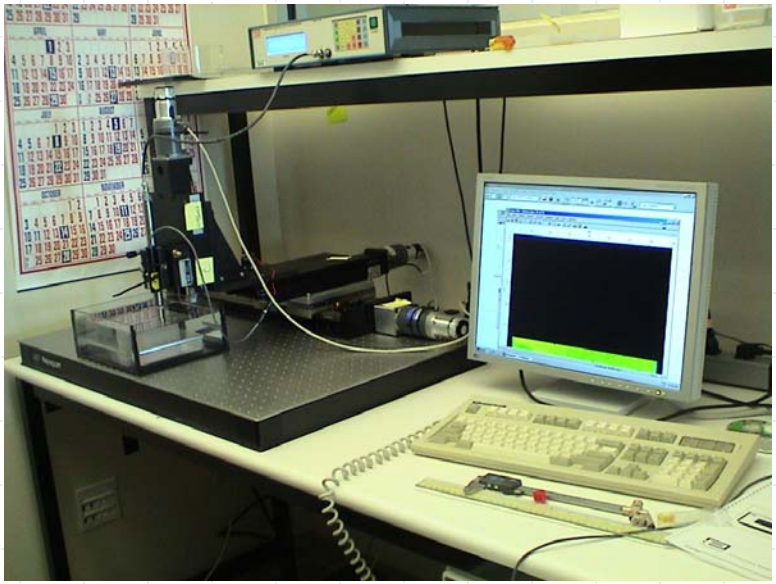
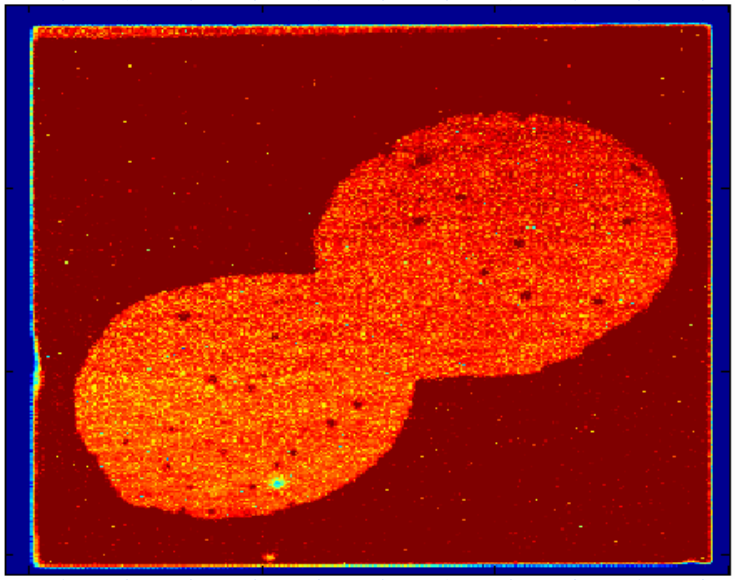
Optimizing Ultrasonic Imaging for Adhesively Bonded Plates





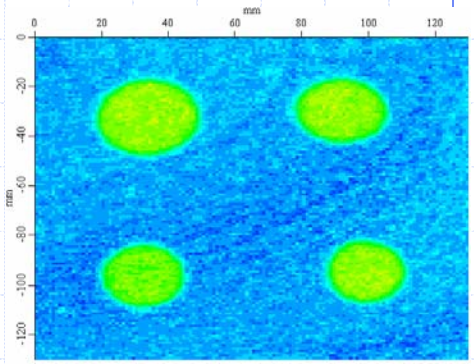
Experimental procedures and data reduction executed by Mike Conboy, Scot Hart, and David Harris/Weiel

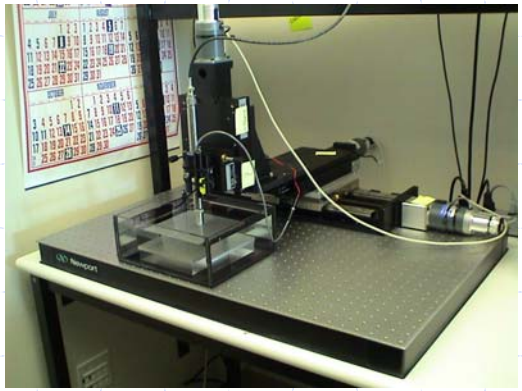
Performed under the guidance of Thomas N. Claytor

Optimizing contrast of ultrasonic scans motivated by introduction of visco-elastic gels.

Things to look forward to...

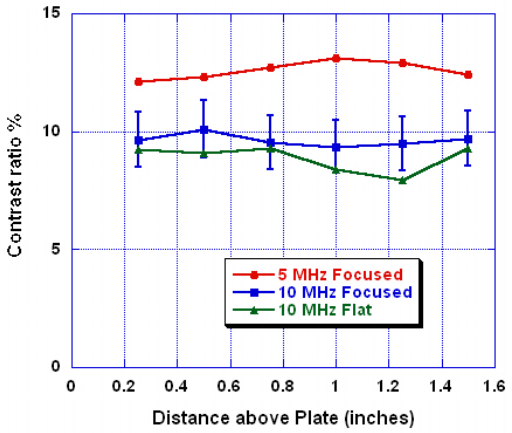
Introduction to Ultrasonic Scanning





Experimental Setup

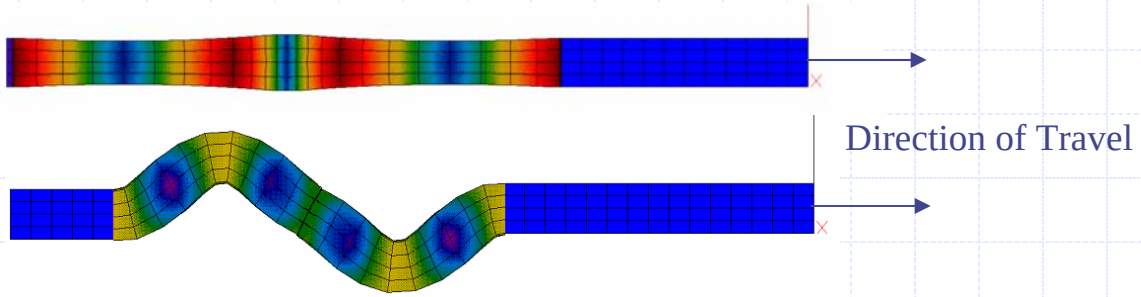
Contrast Ratio Analysis $CR_{measured} = \frac{V_{air} - V_g}{V_{air}}$



