Ultrasonic Imaging of Optics

CASIS Workshop

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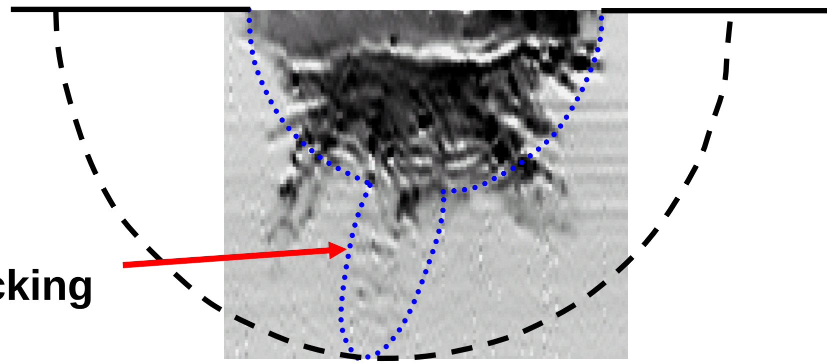
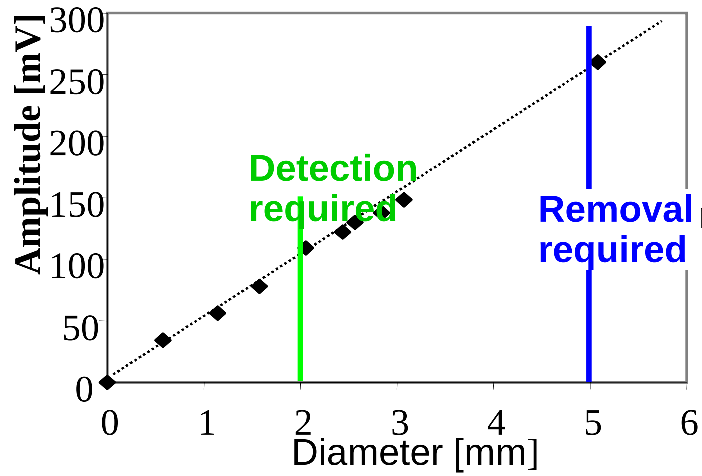
FY99-00 a 5 MHz longitudinal wave method was used to inspect laser features

cracking

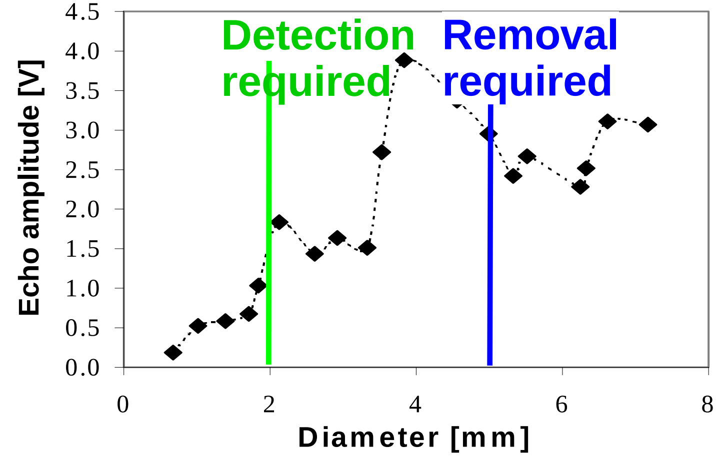


Features without vacuum loading



Hemispherical machine pits

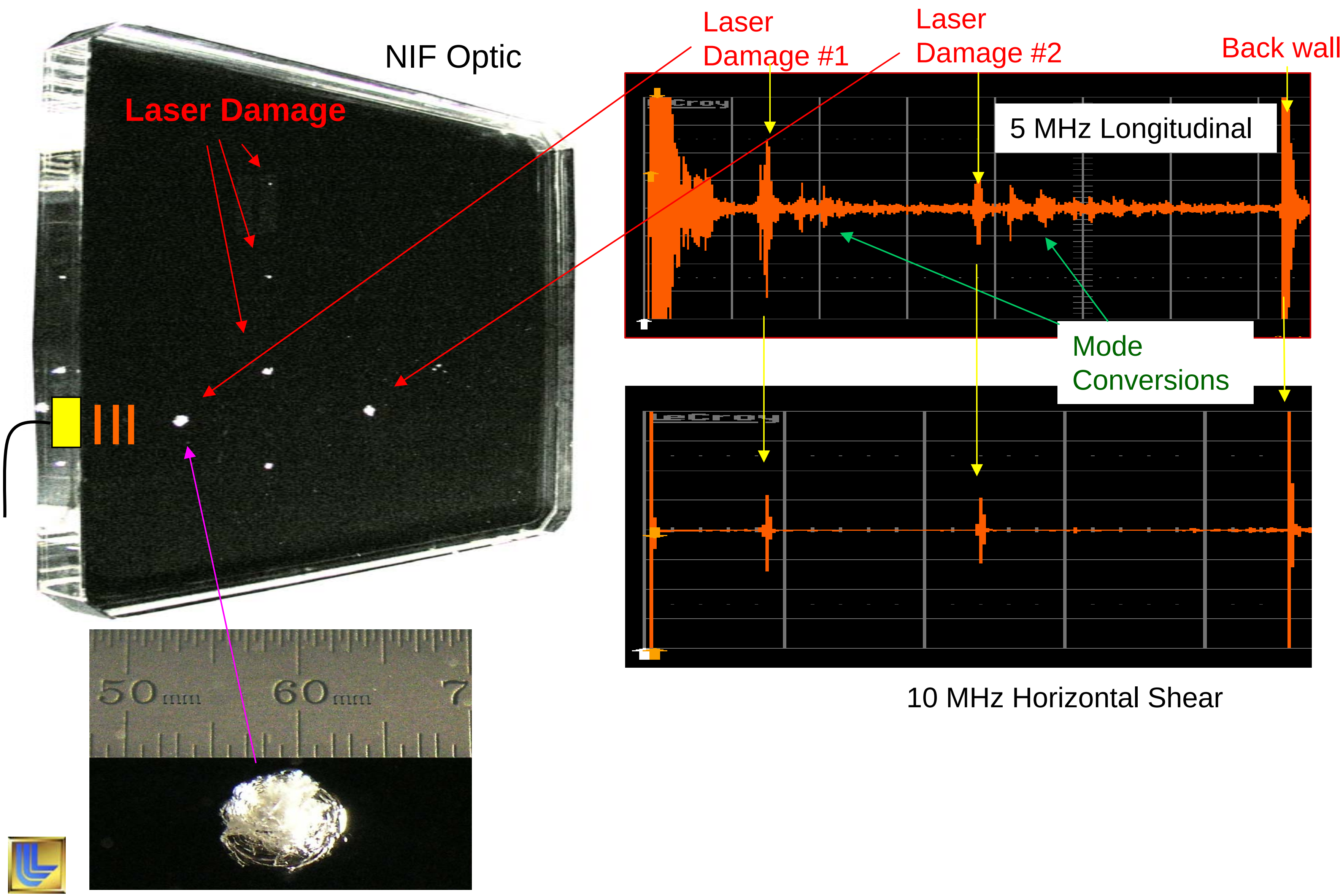
Echo amplitude was monotonic on machined pits but cracking during actual features (without vacuum loading) made sizing difficult.



