Isotope-Tailored Valley Emissions under Resonant Excitation in Monolayer WS_2

Rahul Kesarwani[1, 2*]
Vaibhav Varade[1], Martin Kalbac[2], and Jana Vejpravova[1*]
[1] *Department of Condensed Matter Physics, Faculty of Mathematics and Physics, Charles University, Ke Karlovu 5, 121 16 Prague 2, Czech Republic*
[2] *Department of Low-Dimensional Systems, J. Heyrovsky Institute of Physical Chemistry, Dolejskova 3, 182 23 Prague 8, Czech Republic*
rahul.kesarwani@matfyz.cuni.cz

The unique valley-type electronic band structure found in 2D semiconducting materials positions them as excellent candidates for cutting-edge spintronic and valleytronic devices. However, the intricate spectrum of quasi-particles, such as neutral, charge, and localized excitons, and the presence of defects in the band, reduce electronic and optical efficiency, limiting the use of 2D semiconductor potential for practical applications. Consequently, comprehending and controlling the population of various quasi-particle energy levels while keeping the K+ and K- valleys selectivity becomes crucial. In this study, we systematically introduced sulfur isotopes (^{N}S, ^{32}S, and ^{34}S) into monolayer WS_2 grown via chemical vapor deposition and explored the optical response of excitons, biexcitons, trions, and localized excitons through photoluminescence (PL) analysis under resonance excitation. To achieve this, we designed an in-house PL setup using circularly polarized light and detected the emission for both identical and opposite photon helicities. Given that the optical properties of WS2 are strongly influenced by external variables, we varied the magnetic fields from 0 to 14 T at a fixed temperature of 4K to gain a deeper understanding of optical transitions/scattering at K+ and K- valleys, as well as the formation of quasi-particles and the intricate interplay between the circularly polarized photons and phonons. We proposed a phenomenological model to describe the resonance excitation (up conversion) and valley scattering processes under a magnetic field on monolayer WS_2 for sulfur isotopes ^{N}S, ^{32}S, and ^{34}S. Our findings provide valuable insights for the design and optimization of future devices utilizing 2D materials.

References

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Figures

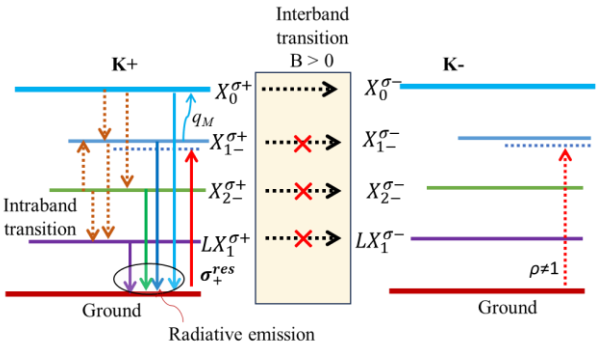

Figure 1: Mechanism of upconversion and band scattering phenomena on magneto-resonance PL at 4K in monolayer WS_2 (S stand for Natural sulfur).