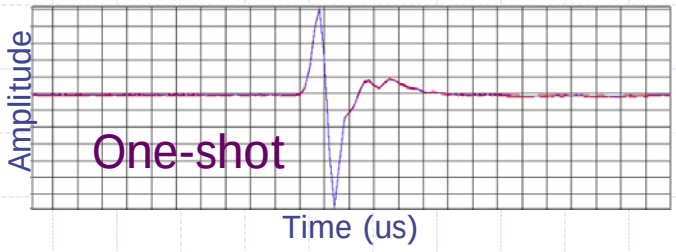
Experimental Results

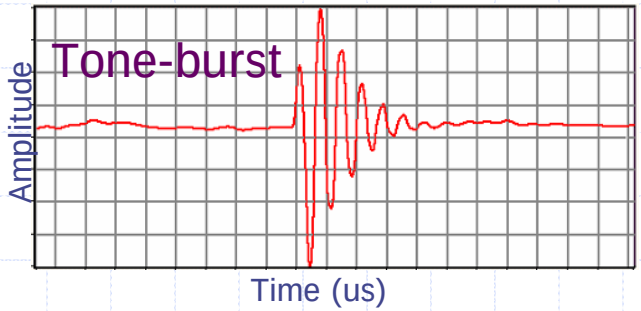
Ultrasonic waves come in two main forms and are often excited by two types of pulses.

- Two major types of ultrasonic (>20 kHz) waves
  - Longitudinal
  - Transverse



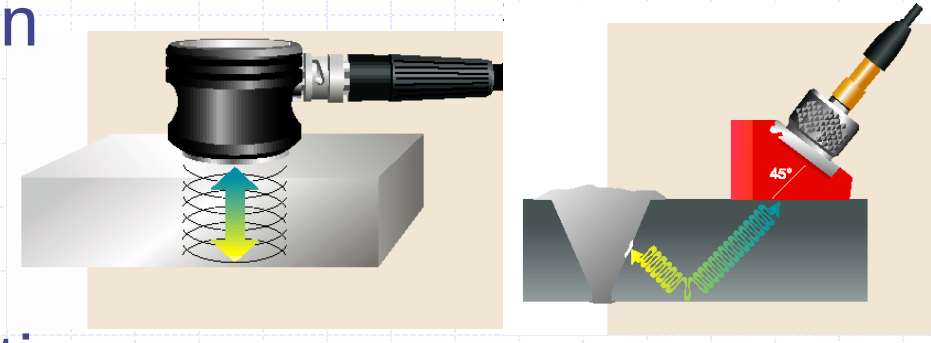
- Two principle shapes of excitation pulse



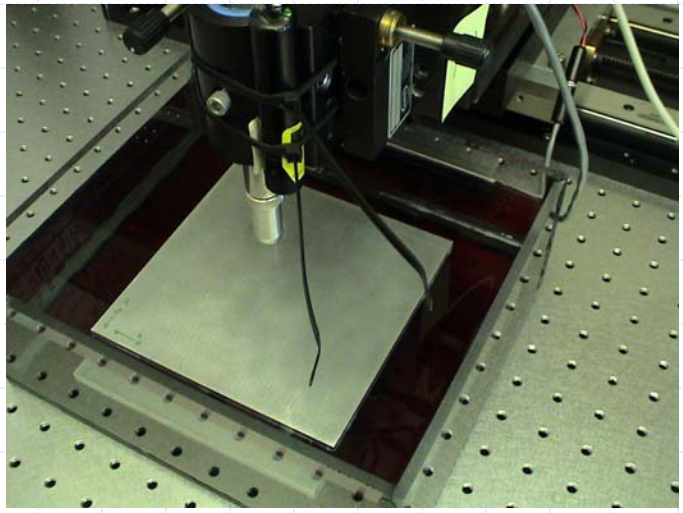


Transducer configurations change for different geometries and desired flaw detection.

- Transducer orientation
  - Normal incidence
  - Oblique incidence



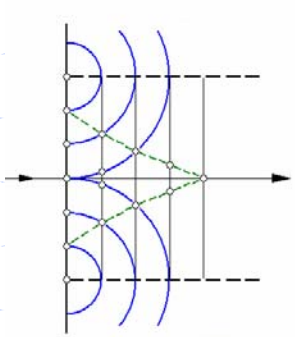
- Transducer configuration
  - Through transmission
  - Pulse-echo

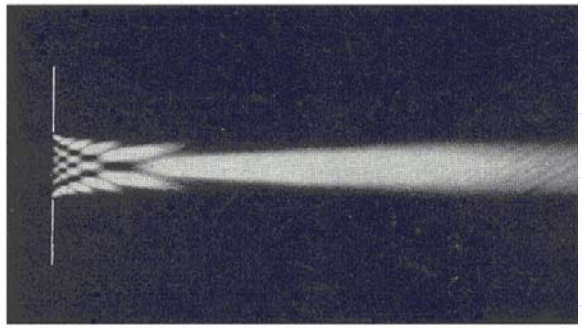


- Transmission technique
  - Contact
  - Immersion

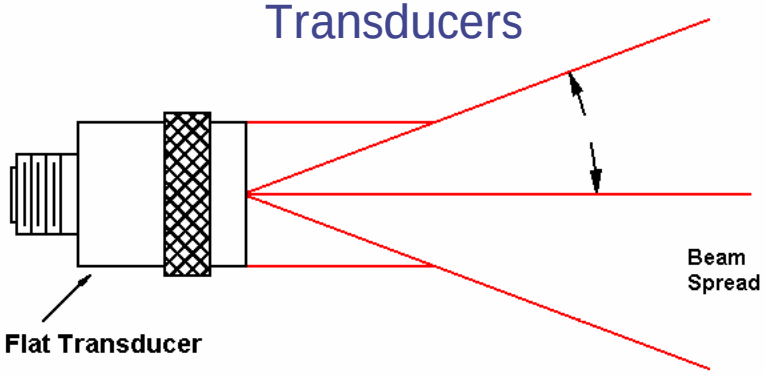
Piezoelectric transducer have some complex characteristics.

