The use of acoustic pulses to 'see' into materials is well-known in echography or sonar applications. In order to push these techniques to ever higher spatial resolution we are exploring the possibilities of generating and detecting very high frequency sound pulses in solids with ultrashort laser pulses. Sub-picosecond optical pulses are used to excite ultrasonic pulses that travel inside the solid or along its surface. To see the tiny vibrations associated with these ultrasonic waves—smaller than the dimensions of a single atom in amplitude—and related refractive index changes, we use a set of ultrashort probe laser pulses and detect interferometrically the changes in optical amplitude and phase at the sample surface. The typical ultrasonic wavelength detected can be as short as a few nanometers. With such a miniature sonar system we can eavesdrop on sound passing through atomic cracks, ultrathin films and minute nanostructures. We can also watch coherent acoustic wave packets in two dimensions rippling across crystal surfaces and microscopic landscapes. \[1-7\]

I mention some examples here. In Fig. 1 the change in the optical reflection caused by longitudinally polarized picosecond ultrasonic pulses arriving at the sample surface for a triple-quantum-well GaAs/Al$_{0.3}$Ga$_{0.7}$As heterostructure is shown (red and purple curves for the optical amplitude ($\rho$) and phase ($\delta\phi$) changes, respectively). \[1\] The electron and hole wavefunctions in a quantum well define the carrier confinement, and according to the deformation-potential coupling of strain to the carrier density in direct-bandgap GaAs the terahertz frequency ultrasonic pulses are generated with a shape directly proportional to a weighted probability envelope of the electron and hole wavefunctions. Excellent agreement is obtained between the measured ultrasonic pulse shapes at around 100 ps delay time and a theory (blue and green curves) based on the confined carrier wavefunctions that also accounts for photoelastic coupling, interface displacements, and multiple optical reflections. \[2\]

I will describe how we have recently been able to extend this technique to generate transversely polarized picosecond ultrasonic pulses, that is, shear pulses. \[2\]

![Fig. 1. Probe amplitude $\rho$ and phase $\delta\phi$ variations for 1.64 eV photon-energy generation and 3 eV detection in a 3-well GaAs/Al$_{0.3}$Ga$_{0.7}$As heterostructure. Top and bottom curves: experiment for amplitude and phase, respectively. Middle curves: corresponding theory.](image)

In addition we present results for real time imaging and acoustic-dispersion analysis of MHz-GHz surface acoustic waves propagating on various crystals and microstructures. \[3\] An example is shown in Fig. 2 for point-generated surface acoustic waves on the (001)-cut anisotropic tetragonal crystal TeO$_2$ coated with a thin gold film. This work has the potential to usher in a new generation of ultrasonic transducers based on engineering carrier wavefunctions and to open the way to diverse studies in surface acoustic wave imaging.

\[7\] オリバ・ライト、菅原 茂博、松田 理、応用物理、vol. 73, No. 6, 732 (2004).