DVM Summary and Acoustic Microscopy Imaging of Cu Sample

Antti Meriläinen[1,2], Robin Rajamäki[3], Ivan Kassamakov[1,2], Markus Aicheler[2], Walter Wuensch[3], Kenneth Österberg[1,2] and Edward Hæggström[1]

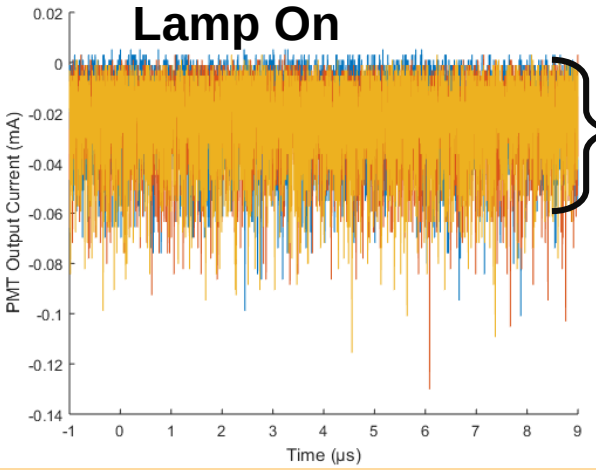
1) Department of Physics, University of Helsinki