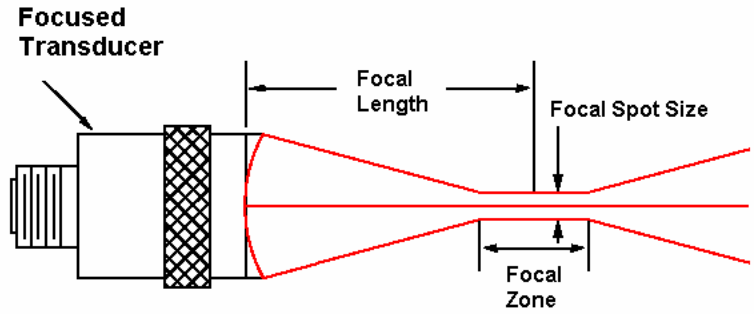
Near and Far Field Characteristics





Simplified Beam Pattern for Focused and Unfocused Transducers

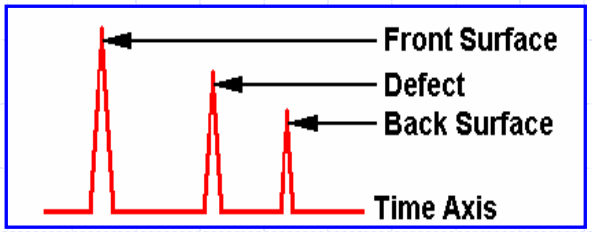




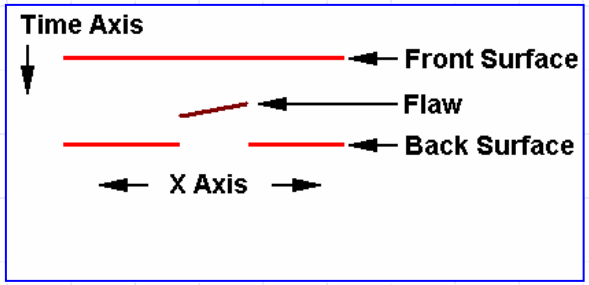
- Modeling transducers as formed of point-sources, interference pattern becomes apparent
- While actual beam patterns are complex, they can be simplified for calculations

In pulse-echo mode three types of scans can be made.

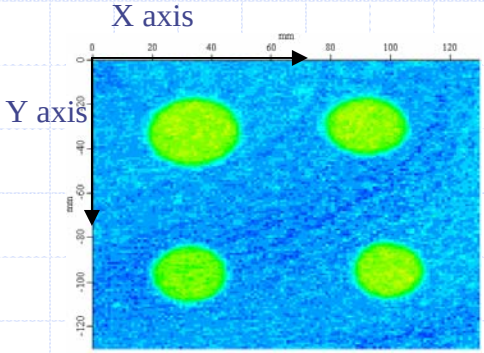
- Types of scan
  - A-scan: 1-D Amplitude vs Time

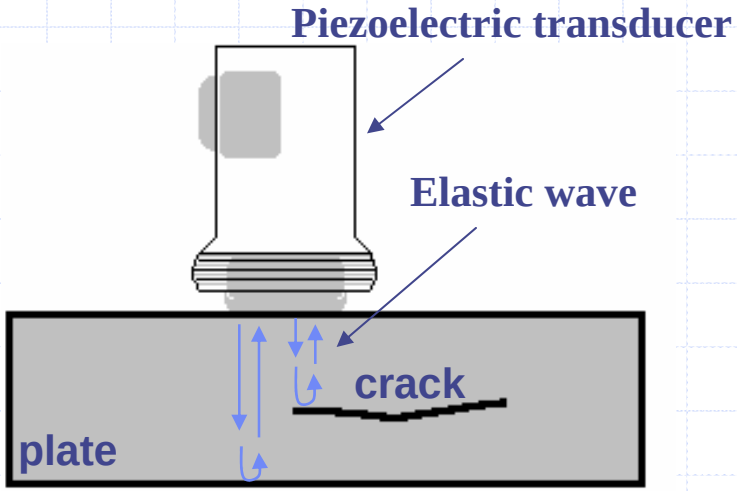


  - B-scan: 2-D

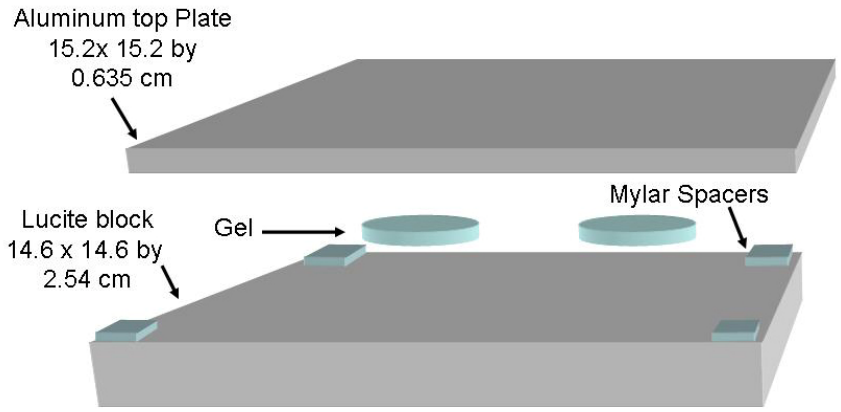


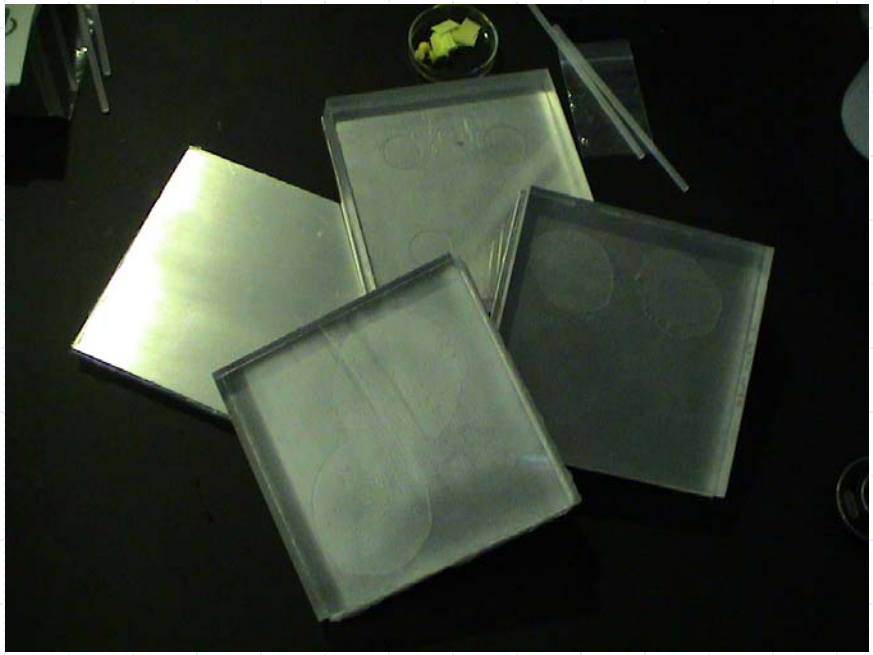
  - C-scan:





