I. Physikalisches Institut (IA)
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Topic for a Master Thesis

Coherent Phonons in the Presence of an external Electric Field

Coherent phonons are crucial for understanding the ultrafast dynamics of solids and can help to better understand the (metavalent) bonding mechanism in materials. In this femtosecond pump-probe experiment, an ultrashort laser pulse (pump) excites the material, inducing collective vibrations of atoms in the crystal lattice. These coherent phonons reflect the coupling between electronic excitations and the atomic lattice structure, which is responsible for the bonding mechanism. A time-delayed laser pulse (probe) measures the response of the system so that the temporal evolution of the phonon dynamics can be followed. This technique allows the interaction of electrons and phonons to be observed directly, providing deeper insights into the bonding mechanism and its relevance to material science phenomena.

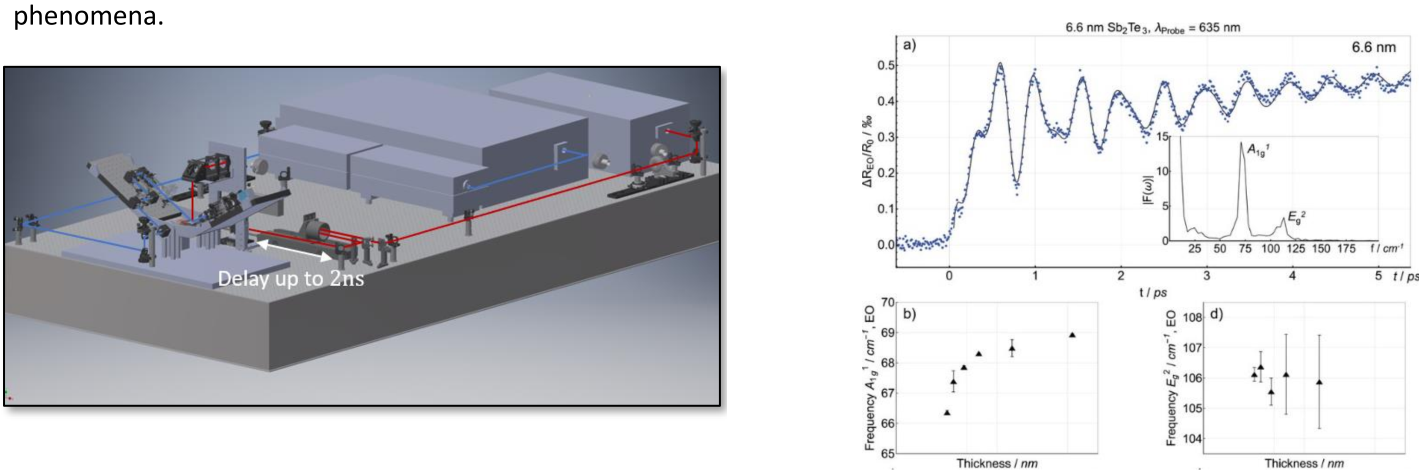

Figure **1**: (**Left**) Simplified schematic of the pump probe setup used in this work. The red line indicates the pump beam which excites the sample and can be delayed with respect to the probe beam which is shown in blue. This allows to measure the material response from femtosecond up to picosecond timescales. (**Right)** Example transient reflectivity trace of a 6.6 nm Sb_2Te_3 film. The oscillations stem from phonon dynamics. The frequencies contained in these oscillations show different dependencies of the film thickness which is shown in the lower two figures. Figure taken from [1].

After the confinement effect in e.g. Sb_2Te_3 was investigated in detail [1] but also pump polarisation measurements were successful, a further parameter will be introduced in this work - an external electric field. For this purpose, the samples are prepared using molecular beam epitaxy (MBE) and contacted with electrodes. This allows a voltage to be applied and the influence of the electric field to be analysed during the pump probe measurements. Raman measurements have already shown that such a field can have a significant influence [2], so that this should now also be shown on the native (picosecond) time scales of the phonons.

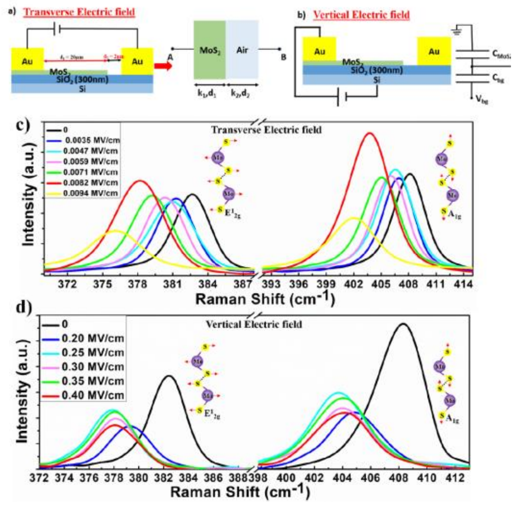

Figure **2**: Raman measurements of MoS_2 with different electric fields. The top figures show the scheme of the device configuration and two different possibilities how to apply an external electric field. The bottom plots are Raman measurements at different voltages/electric field strengths where a clear shift of the peaks is visible. Figure taken from [2].

[1] Mertens, Julian, et al. "Confinement-Induced Phonon Softening and Hardening in Sb2Te3 Thin Films." Advanced Functional Materials 34.1 (2024): 2307681.

[2] Rani, Renu, et al. "Impact of transverse and vertical gate electric field on vibrational and electronic properties of MoS2." Journal of Applied Physics 127.14 (2020).

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