Temperature dependent studies of Raman modes in few-layer $MoSe_2$

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The layered structure of molybdenum diselenide ($MoSe_2$) results in a complicated spectrum of the Raman scattering due to out–of–plane A_{1g}–related modes. In 3L of $MoSe_2$ the spectrum excited with 514 nm excitation [1] is composed of two out–of–plane Raman active modes. The higher energy mode (i) corresponds to vibrations in which Se atoms in all $MoSe_2$ layers move in phase. In the lower energy mode (j) in 3L Se atoms in the central MoSe2 planes vibrate out–of–phase with respect to vibrations of Se atoms in the outer layers.

In this work we investigate how the A_{1g} Raman modes in 3L $MoSe_2$ sample evolve with temperature. Both Stokes and anti-Stokes scattering is studied in temperature range from T=4.2K to T=300K. In Stokes scattering the lower energy component (*j*) does not change its intensity with increasing temperature, while the higher one (*i*) varies having its maximum at 60 K. This behaviour does not occur for anti-Stokes spectra, where both peaks increase with temperature. We assume it may be connected with excitonic resonances recently studied in $MoTe_2$ material [2]. Further studies for different thickness of material are being continued.

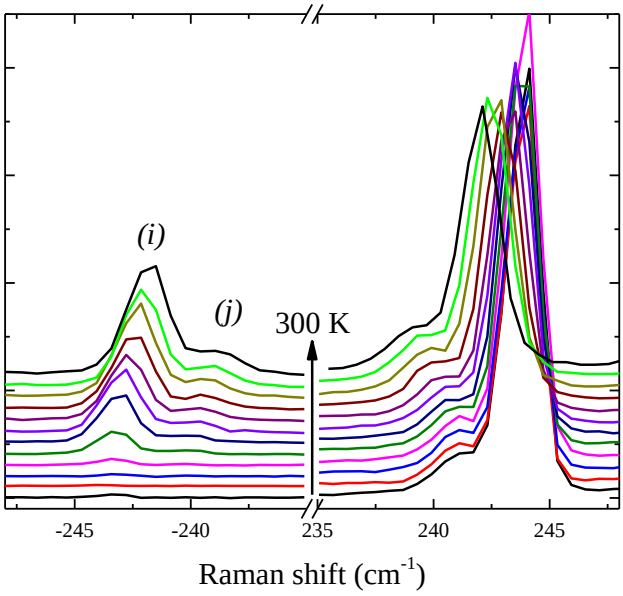

Figure 1: Anti-Stokes and Stokes Raman spectra of A1g mode in 3 layers $MoSe_2$.

[1] P. Tonndorf, R. Schmidt, P. Böttger, X. Zhang, J. Börner, A. Liebig, M. Albrecht, C. Kloc, O. Gordan, D. R. T. Zahn, S. Michaelis de Vasconcellos, and R. Bratschitsch, *Opt. Express* **21**, 4908-4916 (2013)

[2] M. Grzeszczyk, K. Gołasa, M. Zinkiewicz, K. Nogajewski, M. R. Molas, M. Potemski, A. Wysmołek, A. Babiński, *ArXive* 1511:07184.