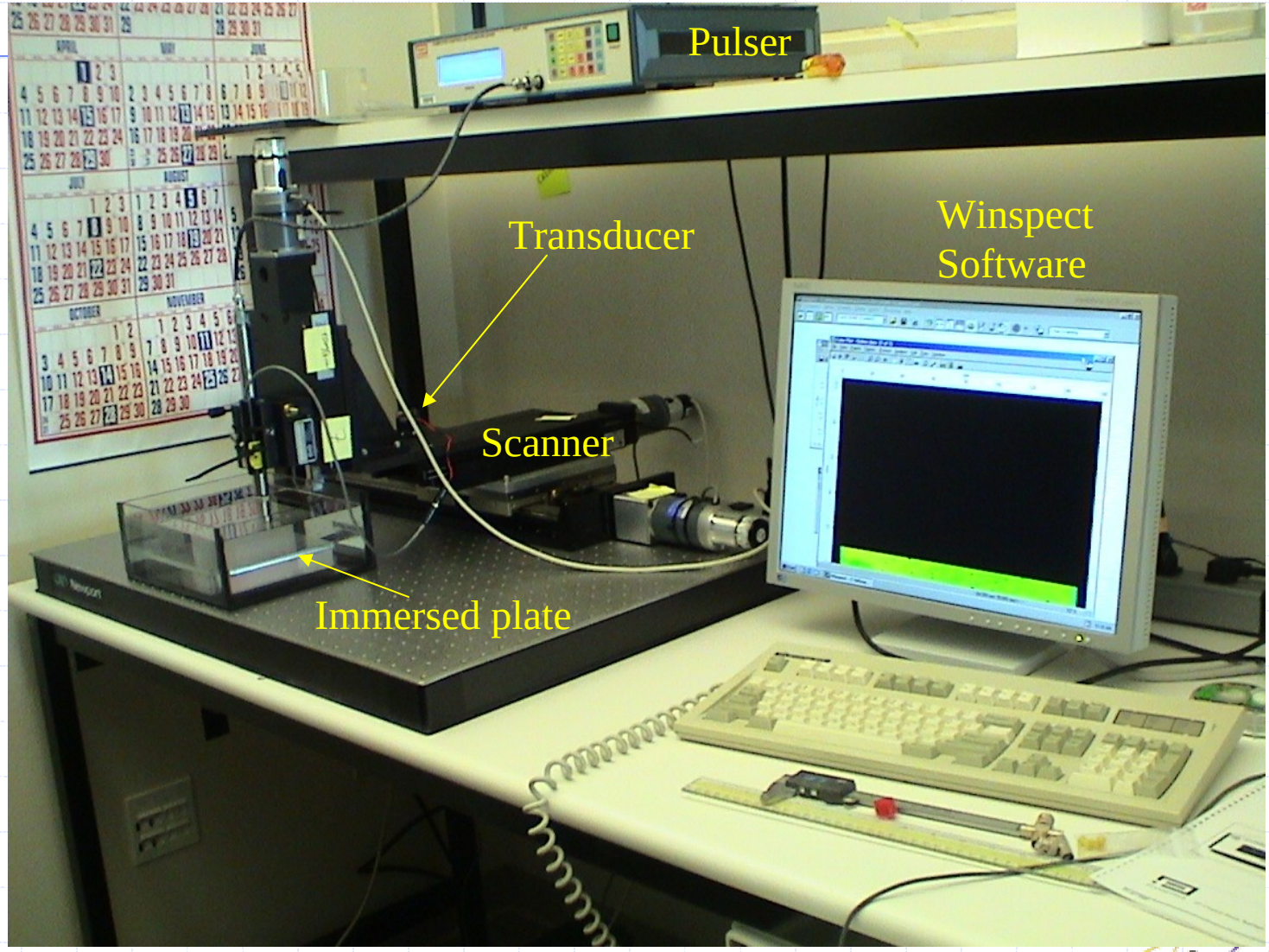
Sample plates were prepared to test CR versus varied scanning parameters.





Gel Layers 0.020 in. (0.051 cm) thick

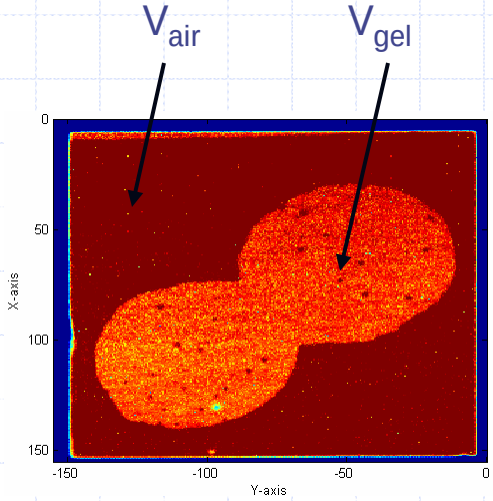
Sample plates were immersed in water, scanned, and the echoes recorded.



The contrast ratio between the air and gel quantified the quality of the C-scans.

- Contrast Ratio:

$$CR_{measured} = \frac{V_{air} - V_g}{V_{air}}$$



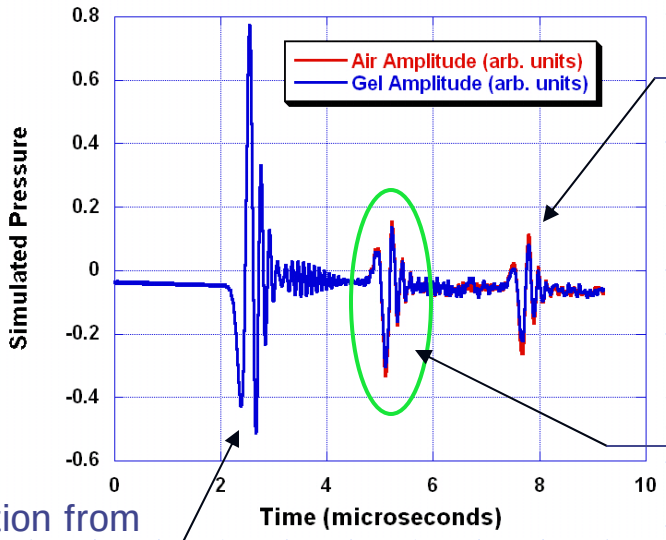
- Voltage measured proportional to amplitude of echo
- Reflection Coefficient gives ratio of echo to incoming signal amplitudes
- Reflection Coefficient for air very close to 1

$$CR_{theoretical} = 1 - \left[\frac{\rho_{al} C_{al} - \rho_g C_g}{\rho_{al} C_{al} + \rho_g C_g} \right]^n = 10.9\% \quad (n = 1)$$

- Successive echoes (n>1) have larger theoretical CR, but lower signal to noise ratio

Wave 2000pro (finite difference) software validated experimental results.

