# Near-field and ultrafast optical microscopy of carbon nanotubes and graphene

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We report on our efforts to study the optical response of CNTs and graphene on nanometer length and femtosecond time scales. Sub-diffraction spatial resolution is achieved using tip-enhanced near-field optical microscopy. In this approach a sharp metal tip acts as an optical antenna enhancing both excitation and emission of a nearby object [1]. Photoluminescence, Raman scattering as well as photocurrent and electroluminescence images with sub 30 nm are obtained [2,3]. This allows us to visualize spatial heterogeneities of the optical responses hidden in confocal measurements and to investigate their microscopic origin.
We study the excited state dynamics and non-linear response of single CNTs and graphene on a time scale of 15 fs by laser pulse shaping. Spectral amplitude and phase shaping is used to control the emission spectrum of graphene and to follow the charge carrier relaxation dynamics [4]. We now aim at combining pulse shaping and near-field microscopy to obtain new insight into the ultrafast phenomena in nanocarbons.

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[3] N. Mauser et al. *Nano Lett.* 14, 3773 (2014)
[4] T. Winzer et al. *Nano Lett.* 15, 1141 (2015)