Graphene plasmonics: from nonlinear optics to controlling magnetic fields

Patterning graphene into elements that confine localized plasmons can strongly enhance the light-matter interaction compared to unpatterned graphene. This plasmonic enhancement can be exploited for more efficient optoelectronic devices like detectors or modulators and also increases optical nonlinearities. Structures on a micrometer length scale provide plasmonic resonance in the THz range. Here we report pump-probe studies on graphene disks and ribbons in order to investigate the nature of the optical nonlienarites. When excited by short and intense THz pulses with a fluence in the $\mu J/cm^2$ range, the transmission increases by about 10%, making it an interesting candidate for nonlinear optics [1,2]. We identified two main effects leading to the overall response, one being electron temperature, the other is based on the Kerr effect[3]. While the thermal effect is rather fast and leads to a decay of the pump-induced change in transmission within a few tens of picoseconds, it is too slow to allow harmonic generation. In contrast, the contribution based on the Kerr effect is much faster and thus might be a promising candidate for harmonic generation. Our latest study on circular plasmons in graphene disks revealed strong unipolar magnetic fields on the order of 0.5 T when the disks are excited by circularly polarized THz pulses with moderate fluence. The circulating charge carriers generate the magnetic fields similar to tiny electromagnets that can be optically controlled on a picosecond timescale[4].

[1] M. M. Jadidi et al., Nano Lett. 16, 2734 (2016).
[2] M. M. Jadidi et al., ACS Photonics 6, 302 (2019).
[3] J. W. Han et al., Adv. Photonics Res. 3, 2100218 (2021).
[4] J. W. Han et al., Nat. Commun. 14, 7493 (2023).