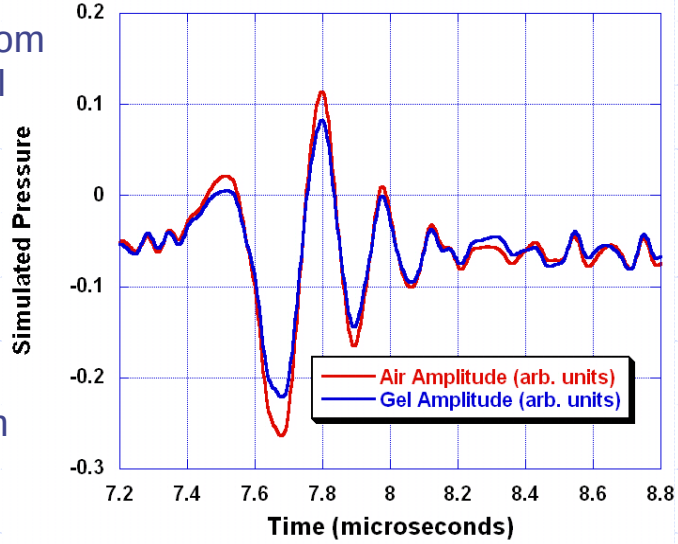
- Peak to Peak comparison pred
  10.6%
  - Transducer modeled as a Gaussian a
  - 20 points per waveform
  - Frequency of 4MHz
  - Material damping disabled



2nd Reflection from Aluminum/Gel Interface

1st Reflection from Aluminum/Gel Interface

Reflection from Top Aluminum Surface



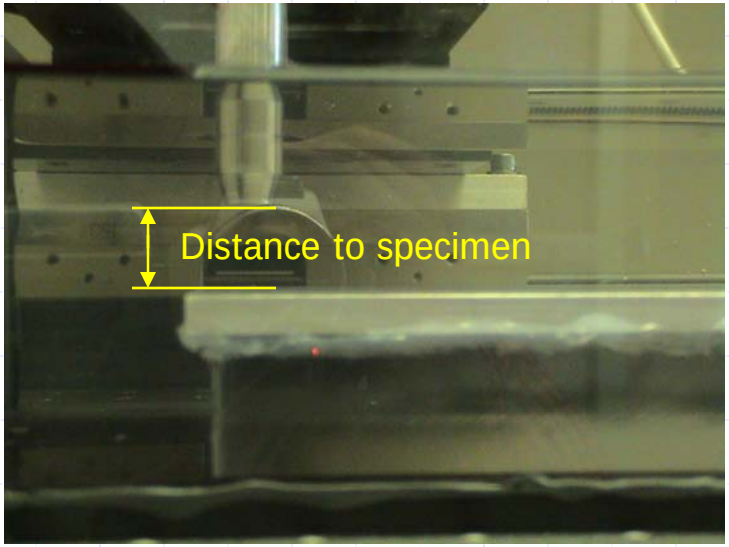
Factors of interest were chosen and varied to determine the effect on contrast.

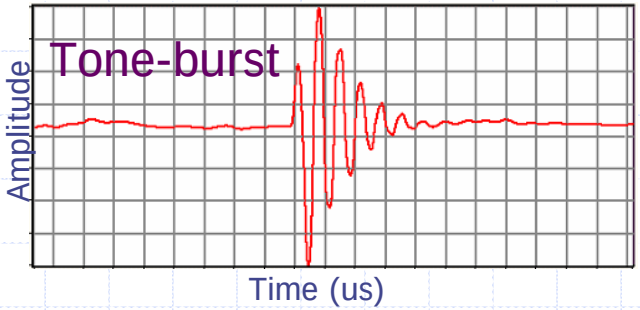
Distance to specimen

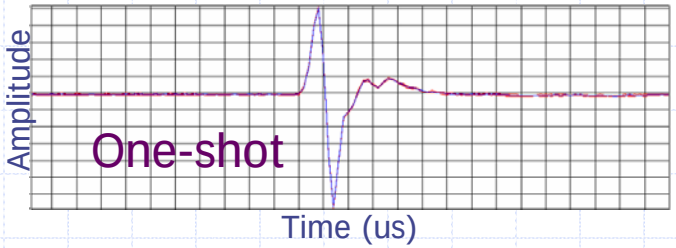
Transducer type

Excitation waveform

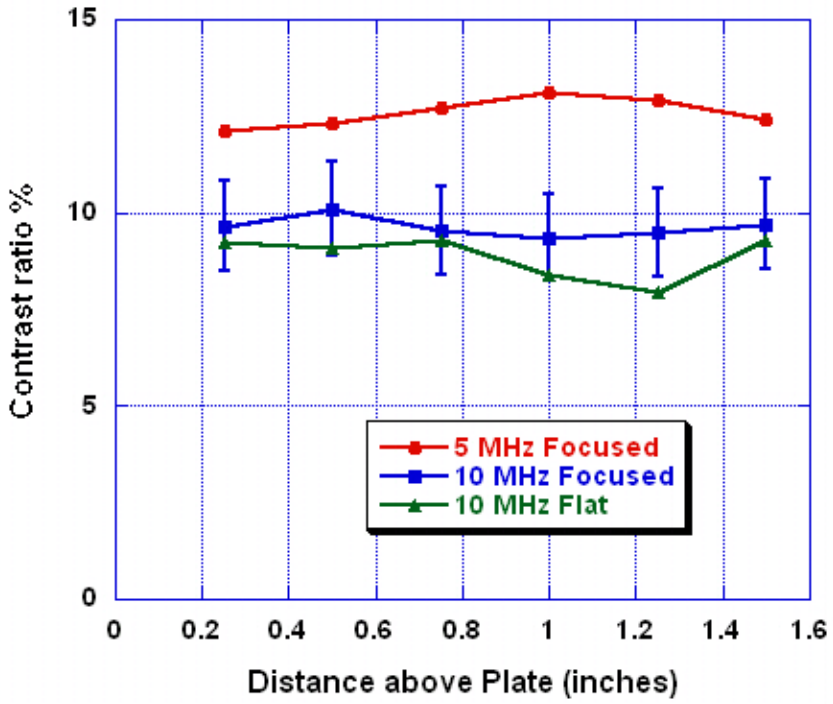
Pulse frequency







Varying Transducer height above the plate did not result in drastic CR changes.

