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Optical detection of longitudinal and shear acoustic waves with laser picosecond acoustics

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The absorption of picosecond light pulses in a medium can generate sub-THz acoustic waves. These cause a transient optical reflectance change that can be monitored by delayed probe light pulses. This technique, termed laser picosecond acoustics, can be used for the nondestructive evaluation of the physical properties of thin films and substrates.
This paper describes a general method for quantitative analysis of such reflectance changes. It is applicable to multiple anisotropic layers that may be opaque or transparent. Longitudinal or shear acoustic waves propagating along the stacking direction of the multilayers modulate the dielectric permittivity anisotropically and inhomogeneously through the photoelastic effect, through local rotation, or through the surface and interface displacements. We describe how the optical reflectance for obliquely incident probe light can be calculated for the modulated medium.
We then demonstrate the method with reference to experimental results for a sample consisting of a silica film on a zinc substrate in which both longitudinal and shear acoustic waves are generated and detected. The analysis yields the film thickness, sound velocity, and photoelastic tensor components, for example.
The method is also applicable to various light scattering problems involving the inhomogeneous modulation of optical properties such as in photothermal experiments.