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Future Directions for Studies and Applications of Coherent and Incoherent Phonons

Phonon physics has advanced rapidly during the past few years and has found many new applications for the study of nanostructures. Using the picosecond ultrasonic technique, short pulses of longitudinal sound can be generated and detected and ultrasonic measurements made on small structures. This has made possible the measurement of the elastic properties of thin films, the adhesion between films, and the geometry of multi-layer structures. In a few experiments, it has also been possible to perform experiments with shear waves using specially prepared samples. A number of different approaches have been used for the study of Rayleigh surface waves. By dividing the pump light into two beams and directing these onto the surface of the sample at different angles, an interference pattern can be set up giving an energy absorption which varies periodically across the surface. This makes it possible to generate surface waves. A spatially varying energy absorption can also be produced by patterning the surface of the sample but, of course, this has the disadvantage that the sample is irreversibly modified. I will describe experiments in which surface waves are generated when a transparent optical mask is placed very close to the surface of the sample. The lower surface of the mask has a series of grooves to produce a variation of the intensity of the pump and probe light pulses across the surface of the sample. Because the light intensity varies with position, the application of the pump light pulse can generate surface acoustic waves with a wavelength equal to the period of the mask. With this technique it is also possible to detect longitudinal sound which propagates nearly parallel to the sample surface.

Ultrafast optics has also made it possible to study heat flow in nanostructures, to measure thermal conductivity, and to determine the Kapitza resistance at an interface between a film and a substrate. This type of measurement is of importance for understanding thermal management issues in computer chips and other semiconductor devices. I will describe a new method for analyzing the results of measurements of heat flow in small structures. This work is being performed in collaboration with Professor H. Ogi at Osaka University.