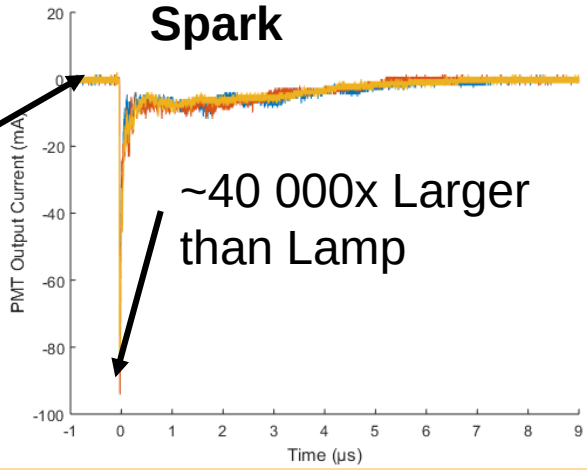
2) Helsinki Institute of Physics

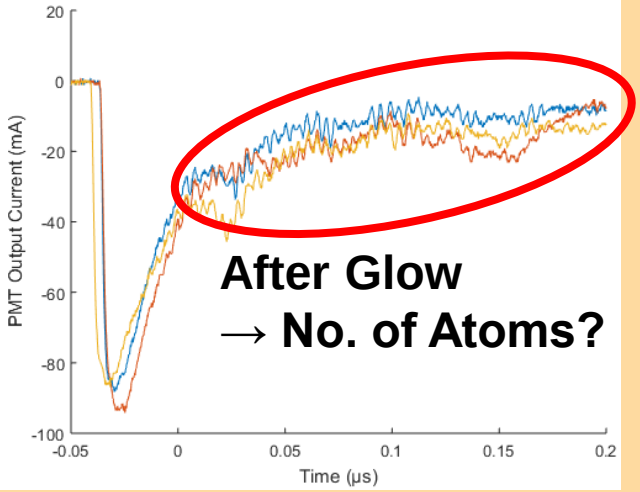
3) CERN

Summary of DVM 2016

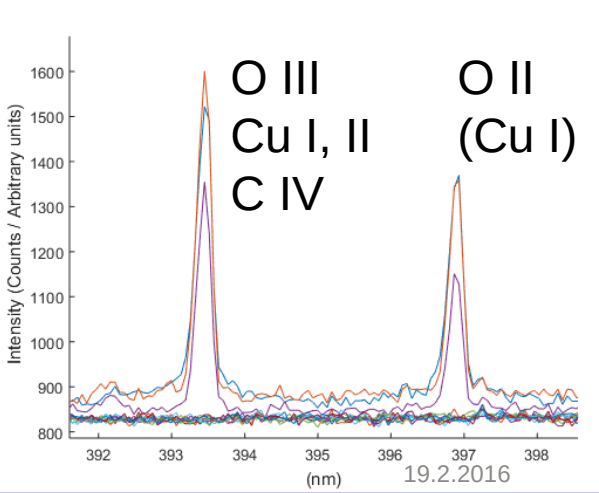
Absorption

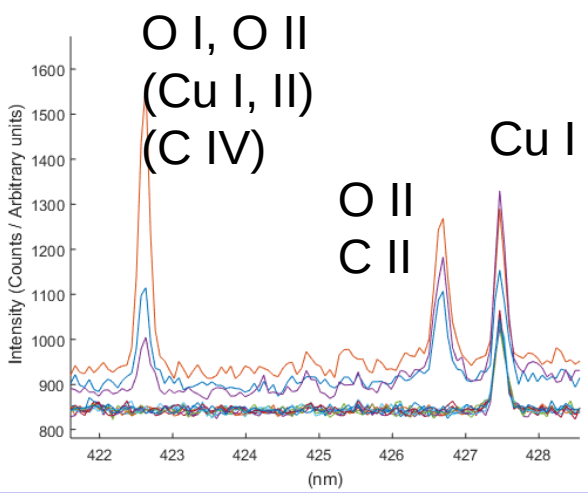


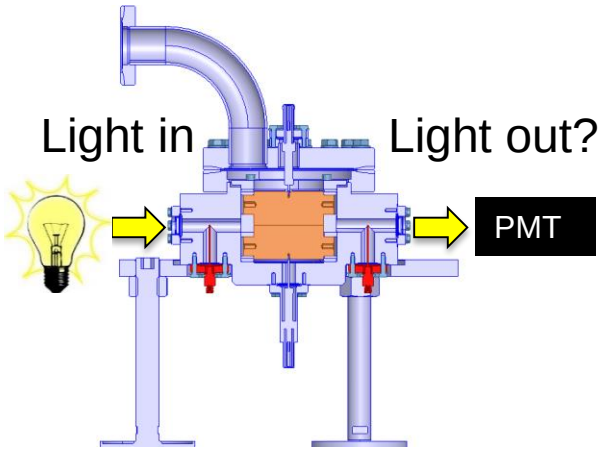




Emission

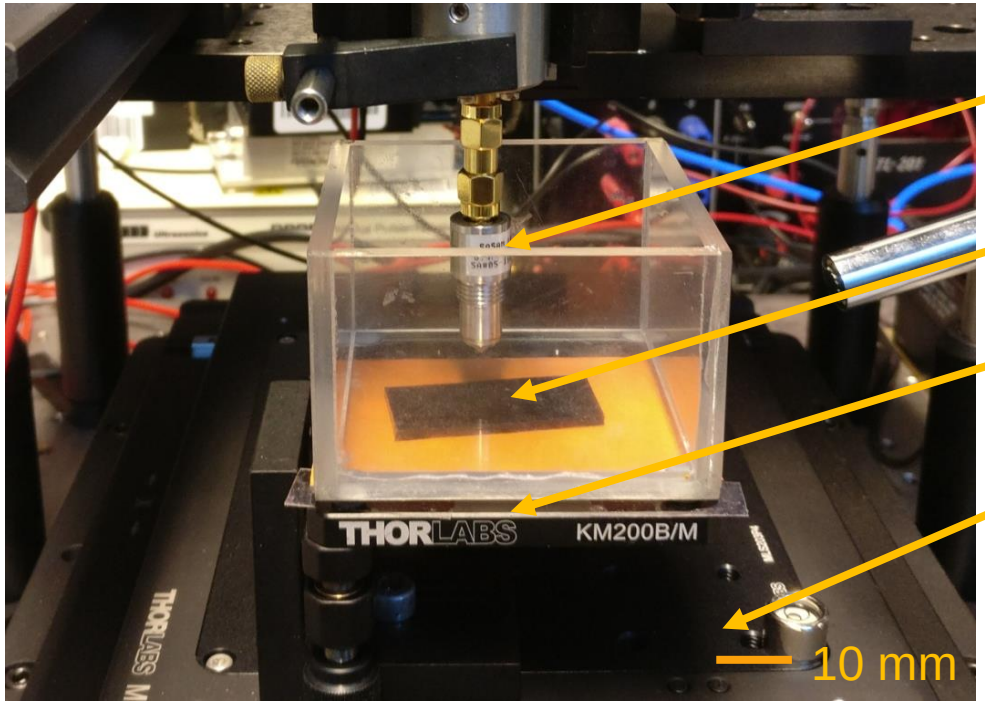




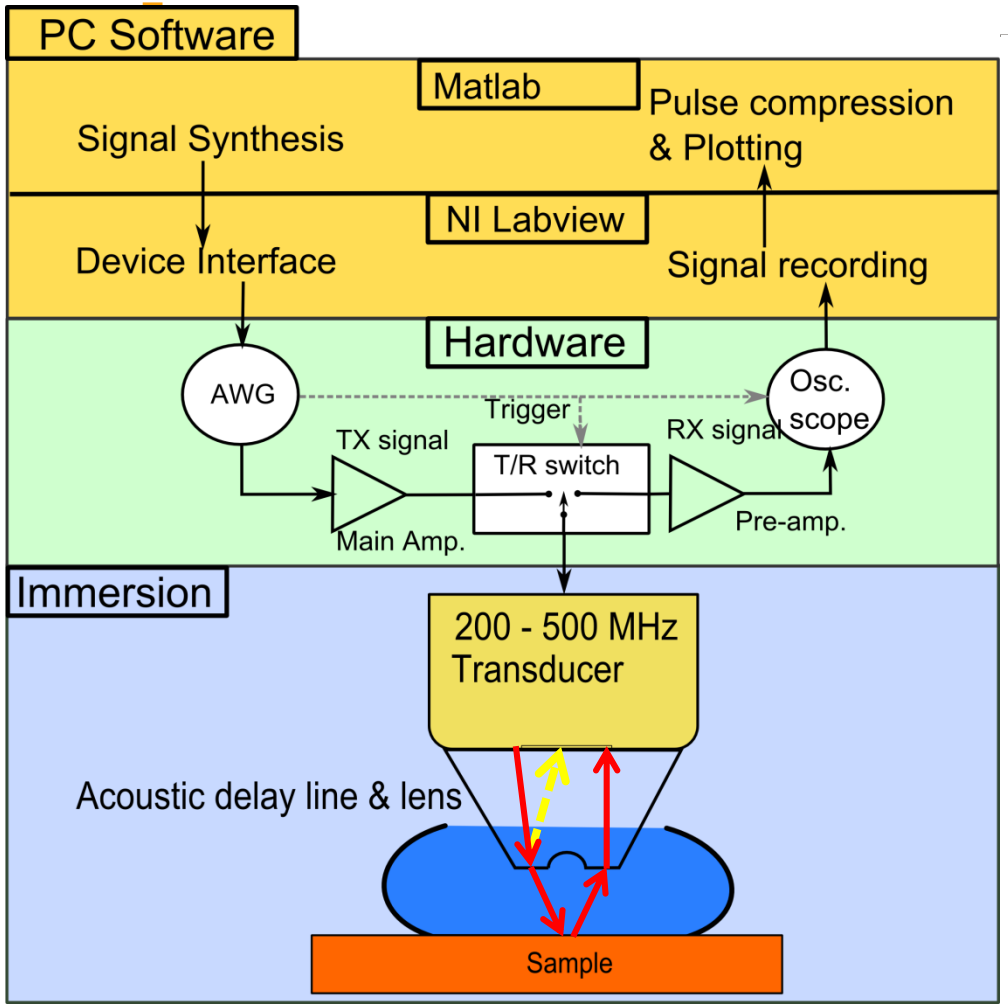


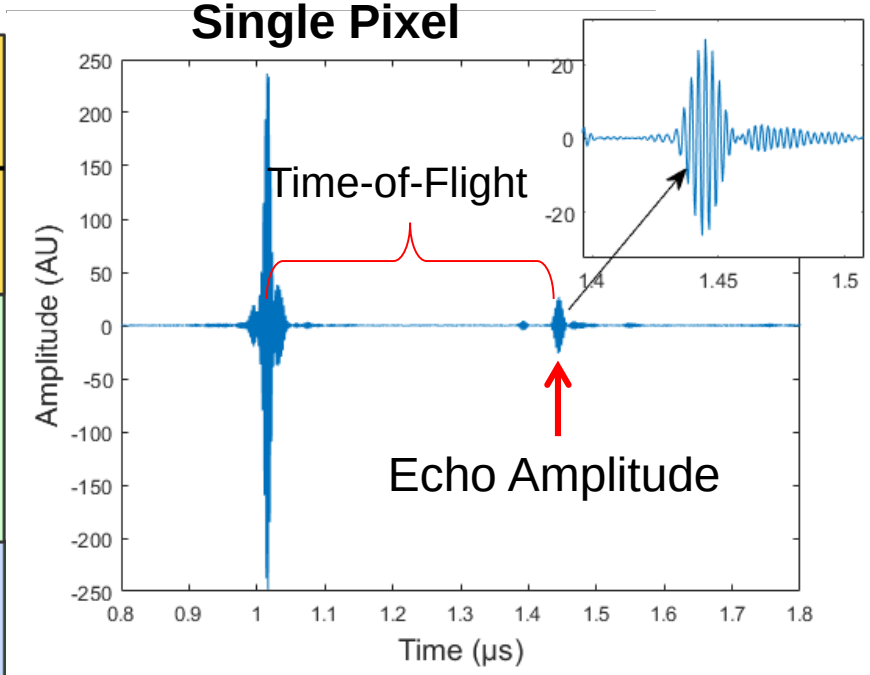
Why Acoustic Microscope

- Optical methods do not measure elasticity
- Tapping mode AFM is not easy to calibrate for elasticity
- µCT Does not see elasticity close to the surface



Pulse Echo Measurements





Time-of-Flight: Surface Topography
Amplitude: Mechanics

Math of Acoustic Reflection

Time-of-Flight

$$s = \frac{c_{Water}}{t}$$

C *is Speed of Sound*

t *is Time of Flight*

Echo Amplitude

$$R_{Water \to Cu} = \frac{Z_{Cu} - Z_{Water}}{Z_{Cu} + Z_{Water}} \approx 93.1\ \%$$

$$R_{ref} = \frac{Z_{ref} - Z_{water}}{Z_{ref} + Z_{water}}$$

$$\frac{A_{Cu}}{A_{Ref}} = \frac{R_{Cu}(Z_{Cu})}{R_{Ref}}$$

$$Z_{Cu} = \frac{R_{ref} + \frac{A_{Ref}}{A_{Cu}}}{R_{ref} - \frac{A_{Ref}}{A_{Cu}}} Z_{Water}$$

$$\boxed{Z_{Cu} = \frac{\boldsymbol{K_{Cu}} + \frac{4}{3}\boldsymbol{G_{Cu}}}{C_{Cu}}}$$