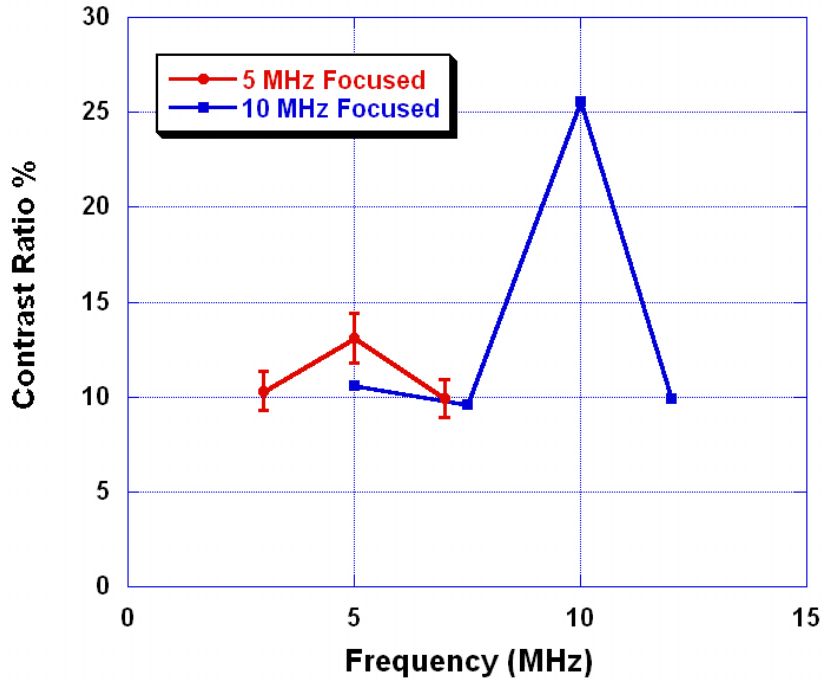


One shot pulses provided by Panametrics Pulser / Receiver

- Focused transducers gave sharper image
  - 5 MHz transducer gave higher CR than 10 MHz transducer
- Surprisingly, distance from plate appeared to have little effect on CR
  - Near field effects
  - Focal length

Using a tone burst pulse, each transducer had a maximum CR at its resonant frequency.

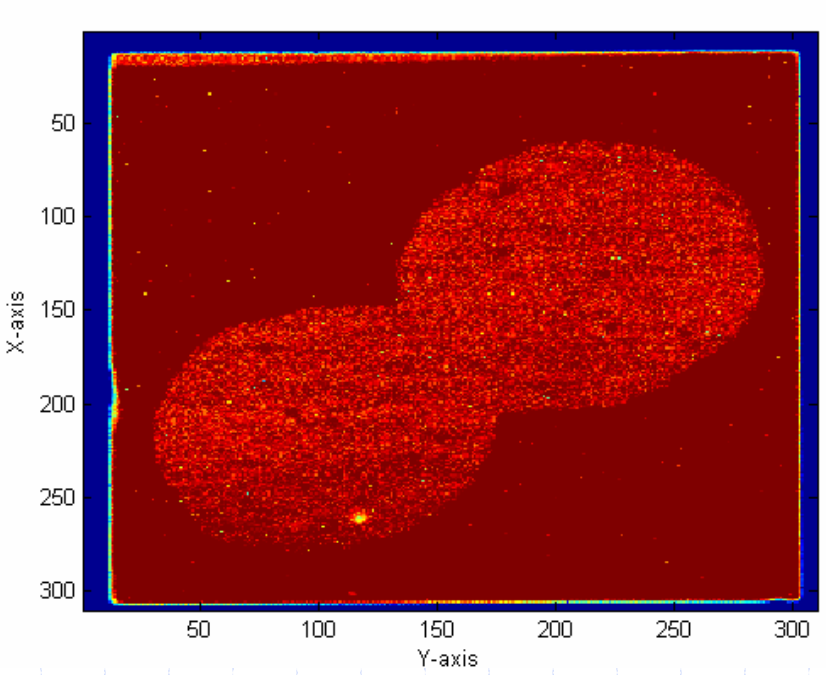
- The contrast ratio seems to increase as incoming signal amplitude increases
- Dramatic increase in CR for 10 MHz transducer needs more data for verification.

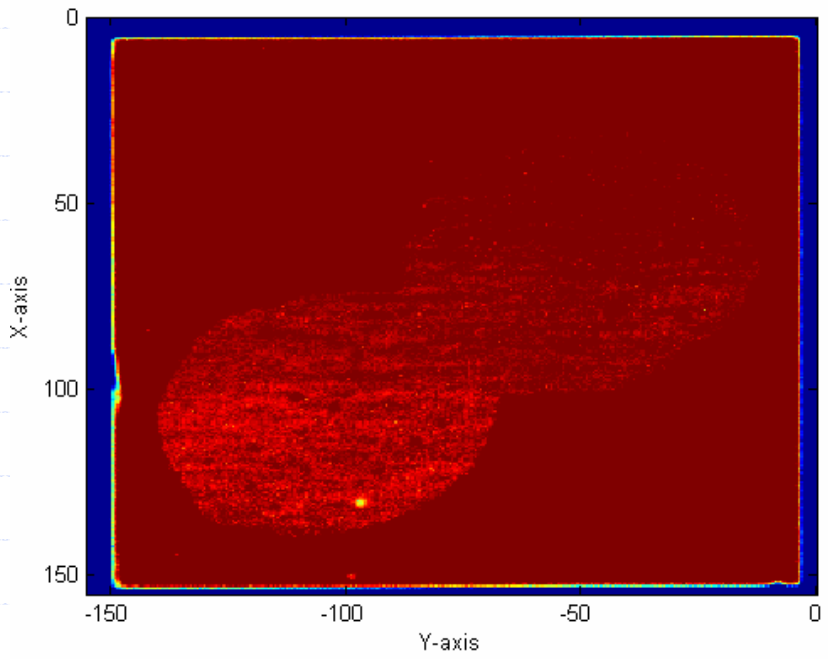


Tone burst provided by MATEC Pulser/Receiver

Small changes in scan procedures and data processing can be significant.

