HL 24: Thermal Properties

Time: Tuesday 12:15–13:00 Location: H14

HL 24.1 Tue 12:15 H14

Combined optical and thermal characterization of III-nitride membranes by microphotoluminescence and Raman thermometry — •Gordon Callsen[1], Mahmoud Elhajhasan[1], Julian Themann[1], Katharina Dudde[1], Guillaume Würsch[1], Jean-François Carlin[2], Raphaël Butté[2], Nicolas Grandjean[2], Nakib Haider Protik[3], and Giuseppe Romano[4] — [1]Universität Bremen, Germany — [2]EPFL, Lausanne, Switzerland — [3]HU Berlin, Germany — [4]MIT-IBM Watson AI Lab, Cambridge, USA

We present the optical and thermal analysis of photonic III-nitride membranes, which provides novel insights into the physics of thermal transport on the micrometer scale [1]. By combining Raman thermometry (RT) with μPL spectroscopy, we demonstrate a non-invasive approach to extract the thermal conductivity κ. This analysis shows that even at 295 K one can still observe quasi-ballistic phonon transport in GaN, which challenges commonly applied models building on purely diffusive transport. Our membranes are made from c-plane GaN and comprise $In_xGa_{1-x}N$ (e.g., x = 0.15) quantum wells that already served as an active medium in various nanolasers [2]. The material is either grown on silicon or sapphire and is subsequently underetched, yielding freestanding structures. On such samples we perform μ-RT, either based on one-laser RT or spatially resolved two-laser RT. The latter is key to our thermal imaging, representing a significant step towards non-invasive and quantitative thermometry on photonic membranes. [1] M. Elhajhasan et al., PRB 108, 235313 (2023) [2] S. T. Jagsch et al., Nat. Commun. 9, 564 (2018)

HL 24.2 Tue 12:30 H14

Impact of AlGaAs interlayers on the thermal conductivity of GaAs micropillars — •Guillaume Würsch[1], Ching-Wen Shih[2], Mahmoud Elhajhasan[1], Katharina Dudde[1], Imad Limame[2], Stefan Reitzenstein[2], and Gordon Callsen[1] — [1]Institut für Festkörperphysik, Universität Bremen, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, Germany

First measurements of coherent heat conduction in semiconductor superlattices (SL) were reported over a decade ago. Interestingly, such an effect that is based on phonon interference can already be observed at room temperature, which sparks interest in measuring and controlling most fundamental phonon parameters like their mean free path l_{mfp} and wavelength λ_{therm}.Observing the effects of phonon interference in SLs can be challenging, because material stacks with superb crystalline quality and interfaces is required. In this work, we follow a step-by-step approach, meaning that we analyse GaAs micropillars (diameter: 0.5 - 2 μm) with a rising number (0 - 7) of $Al_{0.8}Ga_{0.2}As$ interlayers. A thin layer of gold on top of these structures enables the measurement of the thermal conductivity κ via the frequency-domain thermal reflection (FDTR) technique, which is complementary to the Raman thermometry that we apply.Our study on first samples with a small numbers of interlayers provides not only insight into the thermal impact of each individual interface, but highlights the impact of the micropillar diameter. Building on such knowledge will allow us in future studies on larger SLs to disentangle phonon interference effects and phonon scattering phenomena.

HL 24.3 Tue 12:45 H14

Signature of thermal phonon mean free paths monitored by Raman thermometry — •Katharina Dudde[1], Mahmoud Elhajhasan[1], Guillaume Würsch[1], Julian Themann[1], Nakib Protik[2], Dwaipayan Paul[2], Giuseppe Romano[3], and Gordon Callsen[1] — [1]Institut für Festkörperphysik, Universität Bremen, Germany — [2]Institut für Physik und IRIS Adlershof, Humboldt-Universität zu Berlin, Germany — [3]MIT-IMB Watson AI Lab, IBM Research, Cambridge, MA, USA

For an understanding of thermal phonon interference effects, one requires knowledge about the related phonon mean free paths l_{mfp}. In the recent past, spectroscopy methods were developed to determine l_{mfp} based on this idea: One performs thermal transport measurements under the variation of a characteristic experimental length scale L aiming to extract effective thermal properties such as the effective thermal conductivity $\kappa_{eff}(L)$. In this contribution, we analyze how non-invasive one-laser Raman thermometry (1LRT) can pose a novel option to perform thermal phonon l_{mfp} spectroscopy. Therefore, we first analyze bulk silicon at 293 K, while varying the laser focus spot radius (w_e). Here, we find a strong dependence of κ_{eff} on w_e. This dependence is more pronounced at 200 K, because l_{mfp} is increased. The second variable length scale for 1LRT is the light penetration depth (h_α), which is varied in a set of measurements for silicon membranes at 293 K. Again, a dependence of κ_{eff} on h_α is observed. Finally, our variation of w_e or h_α during 1LRT provides first insight into the impact of different thermal phonon l_{mfp} ranges on κ_{eff}.