Structural Characterization of Rolled-up $GaAs/In_{0.2}Ga_{0.8}As$ Multilayer Tubes by Coherent Phonon Spectroscopy

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Rolled-up crystalline multilayers are promising candidates for a wide range of applications in a number of interdisciplinary fields such as in fluid transportation, thin film transistors or thermoelectric devices,[1,2] as well as for microtube lasers[3]. Here, the radial geometry of the structures itself but also the simplicity of the fabrication process[4] compared to conventional techniques makes this type of superlattice especially appealing. It is not necessary to grow the full layer stack by molecular beam epitaxy (MBE) but instead by growth of a strained bilayer which rolls up upon release from the substrate and forms a multilayer roll. Additionally there is the possibility to use novel materials and material combinations which remain challenging for usual growth techniques[5]. A detailed characterization of these structures is necessary to establish a better understanding of their mechanical properties including the adhesion between the individual windings.

We investigated the acoustic phonon modes with asynchronous optical sampling[6] in rolled-up multilayers experimentally and theoretically. The thickness of the layers are in the nanometre range and diameters of the tubes in the micrometre range. The results are compared to plane, unrolled multilayers grown completely by MBE. For these samples the experimentally obtained modes show characteristics of a superlattice and match well to calculations obtained by the Rytov model. In contrast, the rolled-up superlattice tubes exhibit differences compared to the plane structures. The modes cannot be described anymore by the Rytov model due to imperfect adhesion. By using a transfer matrix method where a massless spring is included which accounts for the imperfect adhesion between the layers a good agreement between experiment and calculations is achieved for up to five windings. This allows us a spatially resolved characterization of individual multilayer tubes with micrometre spatial resolution where areas with varying interface adhesion can be identified.

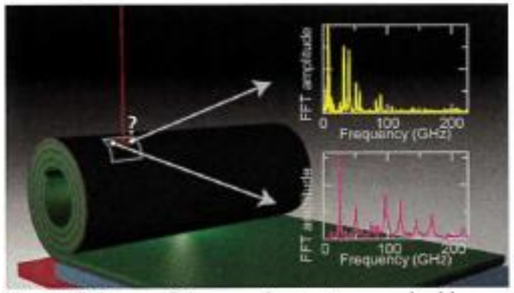

Fig. 1: Scheme of the sample structure excited by a laser pulse. Possible acoustic phonon modes of the multilayer tubes are shown in the Fourier transformations on the right.

References:

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