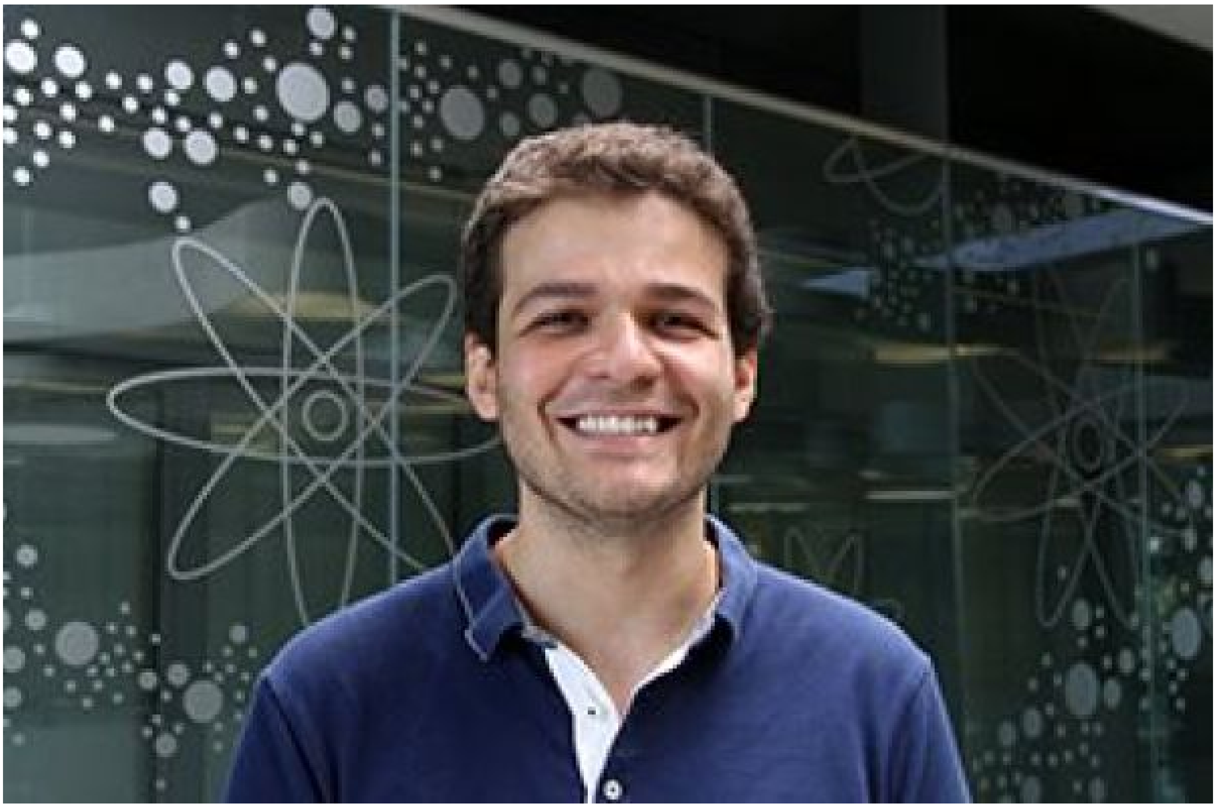

PhD THESIS DEFENSE: Further Into the Infrared with Quantum Dot Photodetector

ONUR OZDEMI

February 04, 2022

11:00 to 13:00

Online (Teams) and ICFO Auditorium

In the infrared, photodetectors are the key components in a wide-variety of applications such as thermal imaging, remote sensing, spectroscopy with newer technologies added to the list such as LiDaR and deep tissue imaging. As the demand for photodetectors increase with a shift towards longer wavelengths, we need high-performance, scalable and low-power consuming alternatives to current infrared photodetector technologies.

Colloidal Quantum Dots (CQDs) are nanoscale-sized semiconductors with quantum-confined charges in all 3 dimensions. They can be synthesized in solution and can easily be deposited onto a desired substrate as a quantum dot (QD) film which allows easy integration with current silicon-based technologies. QDs are efficient light absorbers and their bandgap can accurately be tuned by controlling their size during synthesis. Lead chalcogenide QDs, such as PbS and PbSe, have tunable bandgaps covering the near-infrared (NIR) and short-wave infrared (SWIR) up to 3 m, making them ideal sensitizers for photodetectors.

In this thesis, we utilize PbS QDs with an excitonic bandgap around 1.8 m in combinatio with 2-dimensional transition metal dichalcogenides (TMDCs) to form hybrid photodetector operating in the infrared. With their layered structure similar to graphene an semiconducting character, TMDCs have outstanding electronic properties. Incorporatin few-layers of TMDCs in our PbS QD detectors allows fast and efficient charge transfer fro the QDs to the photodetector contacts through the TMDC layer, boosting detecto responsivity. By combining PbS QDs with two types of TMDCs, WS2 and MoS2, we are able t reach detectivities exceeding 1012 Jones at room temperature with a response up to 2 m.

Probing further into the infrared, we extend the spectral response of our hybrid detectors up to 3 m by utilizing narrower-bandgap PbSe QDs with MoS2 layers.

After a careful analysis and using strategies such as oxide-isolation of metallic contacts, we reached detectivities of 7.7 x 1010 Jones at 2.5 m at RT. With their low-noise and hig responsivities, our detectors improve the potential of hybrid detectors and demonstrate performance comparable to commercial detectors without the need of external cooling costly vapor deposition techniques or complex integration with silicon technology.

Broadening the reach of PbS QDs even further, even beyond the limit of their bulk bandgap, up to 9 m by using a novel doping method, we demonstrate the first PbS QD intraban photodetectors. Having developed this air-stable high n-doping method for PbS QDs observation of intraband transitions taking place between the first two conduction level becomes possible. These intraband transitions have lower energies compared to th bandgap, opening up another degree of freedom in tunable optical response of our QD between 6-9 m. We study how the doping works across a wide range of QD sizes and t different temperatures. Our photodetectors utilizing the intraband transitions n highly-doped PbS QD films have detectivities approaching 105 Jones.

To sum up, we demonstrated lead chalcogenide QD based photodetectors with improved performance and spectral responses progressively shifting deeper into the infrared. Our TMDC-QD hybrid detectors reveal the potential of these systems as alternatives to commercial detectors. Whereas, surpassing the bandgap limit with high doped QDs and intraband transitions opens up new ways to realize optoelectronic devices further in the infrared.

Hosted by: Gerasimos Konstantatos