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Machine learning assisted Raman spectroscopy for temperature mapping in suspended 2D materials systems

Thermal management remains a major challenge for nanotechnology applications, such as nanoscale electronics.[1] However, characterizing the heat-spreading potential of nanoscale materials is challenging due to the profound differences between heat transport at the nanoscale and in bulk. Consequently, thermal conductivity studies are crucial for evaluating the heat-spreading potential of new materials.

In this context, Raman thermometry has emerged as a promising tool for the non-contact characterization of thermal maps, providing nanoscale resolution. More specifically, two laser Raman thermometry can be used to measure temperature maps of heated structures, which can be used to characterize heat transport properties of the studied materials such as the in-plane thermal conductivity. However, the Raman effect is comparatively weak, and therefore relatively long acquisition times are typically required to achieve sufficient signal quality. In recent years, machine learning (ML) studies have demonstrated the potential to significantly enhance the speed and quality of Raman spectroscopy measurements.[2] Nevertheless, studies focusing on the application of ML models to the temperature-dependent aspects of Raman spectroscopy remain scarce.

In this study, we acquire Raman maps of different material systems using a very low acquisition time of 1 s per spectrum with more than 1000 spectra per map. The Raman spectral maps are recorded while heating the samples using a temperature-controlled stage from Room temperature up to 100 °C, allowing a large number of data points to be obtained at each temperature. The temperature-dependent peak position shifts are subsequently evaluated as a function of temperature. Conventional fitting approaches enable the characterization of the temperature dependence based on the peak position shift, with the resulting slopes in good agreement with literature values. These datasets serve as the basis for the development of ML models that enable a more accurate and faster analysis of Raman map scans. The aim is to increase the speed of temperature measurements by a factor of more than 10, providing a promising approach to accelerate the thermal characterization of nanoscale materials.

References

[1] Shi, L. et al. Taylor & Francis, 19, 127-165, 2015.

[2] Qi, Y. et al., Adv. Opt. Mater. 11, 2203104, 2023.