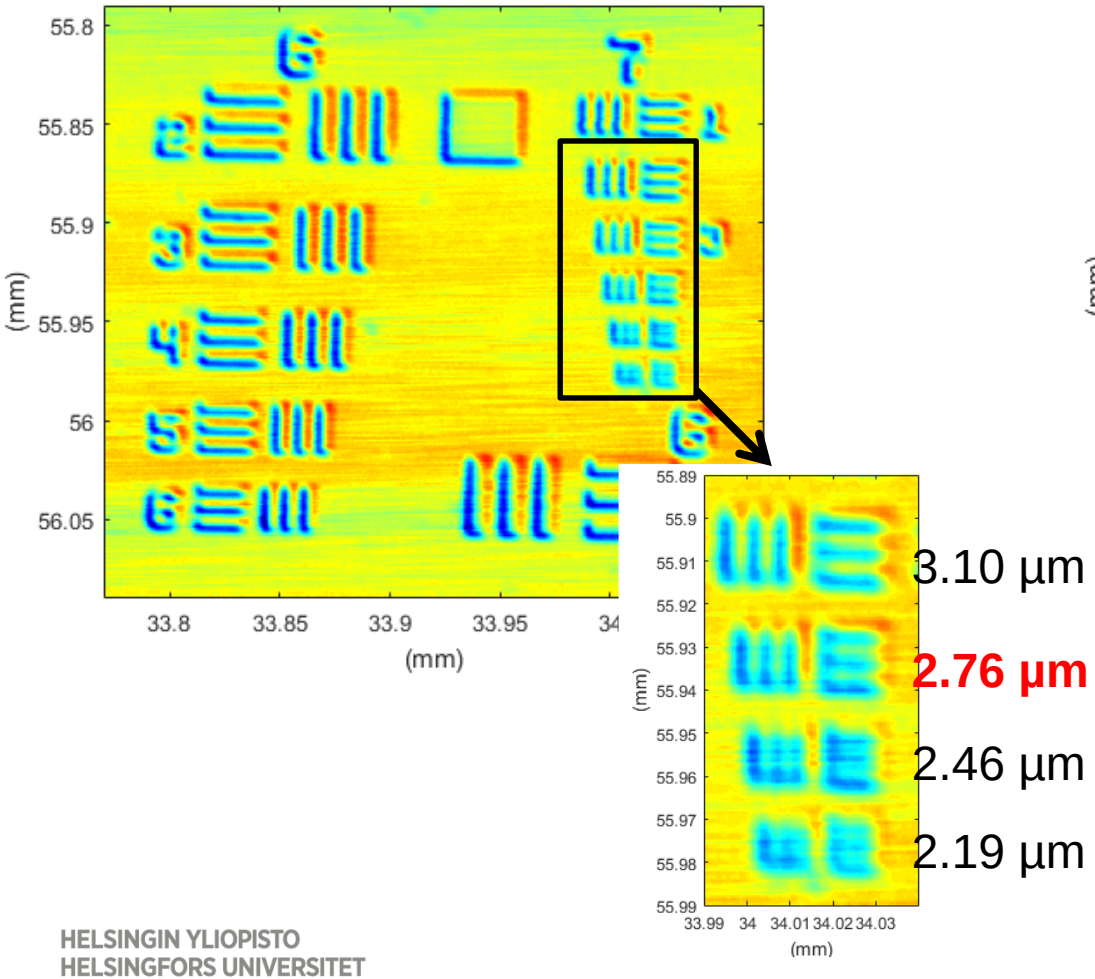
$A = Echoes'\ Amplitude$

K is Bulk Modulus

G is Shear Modulus

Lateral Resolution

Amplitude



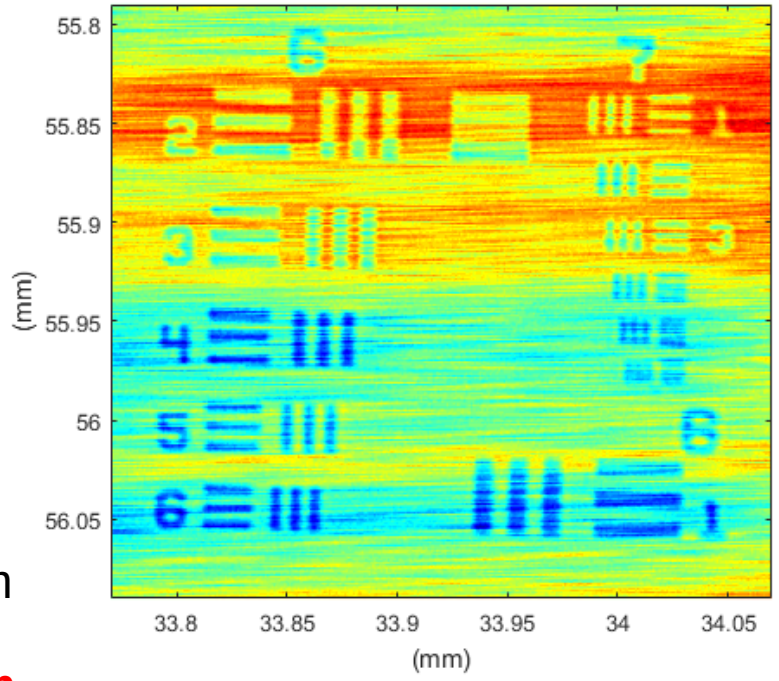
3.10 µm