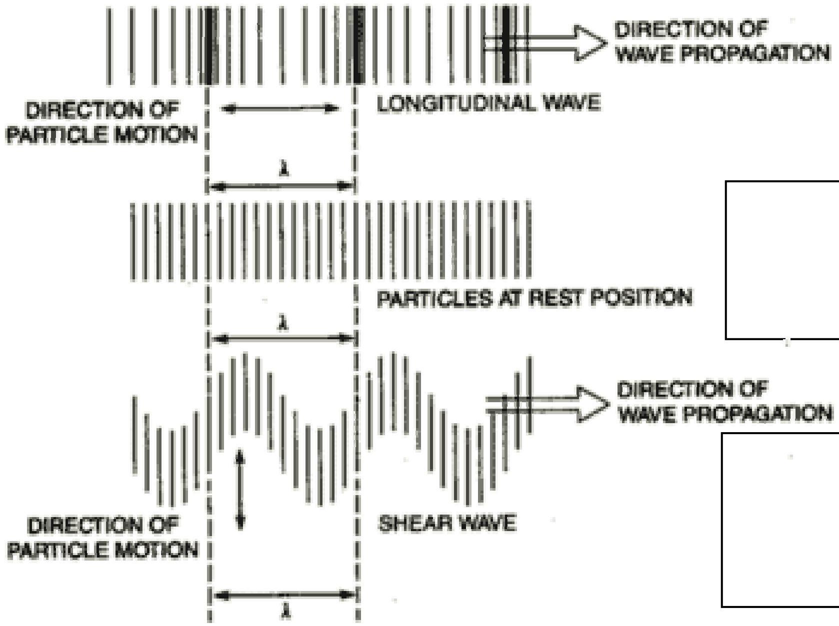
Actual features

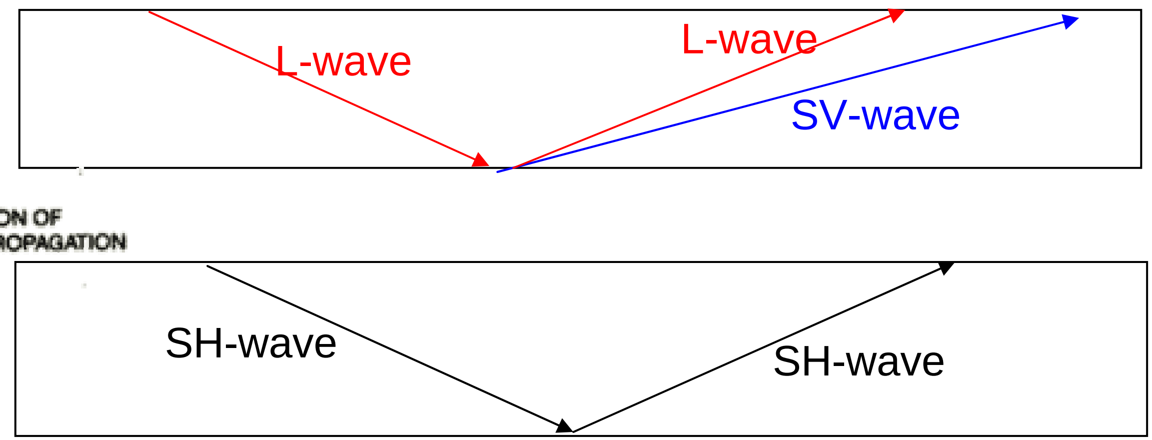
In FY00, 5 MHz longitudinal waves showed detection of laser features, but the initial sizing technique needed improvement.

Horizontally polarized shear waves increases SNR by eliminating mode conversions and multi-path echoes



Longitudinal and shear vertical waves mode convert, but horizontally polarized shear waves do not

