Waveguide coupled cavity-enhanced light emission from individual carbon nanotubes

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Carbon-nanotube-based photonic devices have potential applications in the framework of on-chip optical communications. Single-walled carbon nanotubes (CNTs) exhibit telecom-band light emission at room temperature and they can be directly grown onto silicon substrates, which is favorable in terms of compatibility with silicon photonics. Although CNTs have numerous advantages, their quantum efficiencies are typically low [1] and they have broad spectral linewidths. To overcome these drawbacks, one of the most promising solutions is the use of photonic crystal (PC) nanobeam cavities [2,3]. The small mode volumes of the microcavities can give rise to Purcell enhancement and the high-quality factors of the microcavities can also reduce the linewidth of the CNT emission. In addition, an optical waveguide can be easily integrated with these cavities, connecting the light emitter and other optical components for mutual access. Such waveguide-coupled and cavity-enhanced light emission from CNTs devices has been demonstrated [3], however, the deposition of CNTs has been performed by dielectrophoresis, which uses solution processes. To harness the unique optical properties of CNTs such as single photon emission, it is important to isolate individual CNTs and eliminate contamination during the solution-based processes.

Here, individual CNT telecom-wavelength emitters are integrated onto a microcavity and a waveguide. Using finite-difference time-domain simulations, we have designed an air-mode PC nanobeam cavity with one thin end mirror for guiding the light into the waveguide. CNTs are grown on a SiO_2/Si substrate and transferred on the cavities through an all-dry process ensuring cleanliness of CNTs and devices. We characterize the devices using two geometries: a top detection configuration that measures light emission from CNTs on a nanobeam cavity, and a side detection configuration that collects light emission coupled to the waveguide. The nanobeam cavity with a small mode volume enhances light emission from a chirality-identified single CNT. The cavity-coupled light propagates into the waveguide and is emitted from the waveguide facet with a sharp linewidth and a large off-resonance rejection.

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