2.76 µm

2.46 µm

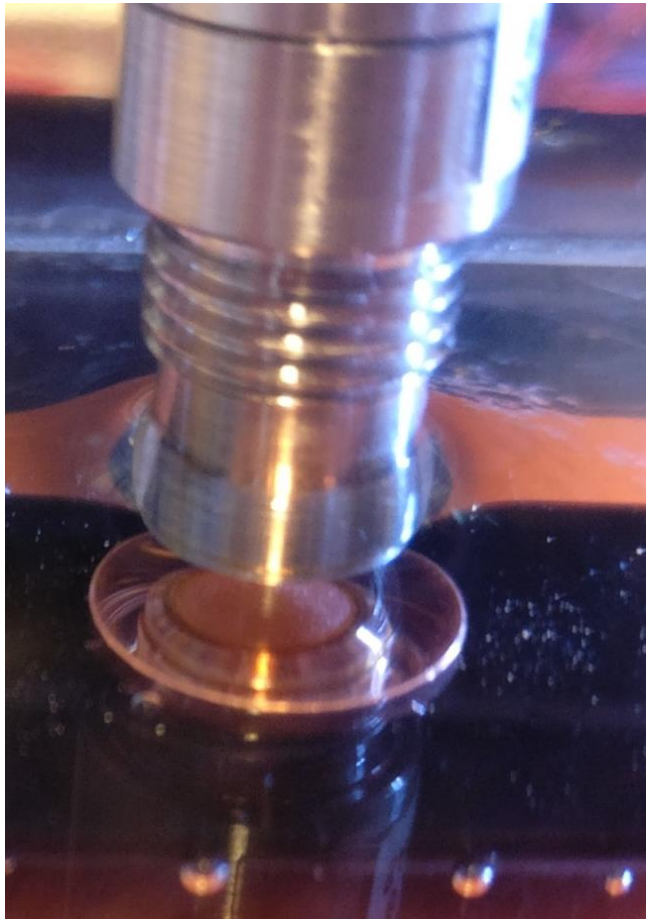
2.19 µm

Time-of-Flight

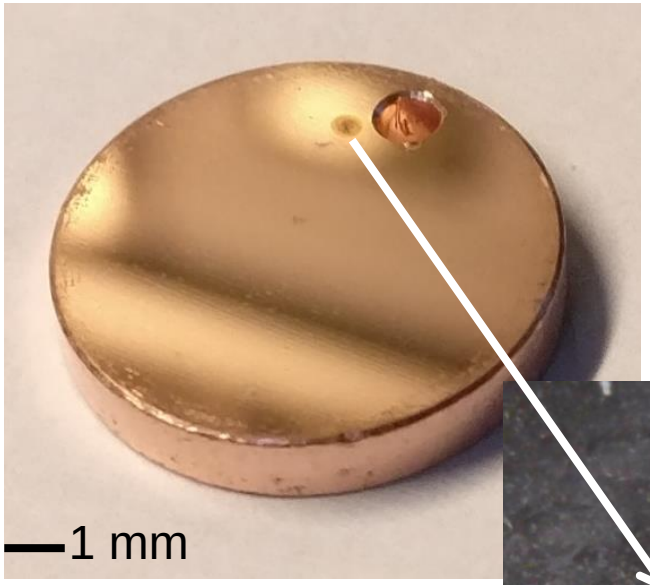


Step Height: 85 nm
(White-light-interferometer: WLI)