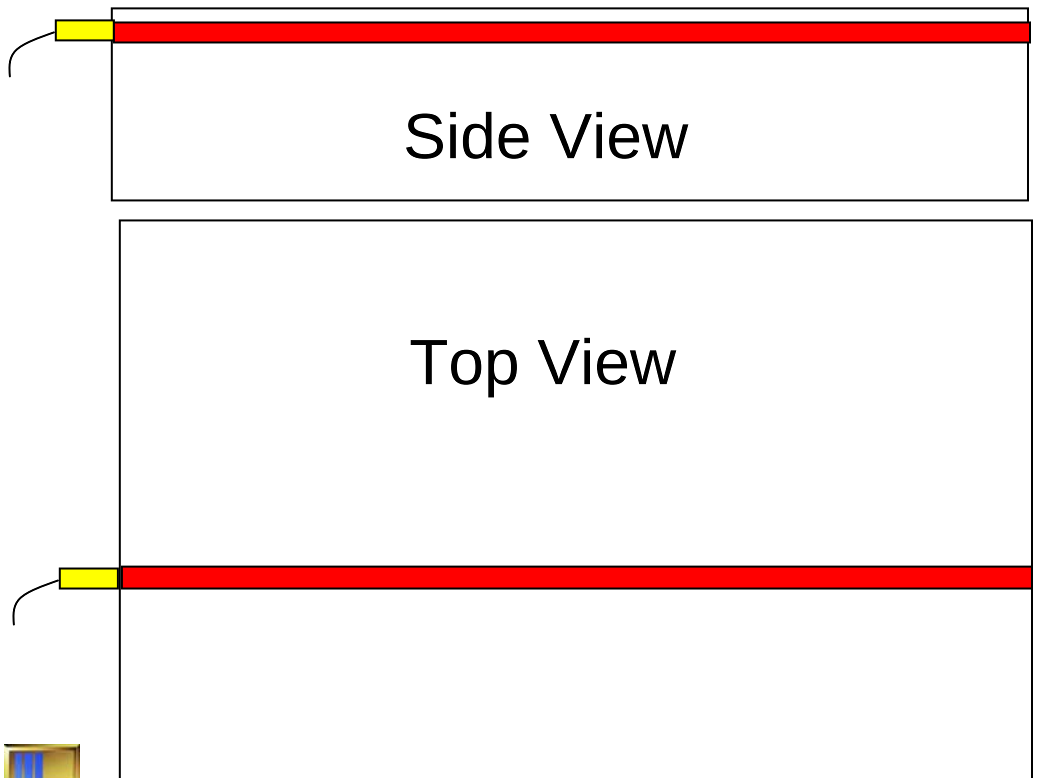


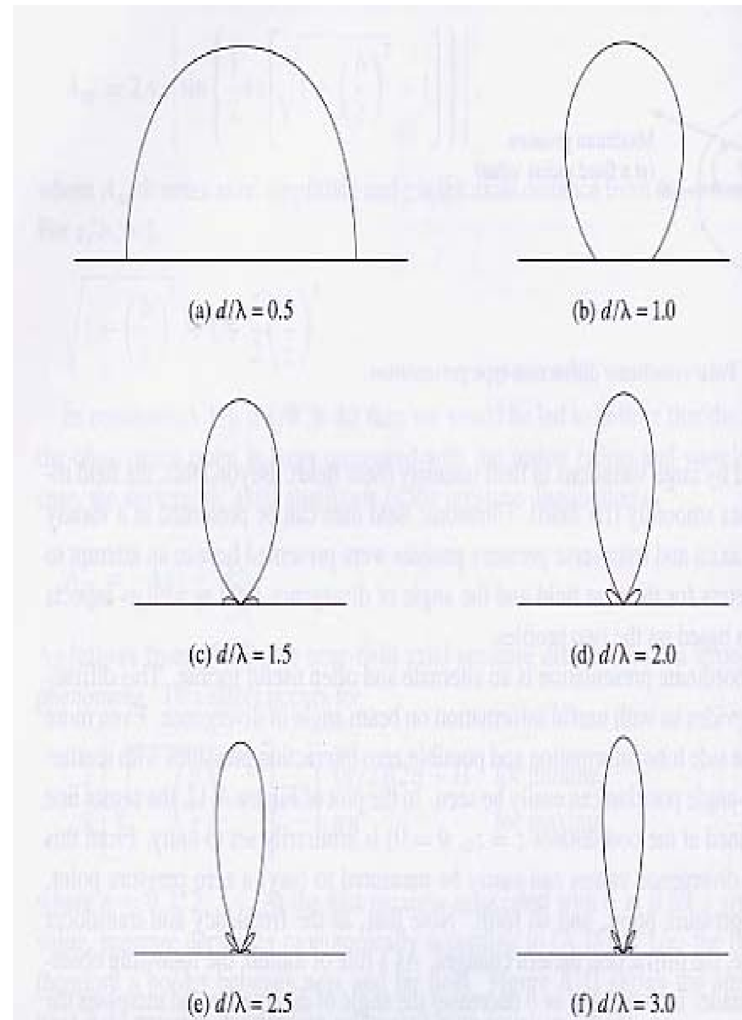


- Reflections from scatterers will include mode conversions between a longitudinal mode and a shear vertical polarization mode
- Reflections from free edges will cause the same mode conversions
- These mode conversions do not occur for a shear horizontal polarization mode of wave propagation

A ½” diameter 10 MHz shear wave transducer has high directivity and minimizes multi-path echoes

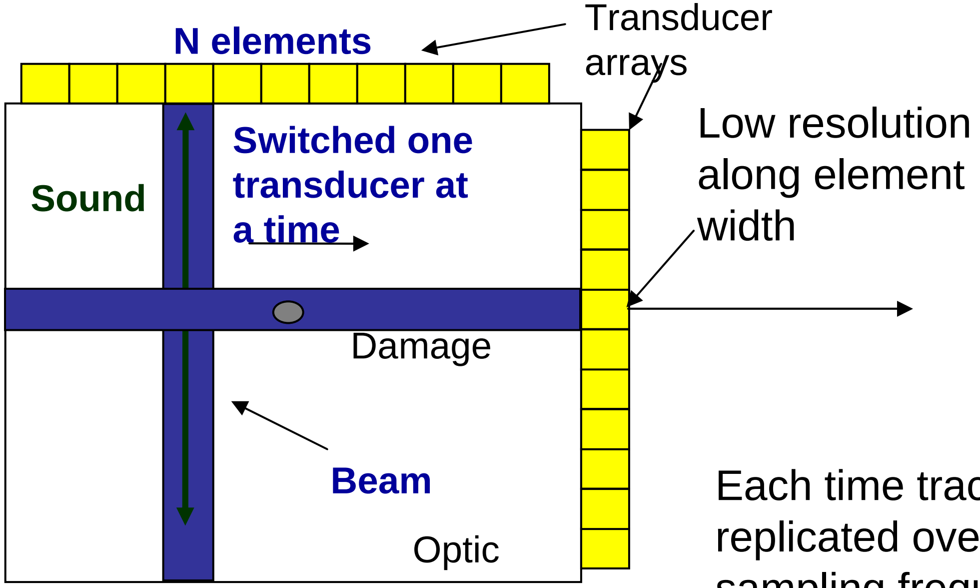
- 10 MHz shear pencil-like beams (d/λ=35)
- Angle of divergence is less than 3 degrees



