Characterization of Energy Coupling Factor Between Optical and Acoustic Phonons Under Photon Excitation in 2D Transition Metal Dichalcogenides

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Under photon excitation, 2D materials experience cascading energy transfer from electrons to optical phonons (OPs) and acoustic phonons (APs). Despite few modeling works, it remains a long-history open problem to distinguish the OP and AP temperatures, not to mention characterizing their energy coupling factor (G). Here, the temperatures of longitudinal/transverse optical (LO/TO) phonons, flexural optical (ZO) phonons, and APs were distinguished by constructing steady and nanosecond (ns) interphonon branch energy transport states and simultaneously probing them using nanosecond energy transport state-resolved Raman spectroscopy. A breakthrough was made on measuring the intrinsic in-plane thermal conductivity of suspended nm MoS_2 and $MoSe_2$ by completely excluding the interphonon cascading energy transfer effect, rewriting the Raman-based thermal conductivity measurement of 2D transition metal dichalcogenides (TMDs). $G_{OP\leftrightarrow AP}$ for MoS_2, $MoSe_2$ are characterized. $G_{OP\leftrightarrow AP}$ was in the order of 10^{15} and 10^{14} $W\cdot m^{-3}\cdot K^{-1}$ and $G_{ZO\leftrightarrow AP}$ was much smaller than $G_{LO/TO\leftrightarrow AP}$. Under ns laser excitation, $G_{OP\leftrightarrow AP}$ was significantly increased, probably due to the reduced phonon scattering time by the significantly increased hot carrier population. Graphene paper (GP) was used to verify the reliability of the proposed method. For GP, $G_{LO/TO\leftrightarrow AP}$ was 0.549×10^{16} $W\cdot m^{-3}\cdot K^{-1}$, agreeing well with the value of 0.41×10^{16} $W\cdot m^{-3}\cdot K^{-1}$ by first principles modeling.