excitonic states play a central role in the optical processes. Here we discuss unique excitonic phenomena in pristine air-suspended carbon nanotubes, where the intrinsic properties of excitons can be investigated. The mobile excitons exhibit long diffusion lengths [1], and in combination with the increased scaling due to one-dimensionality, efficient exciton-exciton annihilation leads to antibunching at room temperature [2]. There exist excitonic fine structures within the large binding energy, many of which are dark states with optical transitions forbidden by spin, momentum, and parity selection rules. By studying the dynamics and diffusion properties of the bright excitons and the even-parity dark excitons, we find that more than half of the dark excitons can be transformed into the bright excitons [3]. Silicon photonic crystal nanobeam cavities can be used to induce cavity quantum electrodynamical effects [4], and we take advantage of the Purcell enhanced decay rate to determine the radiative quantum efficiency of bright excitons to be near unity at room temperature [5]. With high-efficiency light emission and single-photon generation capabilities, carbon nanotubes offer new opportunities in nanoscale quantum photonics.

References

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