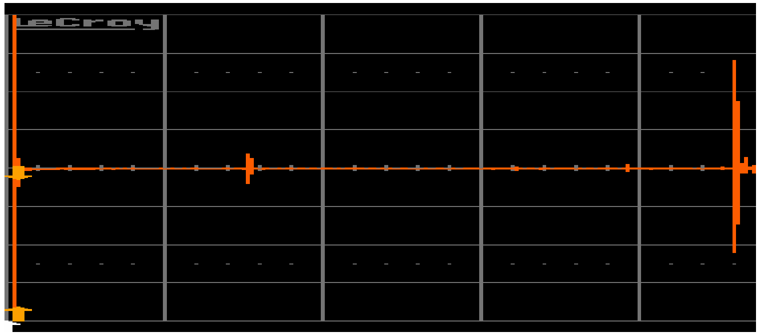


Horizontal shear wave multizonal imaging concept

NX1 time traces are analyzed individually for flaws



High resolution along beamline



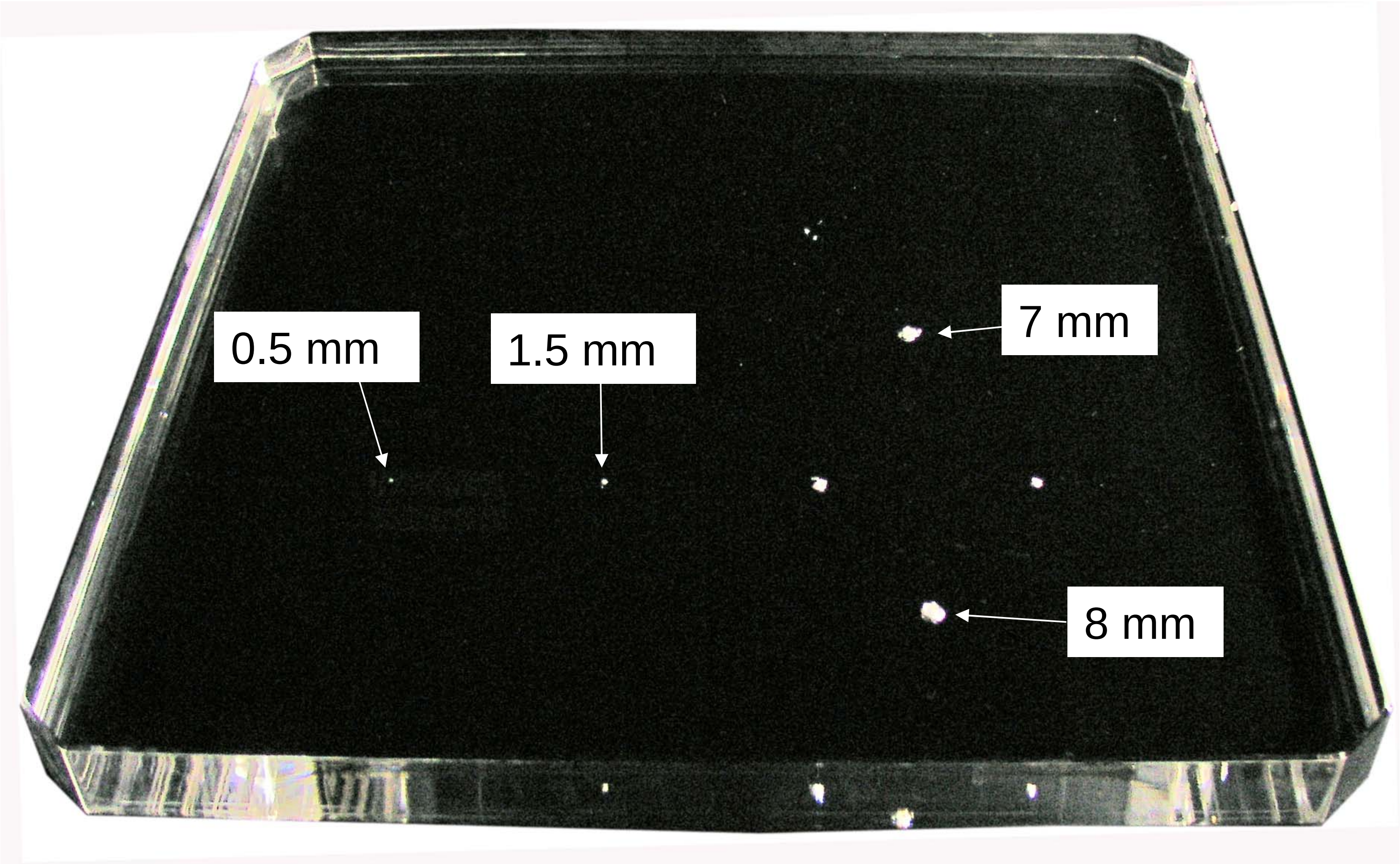
Each time trace is enveloped and replicated over element width @ sampling frequency 100 MHz