10 MHz focused Transducer





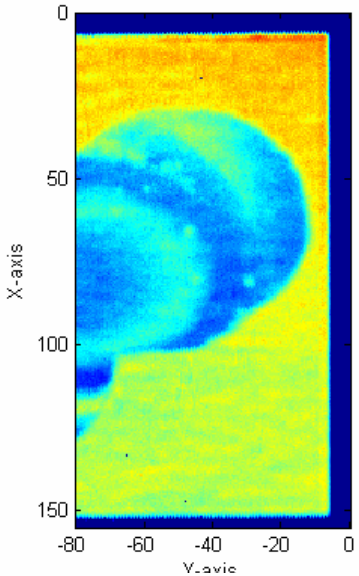
Transducer at 0.5 in. (1.27 cm)

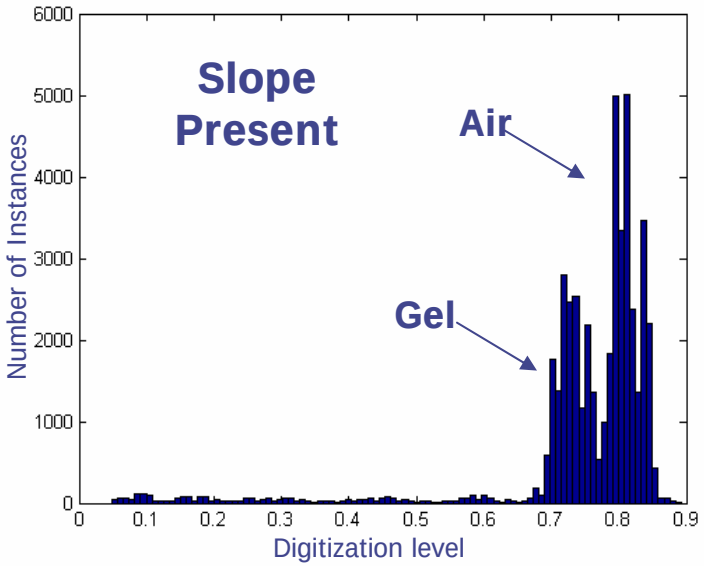
CR = 10.1%

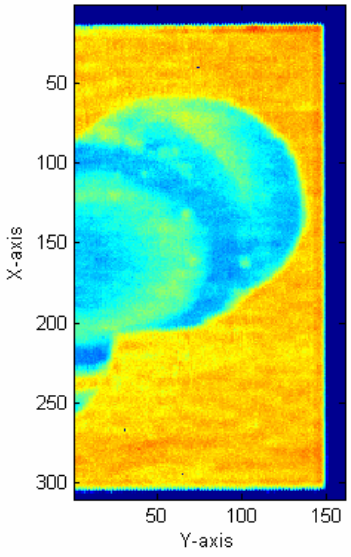
Transducer at 1.0 in. (2.54 cm)

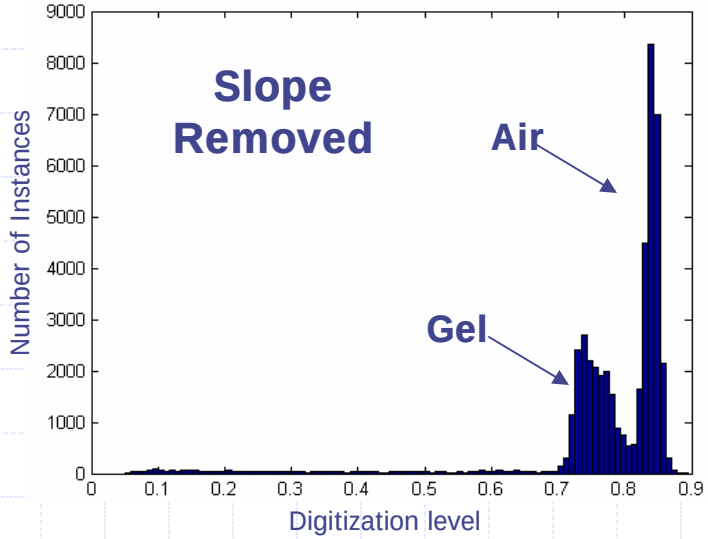
CR = 9.3%

The next step would be to remove any bias, and to complete a statistical analysis on scans.







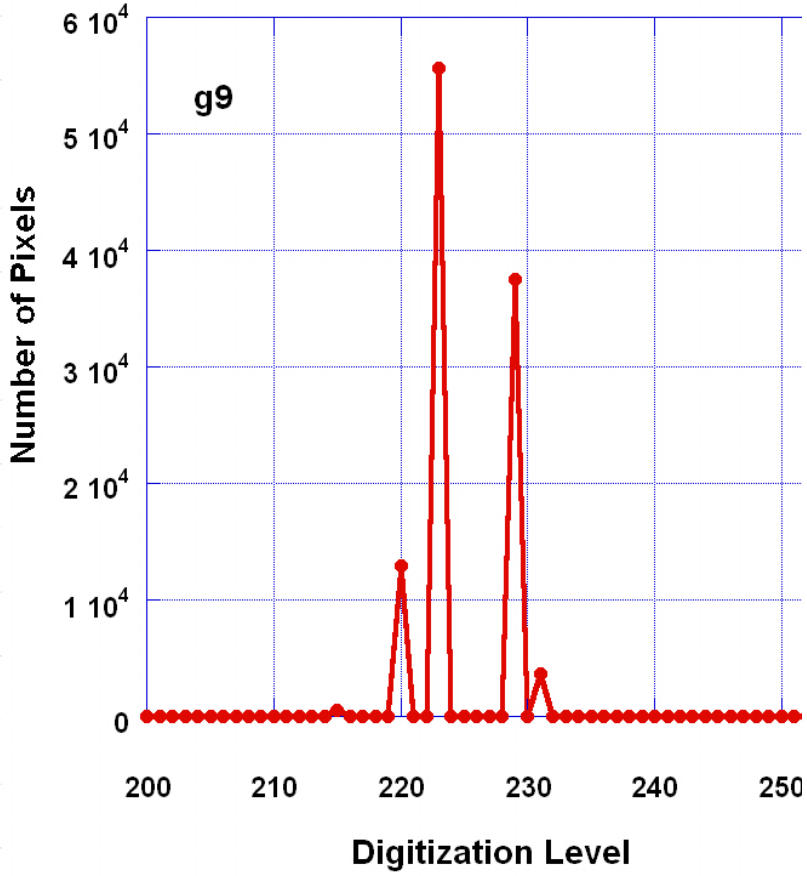


Example: Mathematically removing slope in plate results in sharper better defined histograms

