Pulsed Laser Opto-Acoustic Measurements in Solids from Macro- to Nano-Scale

S.N. Jerebtsov, A.A. Kolomenskii, and H.A. Schuessler[C,S]
Department of Physics, Texas A&M University, College Station, U.S.A.
schuessler@physics.tamu.edu

Recent developments of laser technology provide a unique opportunity to study elastic properties of materials at different scales, ranging from centimeters to nanometers. Lasers can be used for the excitation of elastic oscillations, as well as for their detection. The arsenal of laser methods includes time-resolved techniques at the femtosecond temporal scale, as well as achievement of high stresses in the excitation region close to and above the limit of the mechanical breakdown by a rapid deposition of energy with extremely high specific density. Flexibility of laser opto-acoustic techniques enables investigations of processes and systems that are not easily realizable by other methods. In this talk, some examples of these studies will be presented that include measurements with focused and straight-crested surface acoustic waves (SAWs) and femtosecond measurements of acoustic oscillations in nanoparticles.

We studied the changes of the pulse shape and the phase of the spectral components in converging SAW pulses excited with a femtosecond laser via the thermoelastic mechanism. To produce converging acoustic pulses, the laser beam was focused with an axicon into a circle on the surface of an aluminum sample. The phase absolute value of the spectral components, after the passage of the focal region, experienced a change close to 90 degrees (Gouy phase shift). These observations were confirmed by analytical and numerical calculations based on the two-dimensional wave equation for surface acoustic waves.

Laser generated broadband SAW pulses were also used for studying surface dynamical processes: the changes in a liquid layer deposited on a surface of a Si substrate and the monitoring of the ablation damage of Si surface. The etching depth and the extent of the damaged area increase with the number of pulses, affecting the transmission of SAWs. A model for evaluating the changes in the surface characteristics was developed and used for an assessment of the ablation process.

Recently, nanoparticles of different sizes (from a few to tens of nanometers) and shapes (spheres, rods, pyramids, cages) in solutions and solid crystalline and amorphous matrixes were fabricated and found applications for labeling, manufacturing of materials with engineered optical properties, and development of sensors at the single molecule level. The optical, mechanical, and thermodynamic properties of nanoparticles are size-dependent, and, recently, the possibility to investigate them with a femtosecond pump-probe technique exciting confined acoustic oscillations was demonstrated. We will discuss this technique and the acoustical and optical properties of nanoparticles obtained with it, as well as the possible extension of these studies to the nonlinear regime.