Time traces from 4 directions are multiplied to obtain image

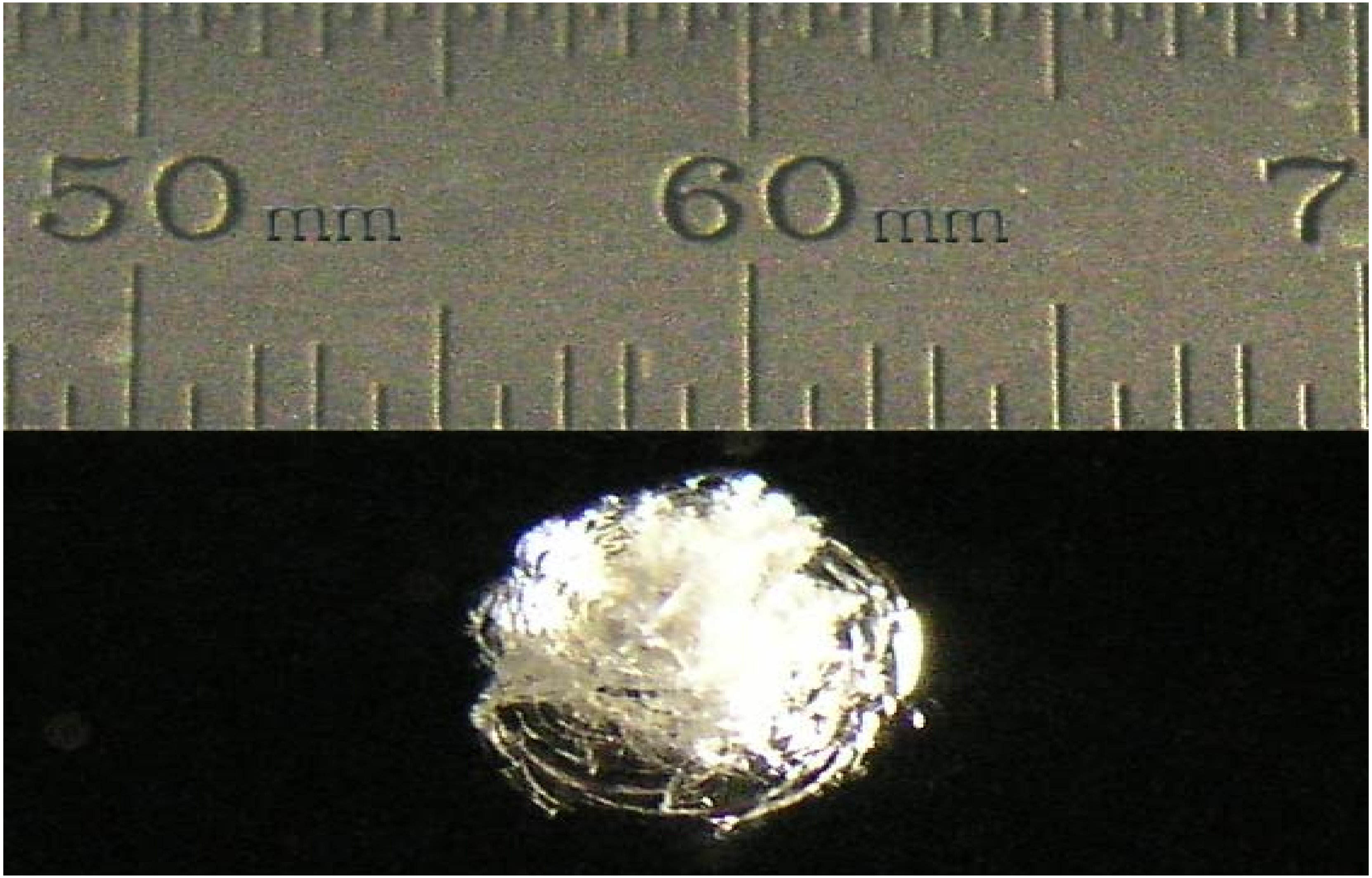
2D – Image of surface depth

Maximum amplitude is correlated to depth

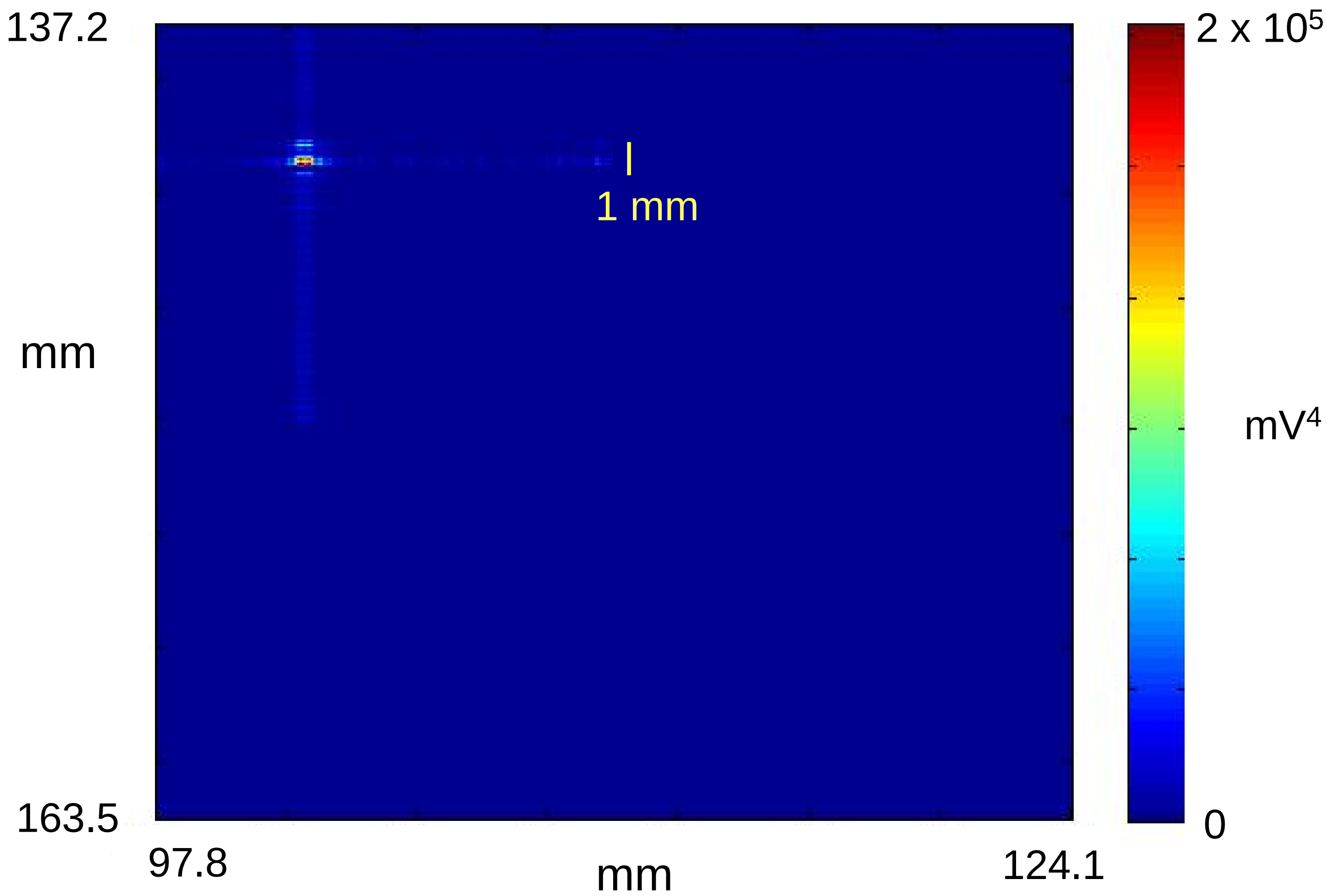
Fused silica optic with laser damage sites



