Investigating Heat Transport in 2D Materials: A Novel Spatiotemporal Approach

S. Varghese[1,2]
J. D. Mehew[2], D. Saleta Reig[1,2], K. J. Tielrooij[1,2]

[1] Department of Applied Physics, TU Eindhoven, Den Dolech 2, 5612 AZ, Eindhoven, The Netherlands
[2] Catalan Institute of Nanoscience and Nanotechnology (ICN2), CSIC and BIST, Campus UAB, Bellaterra 08193, Barcelona, Spain
s.varghese2@tue.nl

Thermal management is crucial for the performance of electronic and optoelectronic devices. Unravelling the heat transfer mechanisms in 2D materials, such as transition metal dichalcogenides (TMDs), is essential for advancing device functionalities. However, current methodologies face challenges, often requiring several known material parameters and significant heating ($\Delta T > 10K$) to accurately assess thermal properties.

In this study, we present a solution to address these limitations by introducing a novel spatiotemporal pump-probe microscopy technique [1]. Our method exploits the spatial heat profile measured at a pre-time-zero pump-probe delay, enabling the detection of residual heat from previous pump pulses within the pulse train. Specifically, our pre-time-zero condition corresponds to a time delay of approximately 13 nanoseconds. We validate the efficacy of our technique by quantifying the thermal diffusivity (D) of four different transition metal dichalcogenide (TMD) materials, obtaining values of 0.18 ± 0.01 cm^2/s for $MoSe_2$, 0.20 ± 0.03 cm^2/s for WSe_2, 0.35 ± 0.03 cm^2/s for MoS_2, and 0.59 ± 0.07 cm^2/s for WS_2, which are consistent with previous findings [2] and atomistic calculations. Additionally, we obtain the thickness-dependent diffusivity of $MoSe_2$, ranging from 3L to 32L, and find agreement with recent literature [3]. These results underscore the precision and versatility of our technique in characterizing the thermal properties of 2D materials.

Moreover, we propose that our approach holds promise for investigating previously unattainable insights into non-diffusive heat transport phenomena in low-dimensional materials, opening new avenues for research and technological advancement.

References

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