Extremely Efficient Photocurrent Generation in Carbon Nanotube Photodiodes

Oregon State University. [1] °**Ethan Minot**[1]
E-mail: ethan.minot@oregonstate.edu

Carbon nanotubes (CNTs) offer unique relaxation pathways for energetic charge carriers. Of particular interest are carrier multiplication pathways that can boost the quantum efficiency of CNT photodiodes. We have studied, both experimentally and theoretically, the photocurrent generation process in individual suspended CNT pn junctions [1, 2]. In our experiments we control the axial electric field inside the pn junction, and also control the Coulomb interaction strength between charge carriers. We determined the photocurrent quantum yield (PCQY) by accounting for the length of the intrinsic region, optical cavity effects, and the integrated absorption cross-section of the exciton resonance. At low electric fields (a few volts per micron), we confirmed previous experimental measurements of modest PCQY in CNT photodiodes. At higher electric fields, however, (~ 10 volts per micron) we found evidence for room temperature PCQY > 100%. The Coulomb interaction strength was varied by using different dielectric environments, and CNTs of different diameters. Our experiments show that the highest PCQY is achieved by increasing the CNT diameter [1], and increasing the relative dielectric constant of the environment [2]. Our work elucidates the role of Coulomb interactions in nanotube-based optoelectronic devices, and will guide future efforts to build high-efficiency photodiodes.

[1] D. R. McCulley *et al*., "Extremely Efficient Photocurrent Generation in Carbon Nanotube Photodiodes Enabled by a Strong Axial Electric Field" Nano Letters **20**, 433-440 (2020).
[2] M. J. Senger *et al*. “Dielectric Engineering Boosts the Efficiency of Carbon Nanotube Photodiodes”, ACS Nano (2021)