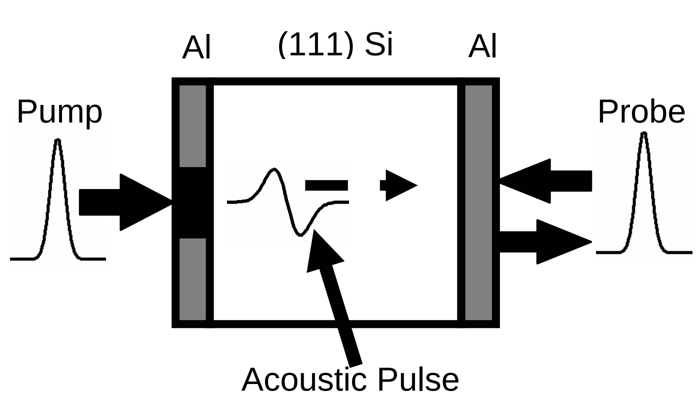
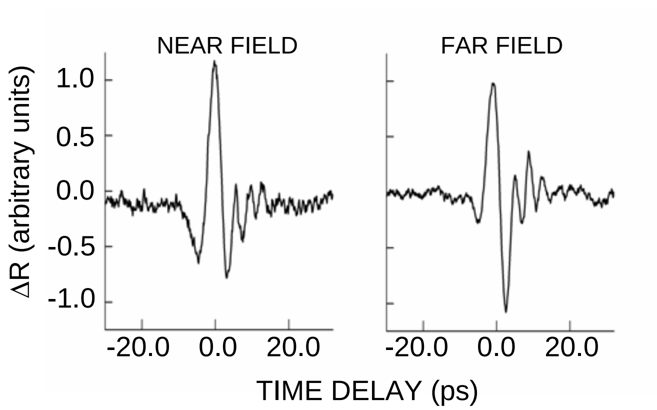
Picosecond Ultrasonics: Diffraction and 2D Imaging.

When an ultrashort light pulse (duration: ~ 100 fs, energy: < 1 nJ) is absorbed at the surface of a thin metal film, the resulting thermal expansion of the surface results in the generation of a strain pulse (composed of longitudinal acoustic phonons) that propagates into the film and the substrate. For a 15 nm Al film grown on a Si substrate this pulse will have a peak frequency and bandwidth both ~ 100 GHz, and a strain amplitude of about 1×10^{-4}. Reflections from buried interfaces will return to the surface, where they can be detected by means of a time delayed optical probe pulse. This phenomena was first studied in depth by researchers in Humphrey Maris' group at Brown University in the late 1980's, and is currently used in a thin film metrology technique (with nm resolution!) that sees widespread use in the microprocessor industry.

Here in Ted Norris' group at the University of Michigan we are working to extend this essentially 1D technique to 2D acoustic imaging of sub-micron scale



objects. To do this we must propagate these “picosecond ultrasonic” pulses for relatively longer distances than in previous work. Our first experiment is shown on the right. 15 nm Al films are grown on both sides of a double polished Si wafer that is 0.5 mm thick. For a tight enough pump beam focus (r ~ 3 μm) the propagation distance is long enough that we are probing the acoustic pulse in the *far field* of the acoustic source. The implication of far field detection is that we may then use the time reversal imaging techniques employed by other U of M researchers with THz electromagnetic pulses. The advantage of using near THz phonons is the much smaller wavelength (10’s nm versus 100’s of μm) and therefore much higher potential resolution. To show far field behavior we studied the temporal shape of our single cycle acoustic pulse and found that it indeed experienced the diffractive shape change that is expected as a pulse propagates from the near field to the far field. We observed this effect (known as the Gouy phase shift) by varying the pump spot size so that in one regime we would see a *near field* wave form and in the other, the *far field* form. This work was published in a recent article: N.C.R. Holme,



B.C. Daly, M.T. Myaing, T.B. Norris, Appl. Phys. Lett. **83**, 292 (2003). We are currently focusing our efforts in the acoustic imaging of nanostructures, stay tuned to this page for future results!