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Laser picosecond acoustics in isotropic and anisotropic materials

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Abstract

We present experimental results concerning the laser generation of picosecond acoustic pulses and their propagation in isotropic and anisotropic materials. We make use of a conventional reflectance detection technique as well as interferometric detection to probe the real and imaginary changes in reflectance. We also demonstrate the detection of transverse acoustic waves by mode conversion at an interface between an isotropic polycrystalline film and an anisotropic substrate.

Keywords: Acoustics; Anisotropic; Interferometry thin film; Isotropic; Laser; Picosecond; Reflectance; Shear; Transverse acoustic wave; Ultrafast phenomena

1. Introduction

Laser picosecond acoustics is receiving growing attention because of its wide range of applications in materials characterisation as well as its potential for elucidating the physics of ultrafast light–matter interactions. A wide range of experiments have been reported on the generation and detection of longitudinal acoustic phonon pulses in thin films, multilayer structures and nanostructures [1–10]. Acoustic waves with frequencies from ~10 GHz to 1 THz can be generated and detected, corresponding to acoustic wavelengths in the range ~5–500 nm. The detection of acoustic echoes on reflection from buried interfaces reveals details of bonding, sound velocities, film thicknesses, ultrasonic attenuation and ultrafast acoustic generation mechanisms. There is still much scope for further research in this field. For example, material anisotropy in single-crystal films or substrates could be exploited to generate picosecond transverse acoustic waves. This would allow the possibility of accessing a greater number of elastic constants of thin film materials than is presently possible with laser picosecond acoustics. In addition, schemes for picosecond acoustic wave detection from surface vibrations have been proposed [7–10], but no set-up for picosecond surface vibration detection with a lateral spatial resolution smaller than 10 μm has been reported. In this paper we deal with the extension of the laser picosecond acoustic technique in these directions, presenting results demonstrating the detection of picosecond acoustic pulses with transverse polarisation by making use of a thin isotropic film on an anisotropic substrate, and describing measurements with a modified Sagnac interferometer which works at normal incidence with a single microscope objective.

2. Interferometric detection using a modified Sagnac interferometer

The measurement of ultrafast changes in refractive index and surface motion forms the basis of present techniques for laser picosecond acoustics. The initial proposal by Thomsen et al. [1] to detect picosecond ultrasonic pulses in opaque thin films relied on the coupling of the refractive index to strain. The detection of such pulses from ultrafast surface vibrations was reported a few years later using both interferometric detection in thin transparent films on opaque substrates and laser-beam deflection [7,8]. Other interferometric methods were also proposed for picosecond acoustics in

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