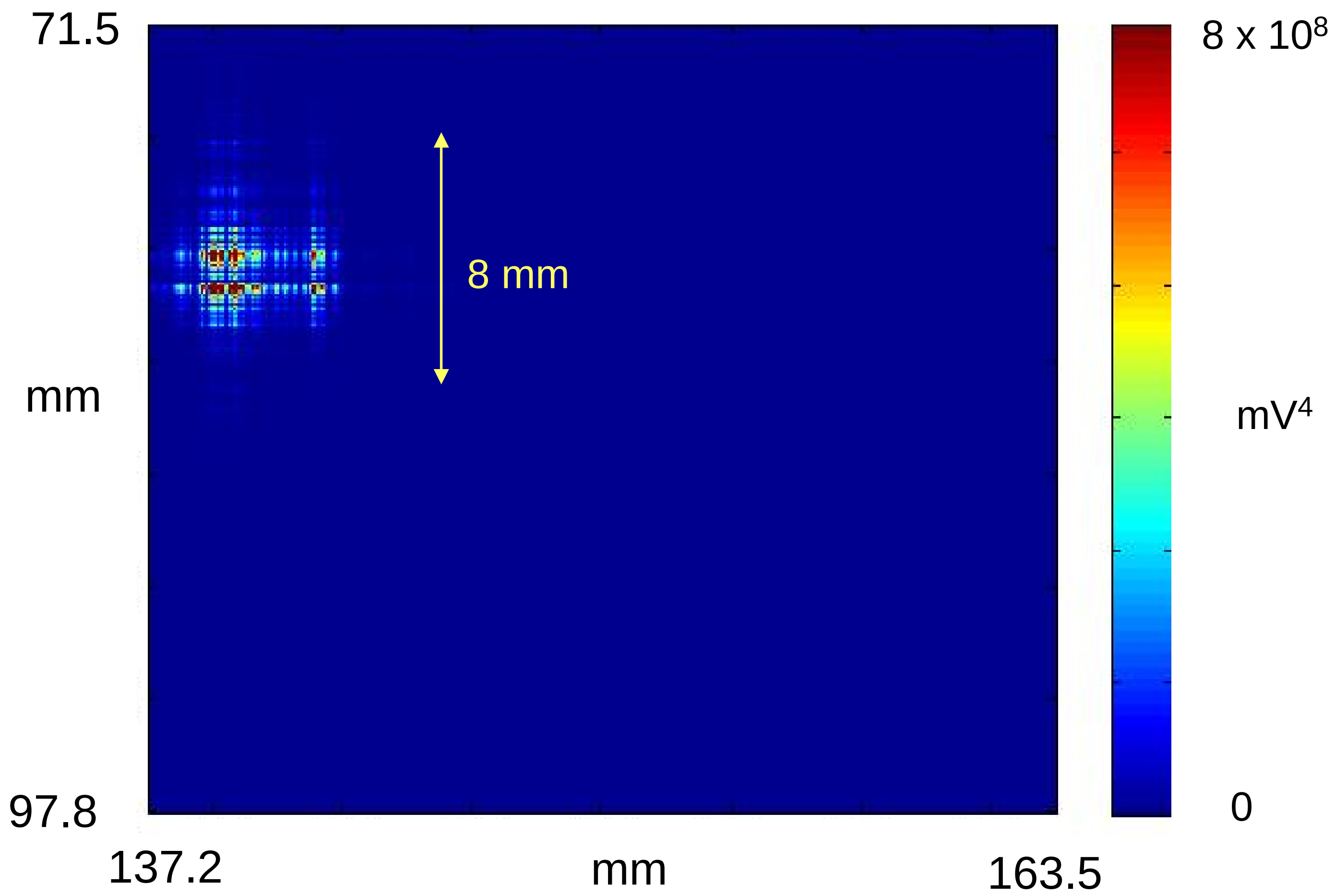
Picture of an ~ 8 mm dia. laser damage site