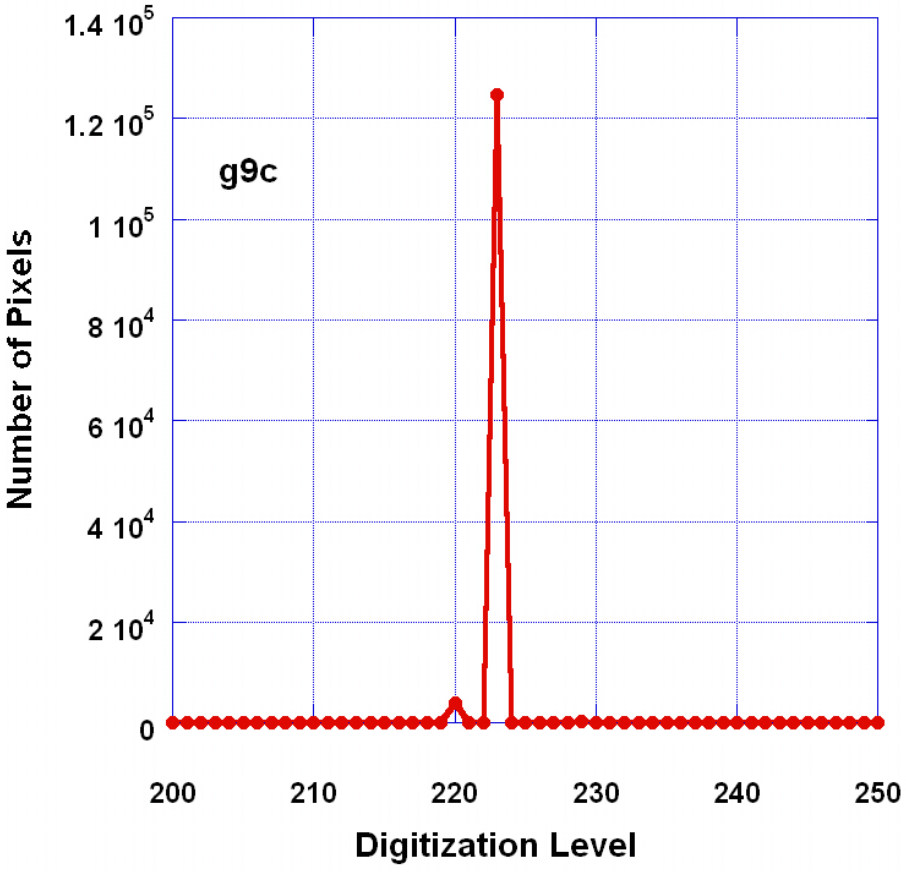
Statistical Analysis of signals and noise would provide confidence levels for detecting air gaps

Further investigation has revealed that the equipment can significantly affect data variance.

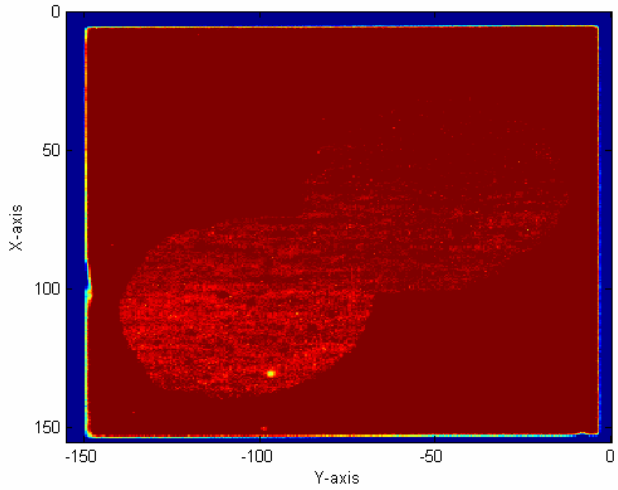
Pulse width 5 ns



Pulse width 10 ns

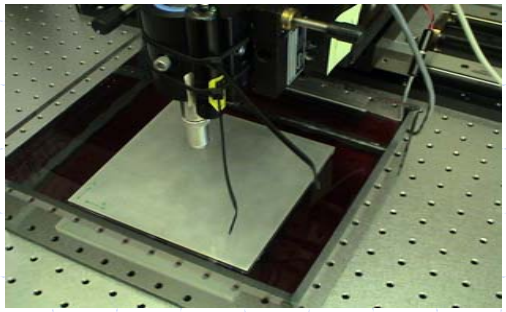


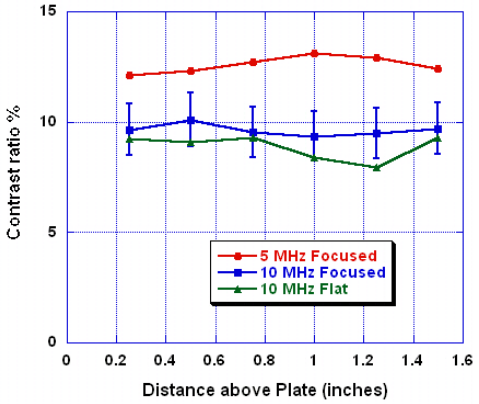
In conclusion, scanning parameters should be carefully selected to optimize contrast.

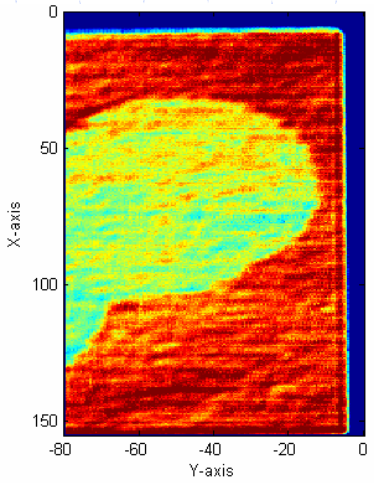


While contrast ratios can be predicted, scanning systems contain inherent variability.

Scanning parameters must be adjusted based on configuration and application for best contrast.







Questions?

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- The Mathworks Inc. (numerical analysis software donation)
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