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Tip-enhanced Raman Spectroscopy and Photoluminescence of 0- and 2-dimensional Semiconductor Nanostructures

The Semiconductor Physics group in Chemnitz focuses on the spectroscopic characterisation of low-dimensional semiconductor nanostructures with particular emphasis on 0-dimensional quantum dots (QDs) and 2-dimensional transition metal dichalcogenides (TMDCs) and primary investigation tools are optical spectroscopies, viz Raman, infrared, photoluminescence spectroscopy. While these spectroscopies already provide invaluable information on QDs and TMDCs when applied in their conventional but diffraction-limited versions, their tip-enhanced analogues, namely TERS, nano-FTIR, and TEPL, with their high spatial resolution in the nanometre range can improve our understanding of semiconductor nanostructures, for instance by measuring the response of a single QD rather than averaging over thousands of QDs or by resolving variations in TMDC properties on the nanoscale. Here, we use two drosophila QD and TMDC materials, namely cadmium selenide (CdSe) and molybdenum disulfide (MoS₂) to demonstrate the added value of tip-enhanced optical spectroscopies. Considering CdSe QDs, their detection by micro-Raman spectroscopy already requires the employment of enhancement mechanisms such as resonance and surface-enhancement. First measurements using TERS on a monolayer of QDs on SERS substrates revealed a TERS enhancement factor of $6 \cdot 10^4$ [1]. The TERS imaging of single QDS became feasible [2] and a detailed lineshape analysis was possible [3]. Regarding the TMDC MoS₂, we thoroughly investigated the local properties of MoS₂ monolayers when deposited onto substrates with plasmonic nanostructures where MoS₂ e.g. experiences high strain at the edges of the plasmonic nanostructures [4]. Moreover, the MoS₂ monolayers near plasmonic hot spots can be subject to temperature increase, hot electron doping, and even phase changes [5]. Finally, TEPL revealed the local origin of enhanced photoluminescence in laser treated monolayer MoS₂ [6].

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