Exciton transport and manipulation in colloidal semiconducting carbon nanotubes

Jared Crochet, Juan Duque, James Werner, and Steve Doorn
Los Alamos National Laboratory, Los Alamos, New Mexico, USA

Prashant Nagpal
University of Colorado at Boulder

Laurent Cognet and Brahim Lounis
CNRS & Université Bordeaux

Exciton transport in carbon nanotubes is determined by the group velocity of the bound electron-hole pair wavepacket and dephasing scattering mechanisms such as exciton-phonon coupling. The electron-hole exchange interaction in small diameter semiconducting carbon nanotubes leads to an anomalous exciton dispersion that renormalizes the exciton effective mass with respect to the free-particle picture. This results in rather large group velocities approaching 1 nm/fs. However, in a colloidal environment we found that coherence lengths are limited to the exciton size, and the intrinsic exciton diffusion constant associated with acoustic phonon scattering is reduced by a factor of 40 to ~ 7.5 cm^2/s. We associate this reduction in diffusion constant to exciton scattering within a disorder potential associated with the dynamic colloidal interface. We also present evidence of strong exciton-plasmon coupling when nanotubes are in proximity to sharp metal tips and edges associated with ultra-smooth (<1 nm RMS surface roughness) gold-pyramid substrates. Propagating and emitting surface plasmon polaritons at the nanotube emission wavelengths, bright localized exciton emission, and a reorientation of the exciton dipole moment all provide evidence for this coupling.

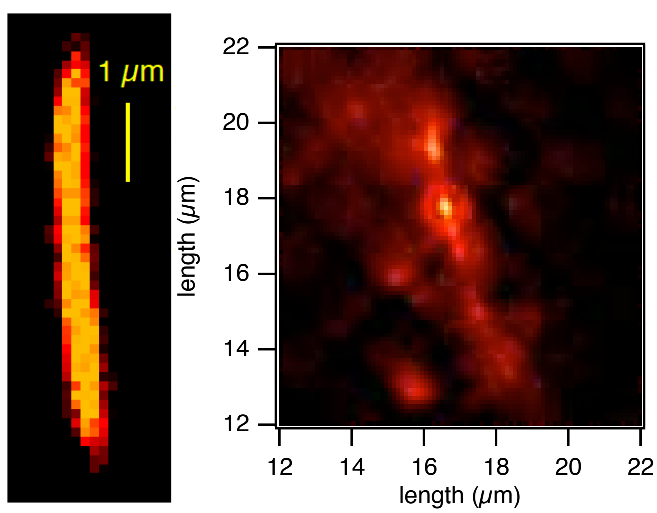

Figure. **Left**, Photoluminescence image of a (6,5) carbon nanotube where the spatial dependence of emission quenching toward the tube ends was used to extract an exciton diffusion length of approximately 200 nm. **Right**, Photoluminescence image of another (6,5) tube in proximity to a sharp tip of a gold pyramid. A characteristic donut pattern is observed that indicates dipole emission perpendicular to the tube axis, which is nearly forbidden under normal circumstances.