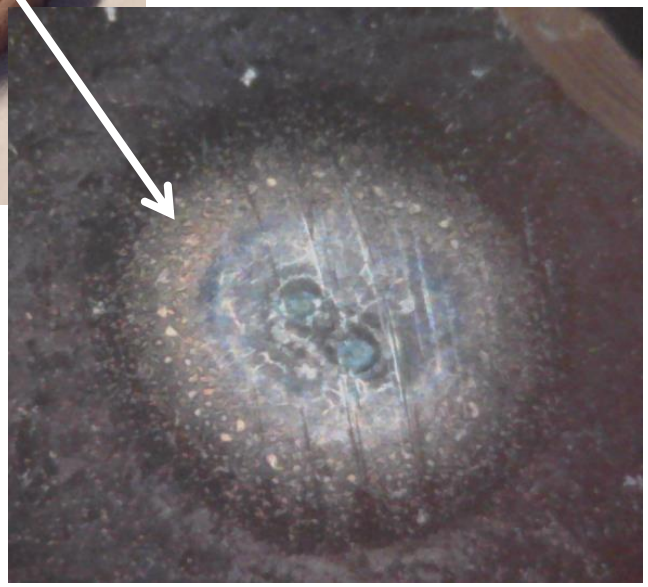
Copper Sample ID5 #495



1 mm

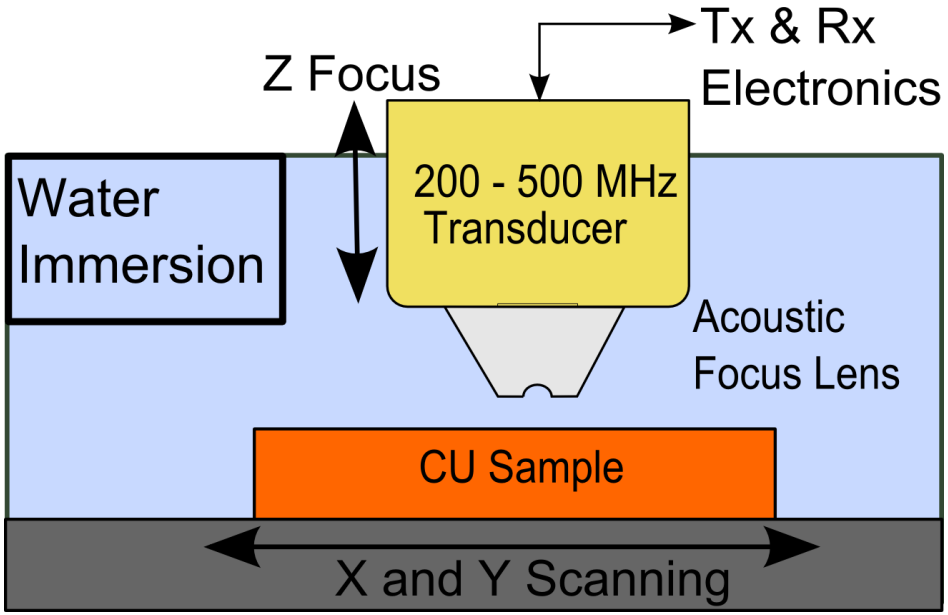


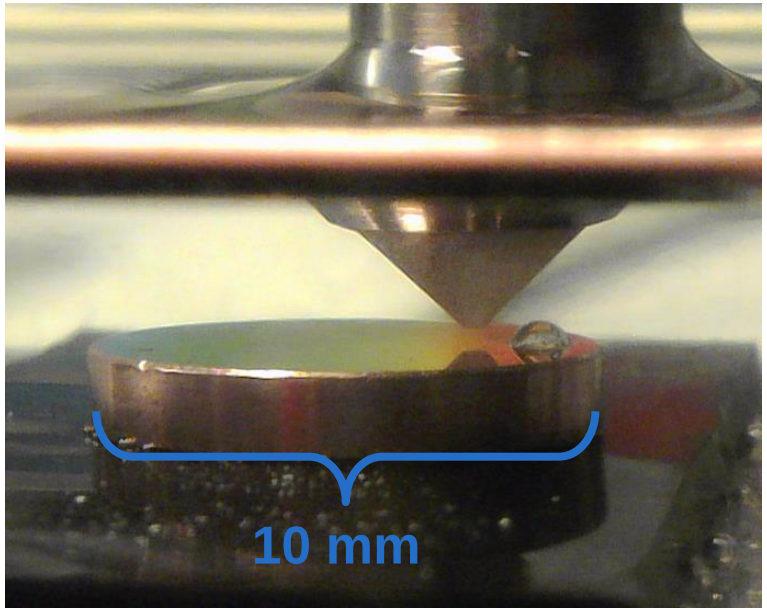
1 mm



0.1 mm

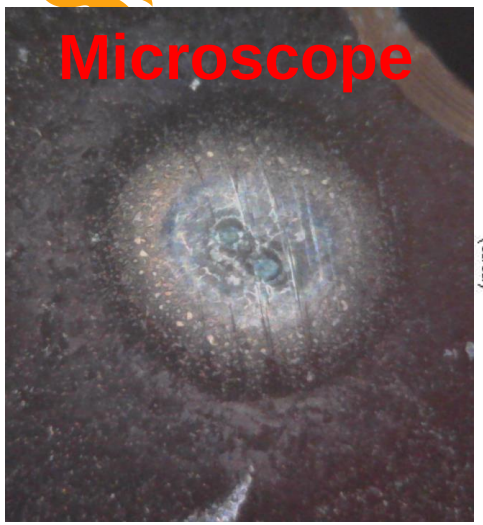
Scanning Acoustic Microcopy

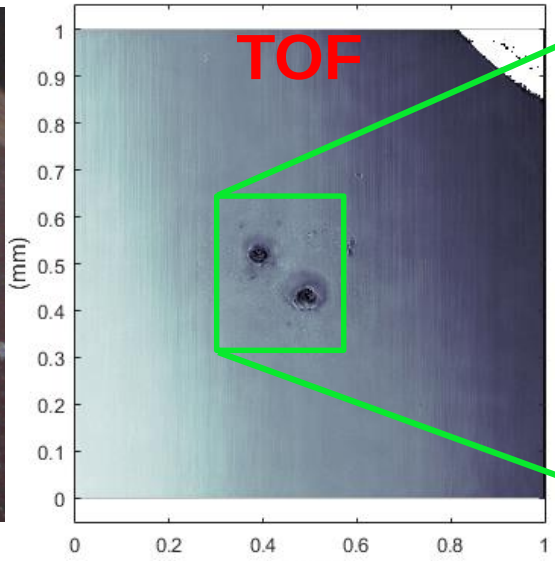


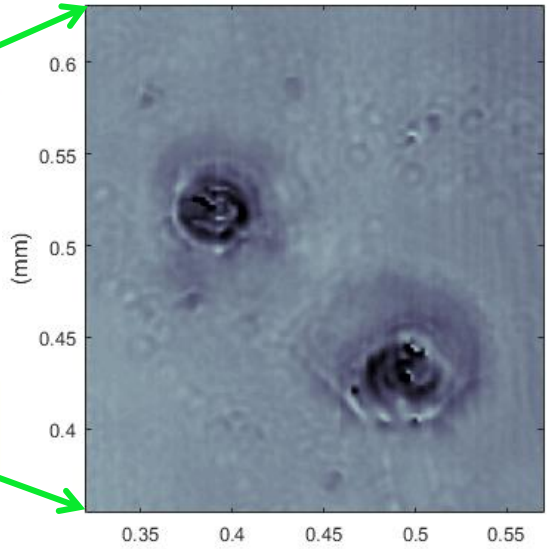


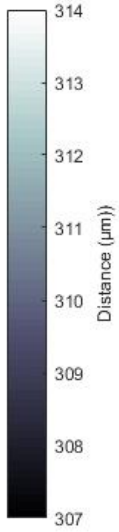
- Frequency range: 240 – 480 MHz
- Pixel-by-Pixel Imaging
- Areas 1 mm * 1 mm
  - ~Stepping 2 µm
- Focus size: less than 3 µm
- Imaging time: ~1 hour/mm^2

