Valley lifetimes in monolayer WSe_2 from time-resolved Kerr-rotation measurements

Manfred Ersfeld[1]
Frank Volmer[1], Lars Rathmann[1], Luca Kotewitz[1], Maximilian Heithoff[1], Mark Lohmann[2], Bowen Yang[3], Kenji Watanabe[4], Takashi Taniguchi[4], Ludwig Bartels[3], Jing Shi[2], Christoph Stampfer[1,5] and Bernd Beschoten[1]
[1]*2nd Institute of Physics and JARA-FIT, RWTH Aachen University, 52074 Aachen,* Germany
[2]*Department of Physics and Astronomy, University of California, Riverside, California 92521, USA*
[3]*Department of Chemistry and Materials Science Engineering Program, University of California, Riverside, California 92521, USA*
[4]*National Institute for Materials Science, 1-1 Namiki, Tsukuba, 305-0044, Japan*
[5]*Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, 52425 Jülich, Germany*
Manfred.Ersfeld@rwth-aachen.de

Two-dimensional transition metal dichalcogenides (TMDs) offer the possibility to address the electron's valley degree of freedom making them interesting for valley-based electronics, so-called valleytronics. We report on nanosecond long, gate-dependent valley lifetimes of free charge carriers in WSe_2, unambiguously identified by the combination of time-resolved Kerr rotation (TRKR), Photoluminescence (Fig. 1a) and electrical transport measurements. While the valley polarization increases, black data points in Fig. 1b for U_{BG} >0, when tuning the Fermi level into the conduction (Fig 1b) or valence band, there is a strong decrease of the respective valley lifetimes, black data points Fig. 1c, consistent with both electron-phonon and spin-orbit scattering. The longest lifetimes are seen for spin-polarized bound excitons in the band gap region, red data points in Fig. 1c. We explain our findings via two distinct, Fermi level-dependent scattering channels of optically excited, valley polarized bright trions either via dark or bound states. By electrostatic gating we demonstrate that WSe_2 can be tuned to be either an ideal host for long-lived localized spin states or allow for nanosecond valley lifetimes of free charge carriers (>10 ns) explaining the huge variation in previously reported lifetimes extracted from TRKR [1],[2],[3]

References

[1] Yang, L.; Sinitsyn, N. A.; Chen, W.; Yuan, J.; Zhang, J.; Lou, J.; Crooker, S. A.; Nat. Phys.,11 (2015) 830–834Authors, Journal, Issue (Year) page
[2] Molina-Sánchez, A.; Sangalli, D.; Wirtz, L.; Marini, A., Nano Lett., 17 (2017) 4549
[3] Hsu, W.-T.; Chen, Y.-L.; Chen, C.-H.; Liu, P.-S.; Hou, T.-H.; Li, L.-J.; Chang, W.-H., Nat. Commun., 6 (2015) 8963

Figures

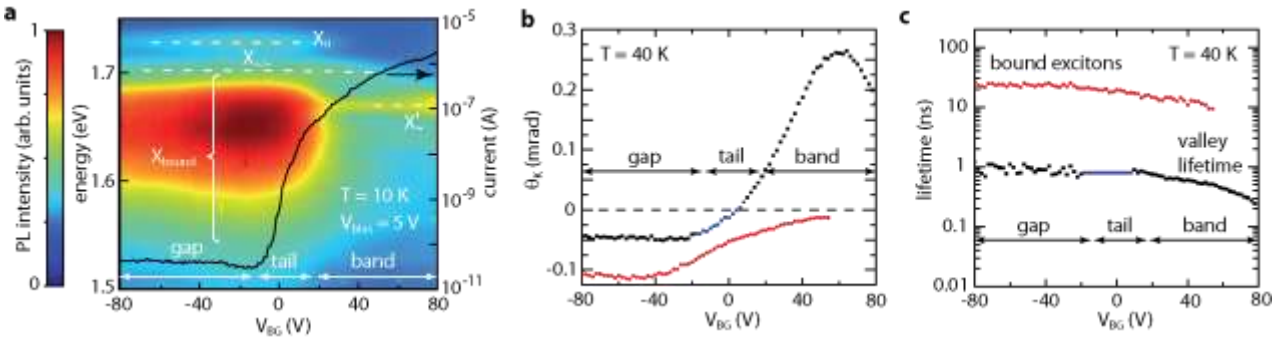

Figure 1: a) Gate-dependent photoluminescence and electrical transport measurements are used to determine the position of the Fermi level within the band structure of the TMD as a function of gate-voltage. b) Gate-dependent Kerr rotation amplitudes θ_K and c) lifetimes.