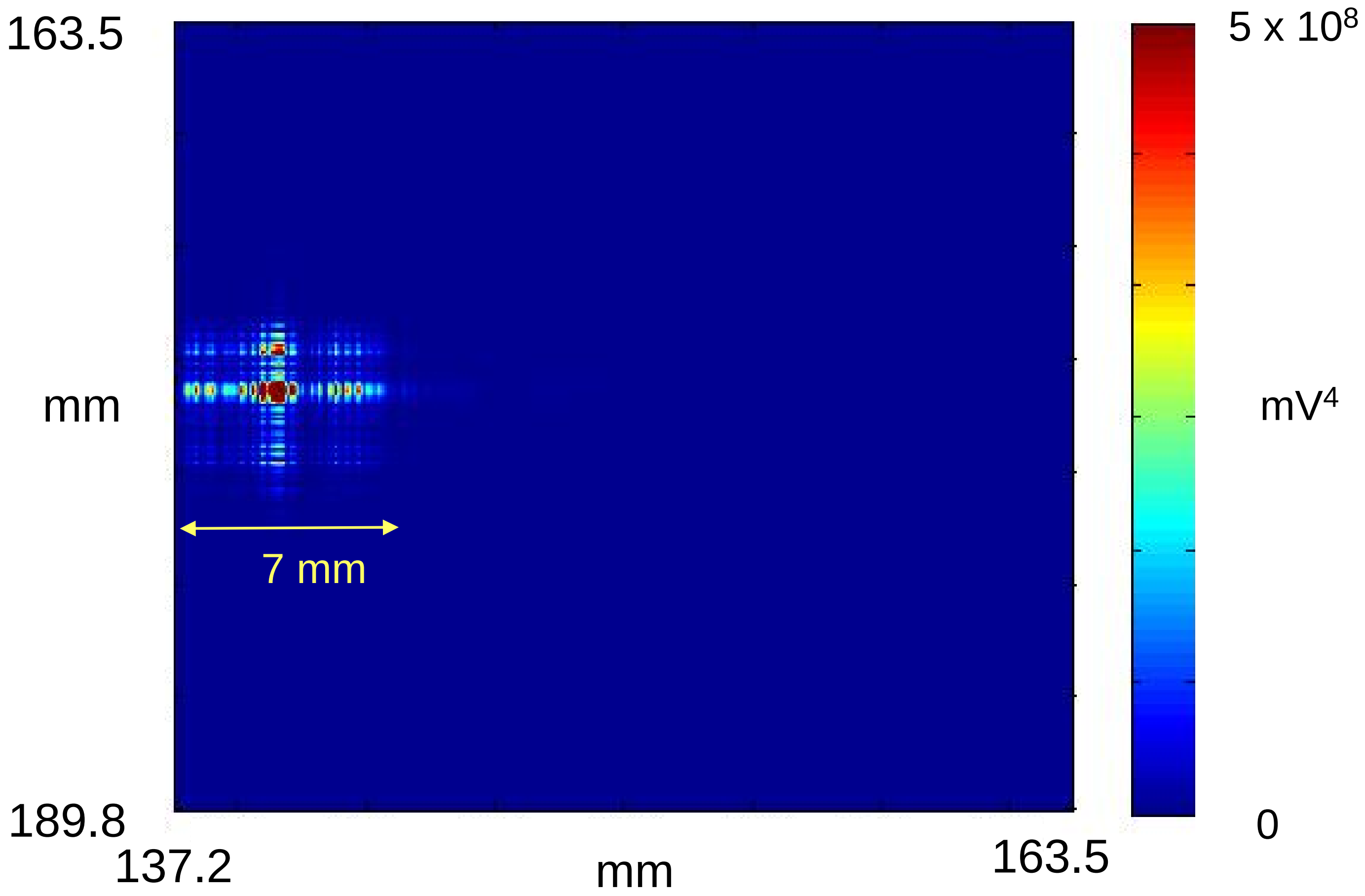
0.5 mm laser damage image



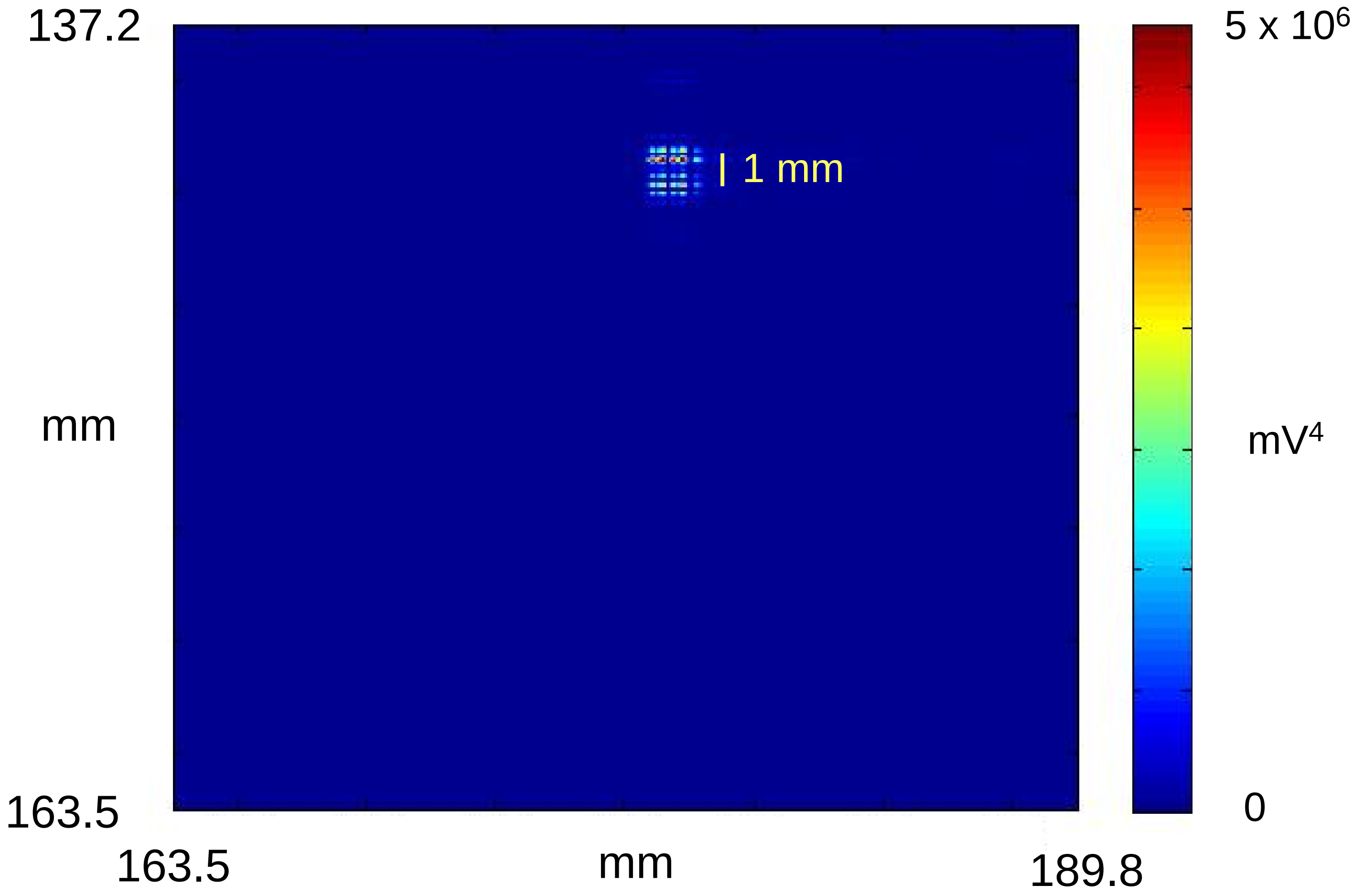
8 mm laser damage site



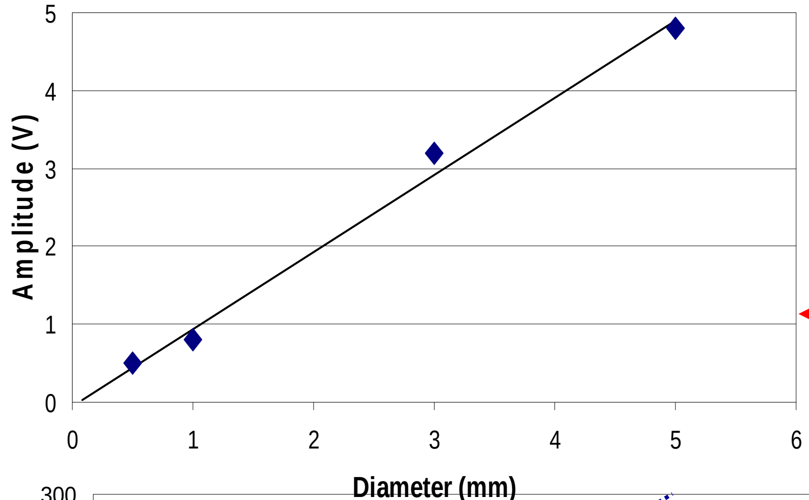
7 mm laser damage site

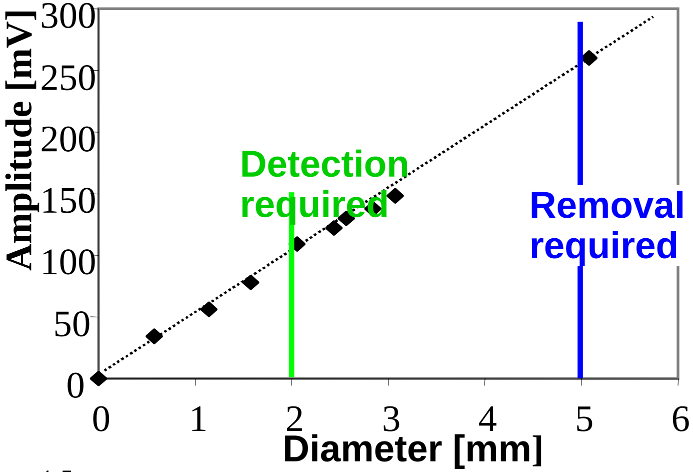


1.5 mm dia. laser damage site

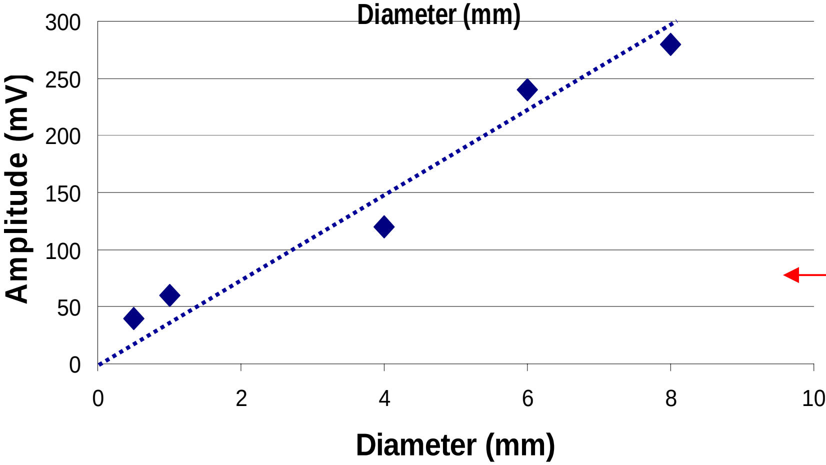


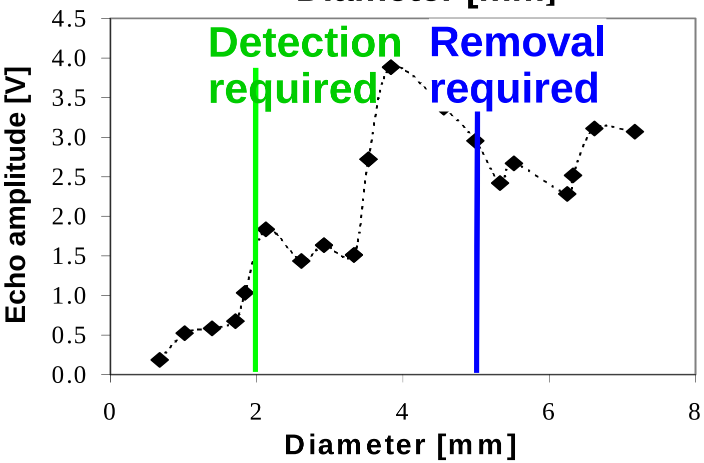
We have shown that 10 MHz shear waves produce a monotonic sizing relation for machine and laser damage





Hemispherical machine damage





Actual laser damage

10 MHz shear waves

5 MHz longitudinal waves

Concluding Remarks

- An ultrasonic technique using 10 MHz horizontally polarized shear waves was demonstrated for on-line testing of optics
  - The 100 MHz - 1 GHz surface acoustic wave microscopy technique shown in yesterday’s presentation is suitable for off-line testing
- We have demonstrated that an acoustic technique using horizontal shear waves can image laser damage with detection, localization, and accurate sizing over a range of 0.5 mm – 8 mm
- We have improved the ultrasonic technique over the FY00 status
  - 10 MHz Shear waves have improved signal to noise, eliminated multiple echoes, and improved resolution
  - Surface area sizing is now done using the time of arrival from two transverse directions
  - Amplitude of reflection yields depth information
  - Array data and any reconstruction methods yield easier to understand images of the top surface as opposed to RF waveform data used in FY00
- We expect to detect at least 0.1 mm or smaller features