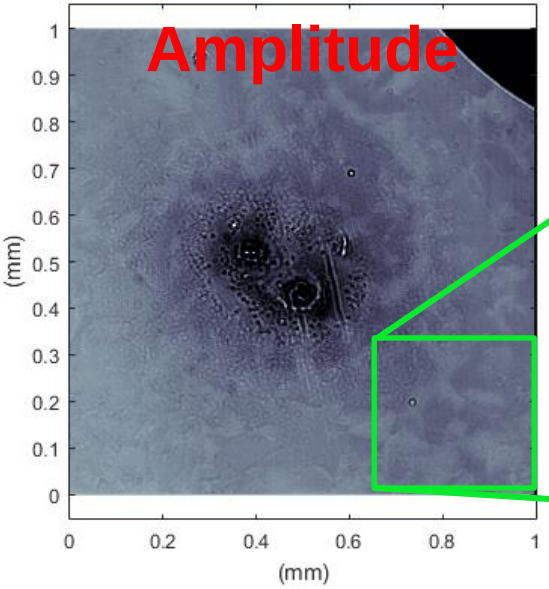
Results: Copper Sample

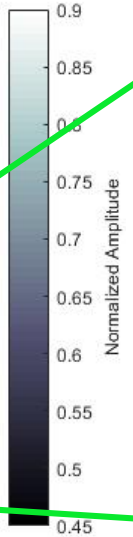


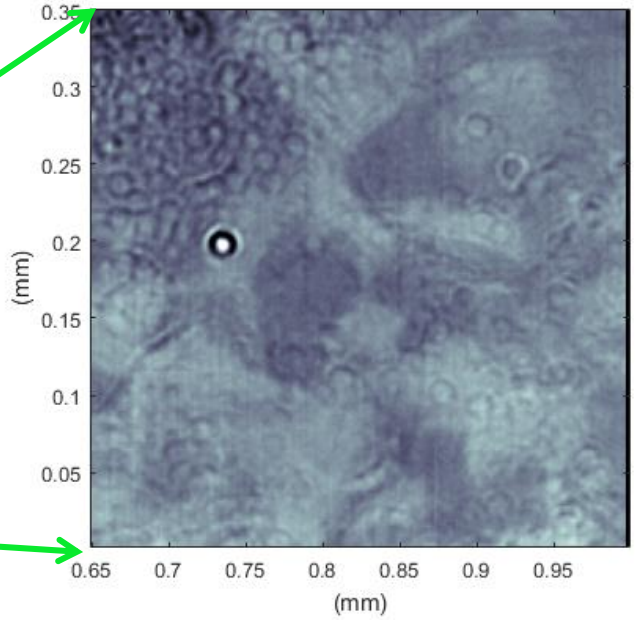


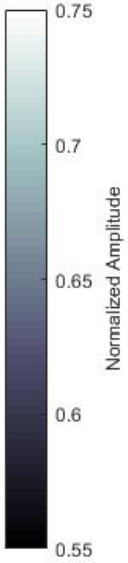




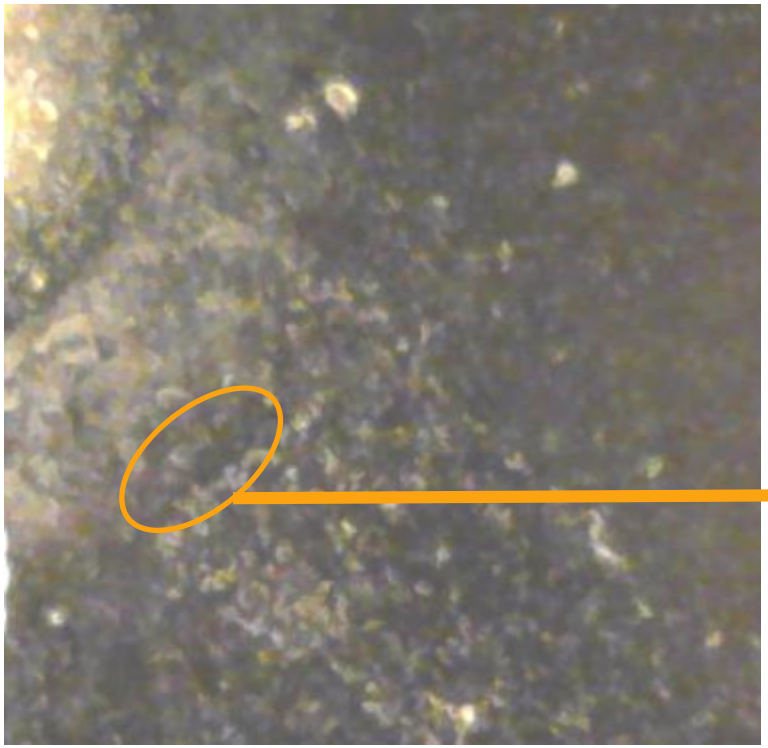


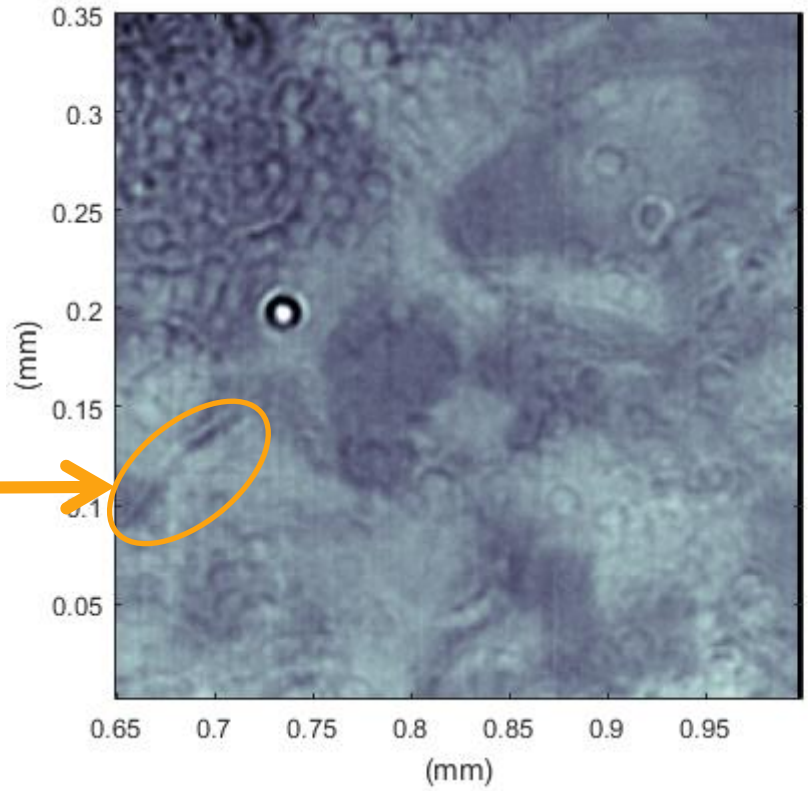


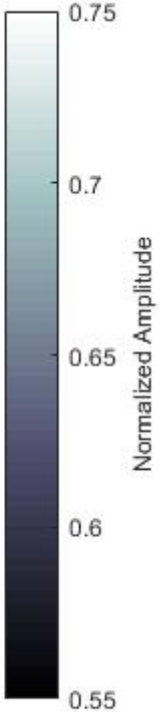




Results: Copper Sample

