A novel technique to measure thermal diffusion of thin films

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Understanding heat transport at the nanoscale is of great importance to fundamental science and the development of efficient electronic devices. A precise understanding and control of the transport mechanisms is important for enabling thermoelectric, optoelectronic, and medical applications. For these reasons, there is great interest in the development of tools to study nanoscale heat transport through electrical [1,2] and optical [3,4] techniques. However, there lacks a technique that meets the following requirements: (i) minimal sample fabrication, (ii) high sensitivity to small temperature changes, (iii) simple mathematical modelling and (iv) few input parameters.

Here we address these challenges and demonstrate a novel method for quantifying thermal diffusivity (*D*) in nanometre thick materials by spatiotemporally probing a temperature-dependent optical resonance using visible light. Our experimental setup combines two femtosecond laser pulses in a pump-probe configuration: one to excite the sample (pump) and the other to probe the pump-induced changes in reflectivity [5]. By raster scanning the probe over the pump spot we resolve the spatial profile of the reflection signal with nanometre spatial precision. We achieve femtosecond temporal resolution by delaying the arrival of one pulse with respect to the other.

Over picosecond timescales we observe the diffusion of the electronic excitation in which the spatial profile broadens by 10´s of nanometres. However, on much longer timescales (>10 ns) we observe a significantly broadened profile which we attribute to the diffusion of heat carried by phonons. We determine the thermal diffusivity of the sample using a simple model based on the heat equation where the only input parameter is the initial width of the spatial profile. As a proof of concept we measure the diffusivity of suspended transition metal dichalcogenide flakes and find excellent agreements with reported literature values of heat capacity and thermal conductivity [6].

References

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