

# Accessing the phonon dispersion of nanostructures via grazing incidence inelastic x-ray scattering spectroscopy

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The vibrational properties of a crystalline material, the so-called lattice dynamics, are a prototypical example of structure-function relations and have far reaching implications for fundamental material properties and subsequent device functionality. Further, with the ever more commonplace deployment of the unique advantages of nanostructured materials and devices, where novel crystallographic phases are stabilised and finite size effects can dominate, it is imperative we develop methods for exploring the full vibrational behaviours of these systems. However, probing the lattice dynamics of nanostructures presents a formidable experimental challenge due to the intrinsically low sample volume. By employing advanced nanofabrication methods [1,2] to produce a highly aligned 2D hexagonal comb-like array of nanowires and combining this with meV-resolution grazing incidence inelastic x-ray scattering (GI-IXS) at a 4th generation synchrotron source (ESRF, France) we demonstrate the first direct phonon dispersion characterisation of a nanostructured system. These studies were supported by large reciprocal volume mapping via synchrotron based, grazing incidence x-ray diffraction to characterise the static structure prior to the dynamic investigations.

The InP system, normally zincblende in bulk but stabilised into the wurtzite structure at the nanoscale [3], is chosen as a demonstration case due to its promise as a future solar cell candidate material with absorption efficiencies of 71%, photoconductivity lifetimes of over 1 ns and, when implemented in triple junction cells, the potential to reach solar power conversion efficiencies of up to 47%, all with the reduced material costs inherent to a nanowire array [4-6]. We probe a mixture of acoustic and optical phonon dispersion relations along the primary directions;  $\Gamma$ -K-M,  $\Gamma$ -M,  $\Gamma$ -A and compare to *ab initio* lattice dynamics simulations for the wurtzite InP phase, showing good agreement. These methods and their successful demonstration opens the door for exploring lattice dynamics in a vast range of nanostructured materials and are expected to become a key part of the experimental toolkit for the understanding and development of future nanostructured devices.

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