ICFO



PhD THESIS DEFENSE: Photodetectors Based on Graphene pn-Junctions for Mid-Infrared and Terahertz Range

SEBASTIAN CASTILLA GOMEZ

January 31, 2022
15:00 to 18:00
Auditorium and Online (Teams)

Long wavelength light contains the infrared and terahertz (THz) spectral range of the spectrum. This wavelength range spans approximately from 1 m to 1 mm. Severa applications can be explored in this spectral range such as thermal imaging, temperatur monitoring, night vision, etc. Moreover, molecular vibrations resonate at these energies tha are the fingerprints for compounds identification via molecular spectroscopy. Also, THz ligh has an important role in security since at these frequencies is possible to achieve a highe resolution for imaging compared to millimeter waves that are typically used in airports Despite all these potential applications, long wavelength light technology still remain non-fully exploited. One of the reasons is due to the lack of competing instrumentation suc as sources, modulators, detectors, sensors, etc. In particular, regarding the detectors, th

commercially available technology present some issues such as the temperature o operation, speed, sensitivity, dynamic range, broadband frequency operation, CMO compatibility, size and compactness, etc. The extensive research during the last years o graphene and other 2D materials has opened new possibilities of novel light matte interactions that can unveil the next generation photodectectors and sensors, ascribed to th advantages respect to conventional semiconductors.

In this thesis, we focus on developing novel photodetection platforms in the mid, longwave infrared and THz range based on graphene pn-junctions with integrated metallic nanostructures and hyperbolic 2D material. We have successfully integrated an antenna with a graphene pn-junction for highly sensitive and fast THz detection in this regime. This novel terahertz detector exploits efficiently the photothermoelectric (PTE) effect, based on a design that employs a dual-gated, dipolar antenna with a nanogap. We have demonstrated that this novel detector leads to an excellent performance, which fulfills a combination of figure-of-merits that is currently missing in the state-of-the-art detectors. We also overcame the main challenge of infrared photodetectors, which is to funnel the light into a small nanoscale active area and efficiently convert it into an electrical signal. We achieve this by efficient coupling of a plasmonic antenna to hyperbolic phonon-polaritons in hBN to highly concentrate mid-infrared light into a graphene pn-junction. We use a metallic bowtie antenna and H-shape resonant gates that besides concentrating the light into its nanogap, their plasmonic resonances spectrally overlap within the upper reststrahlen band (RB) of hBN (6-7 ?m), thus launching efficiently these HPPs and guiding them with constructive interferences towards the photodetector active area. Additionally, by having two different antennas orientation, it allows us to have sensitive detection in two incident polarizations. Furthermore, we have shown mid and long-wave infrared photocurrent spectroscopy via electrical detection of graphene plasmons, hyperbolic phonon-polaritons and their hybridized modes. We combined in one single platform the efficiently excited polaritonic material that also acts as a detector itself. We identified peaks in the photocurrent spectra that evolves and blue shift by increasing the gate voltage, which are related to the polaritonic resonances. Finally, we investigated the electrical detection of molecular vibrations coupled to hyperbolic phonon polaritons in hBN. We detected this strong light-matter interaction via a graphene pn-junction placed at the vicinity of the molecules-hBN stack. The edges of the gap of the local gates launch efficiently the hBN HPPs that interact with the CBP molecular resonances that are spectrally located at the upper RB. We explored this interaction as a function of the thickness of the molecular layers, near and far field contribution, etc.
Hosted by: Frank Koppens