Resonance Raman scattering provides new ways for high-sensitivity temperature probing
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When a nm-thick WS$_2$ is experiencing resonance Raman scattering under 532 nm laser excitation, its two Raman peaks ($A_{1g}$ and $E_{2g}$) have different variation behaviors against temperature, while their ratio ($\text{Ratio} = I_{A_{1g}} / I_{E_{2g}}$) shows universal behavior regardless of the sample structure (thickness, suspended or supported). This ratio changes by more than 100-fold from 177 K to 477 K, demonstrating its robustness in high-sensitivity temperature probing. Credit: Hamidreza Zobeiri et al

Raman-based thermometry has been used for decades, mostly by tracking the wavenumber shift to measure temperature. This renders a very unique material-specific nature of Raman thermometry, making it possible to achieve very specific temperature measurement and probe a temperature drop across a sub-nm spacing.

However, Raman wavenumber is subjected to various experimental noises and uncertainties, such as optical focusing, optical interference within a material and across an interface. The ultimate measurement sensitivity is documented low. Although Raman scattering intensity also changes with temperature, it is rarely used for temperature measurement since it is hard to control all the experimental conditions to well define the scattering intensity.

In resonance Raman scattering (e.g WS$_2$), due to the slight bandgap change against temperature, the scattered Raman intensity is very sensitive to temperature, and the intensity of a single Raman peak is still difficult to use for temperature measurement.

By using WS$_2$ nanofilms, either supported or suspended, the three teams at Iowa State University, Shenzhen University, and Shanghai University of Engineering Science discovered that the two Raman peaks of WS$_2$ ($E_{2g}$ and $A_{1g}$), although each of them shows different variation trend against temperature, their intensity ratio

Thermal scientists from the Iowa State University, Shenzhen University, and Shanghai University of Engineering Science, have developed a new thermal probing technique based on the ratio of two resonance Raman scattering peak intensities.

Publishing in the International Journal of Extreme Manufacturing, the team led by Prof. Xinwei Wang at Iowa State University, systematically studied and proved that the ratio of two resonance Raman peak intensities of a 2D material can be used as an indicator for high-sensitivity temperature measurement. This new development will significantly broaden the traditional Raman-based temperature measurement (based on wavenumber shift) while significantly improving the measurement sensitivity and robustness.

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surprisingly shows a very universal behavior, regardless of the material's physical size, suspended or supported, nm-level or macrosize.

Also this ratio shows dramatic change from 177 K to 477 K (>100-fold). This clearly demonstrates its capability for temperature measurement. Using this ratio as the indicator, the teams have characterized the thermal diffusivity and thermal conductivity of suspended WS$_2$ nanofilms with their energy transport state-resolved Raman (ET-Raman). The results agree very well with the measurement based on Raman wavenumber.

One of the team leaders, Prof. Xinwei Wang said, "This Resonance Raman Ratio (R3) method is superior to the classical wavenumber-based temperature measurement in three aspects."

First, since the intensity ratio is used, any optical focusing or optical interference-induced intensity shift will be automatically eliminated in the ratio. This will dramatically improve the measurement robustness. Second, for many wavenumber-based methods, at low temperatures the Raman wavenumber becomes much less sensitive to temperature change, making the measurement less reliable.

However, the R3 method has an almost universal sensitivity from 177 K to 477 K. For even lower temperatures, measurement is possible by searching for appropriate materials whose bandgap change will cause larger intensity variation at lower temperatures. Third, the finding will make WS$_2$ a promising temperature sensor for measuring the temperatures of non-Raman active materials. The sensor's time response will be extremely fast.