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Thermal diffusivity measurements with a single nanoparticle

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Tailoring the thermal conductivity of materials is of high technological importance. Efficient thermoelectric materials are good electrical and bad thermal conductors at the same time. In recent years great efforts have been undertaken to develop nanocomposites that own these properties. We have extended photothermal single particle microscopy to characterise the thermal diffusivity of a great variety of materials on the nanoscale. In photothermal microscopy a single particle is heated optically resulting in a temperature profile around the particle. This leads to a refractive index profile which is detected by a non-absorbed probe laser beam. Usually the transmission of the probe laser is detected when the particle is heated and not heated.

We measure the modulation of the detection laser beam at several modulation frequencies where the oscillation of the heating laser is fast compared to the thermal transport. Thus the modulation of the detection laser beam decreases with frequency and the maximal signal shifts with respect to the heating laser beam (see fig. 1 (*left*)). The comparison between the experimental data and detailed numerical calculation[1] yields the thermal diffusivity (see fig. 1 (*right*)). We show that photothermal microscopy is capable to determine the thermal conductivity in a great variety of materials.

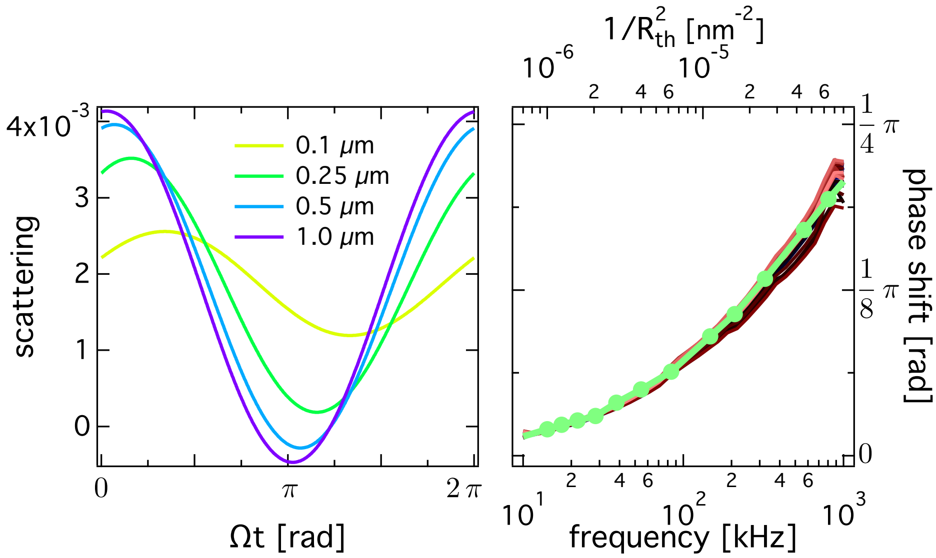

Figure 1: (*left*) The action of a modulated heat source is calculated on a laser beam at different times during the modulation cycle Ωt. The modulation amplitude and the shift of the maximum depends strongly on the thermal diffusion length R_{th}. (*right*) The calculated phase shift is plotted against $1/R_{\text{th}}^2$ whereas the experimental data are plotted against the modulation frequency. The comparison between experiment and calculation gives the thermal diffusivity of $(3.8 \pm 0.6) \cdot 10^{-08}\,\text{m}^2\,\text{s}^{-1}$.

References

[1] M. Selmke, M. Braun, F. Cichos: *Photothermal single particle microscopy: Detection of a nanolens*. ACS Nano **6**, 2741–2749 (2012)