Intersubband transitions in transition metal dichalcogenides (TMDs)

Peter Schmidt
Fabien Vialla, Mathieu Massicotte,
Mark Lundeberg, Frank Koppens

ICFO – Institut de Ciències Fotoníques, The Barcelona Institute of Science and Technology, Castelldefels (Barcelona) 08860, Spain

peter.schmidt@icfo.eu

The discovery of intersubband transitions in III-V semiconductor heterostructures [1] has had a huge impact on large parts of the condensed matter physics community and ultimately led to the development of quantum well infrared photodetectors [2] and quantum cascade lasers [3]. One of the main constraints, however, are the strict lattice matching conditions of the heterostructures – limiting the available materials to combine – and its expensive and complicated growth.

Recently, another type of heterostructures has appeared, so-called van der Waals heterostructures [4] which combine different two-dimensional (2D) materials. In these heterostructures no lattice matching is required since the interaction between different layers is only mediated by van der Waals forces. This gives rise to a virtually unlimited number of combinations of different 2D materials. Furthermore, the fabrication of van der Waals heterostructures does not involve expensive and costly equipment but allows for simple CVD growth and transfer. Indeed, 2D materials are an ideal candidate for intersubband transitions since its atomically sharp interfaces define a perfect quantum well. Until now however, the observation of intersubband transitions in 2D materials has not yet been reported. This is mainly due to two reasons: First, exfoliated flakes are typically rather small, much smaller than the spot size of a mid-infrared or terahertz laser source. Chemically synthesised flakes can be larger, however their thickness is limited to a few monolayers and a thickness dependent study is not possible.

Here, we present an innovative measurement technique that allows us to overcome these constraints and measure intersubband transitions in semiconducting TMDs. We demonstrate absorption due to intersubband transitions in the conduction band of MoS_2 and valence band of WSe_2. By varying the doping of the TMD flakes we can compare the extracted values of the absorption to a simple model for an infinite square well potential and find a good quantitative agreement.

References

[1] West *et al.*, APL 46, 1156 (1985)
[2] Levine *et al.*, APL 50, 1092 (1987)
[3] Faist *et al.*, Science 264, 553-556 (1994)
[4] Geim *et al.*, Nature 499, 419-425 (2013)