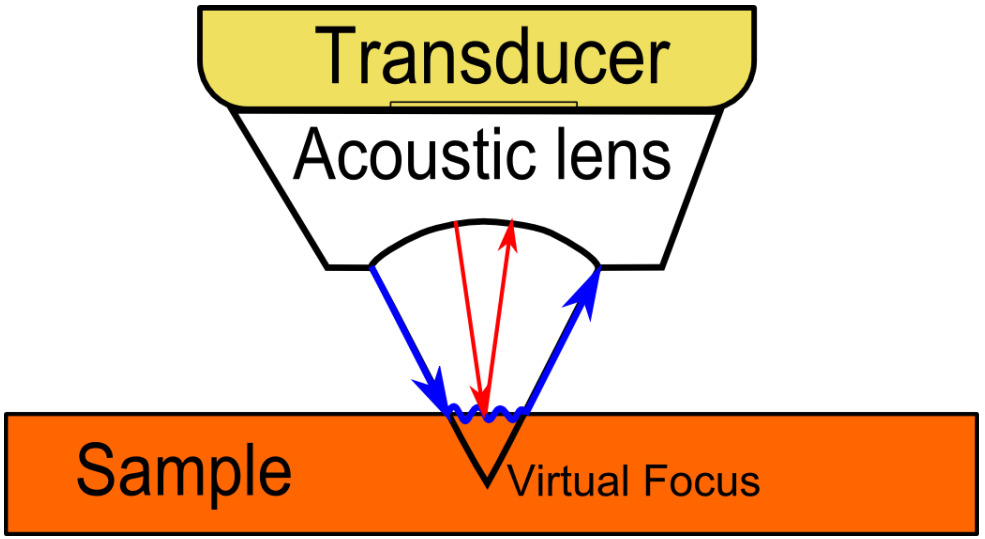






Future Work

- Surface Elasticity (GPa)
  - Acoustic Impedance Calculations
  - Scattering from non-flat surface
- Surface Wave-Velocity
  - Another acoustic parameter
  - V(z) -Technique
  - **Young's Modulus**
- Look Under the Surface
  - Hard with Focused Transducer
  - Time-Reversal -Techniques?



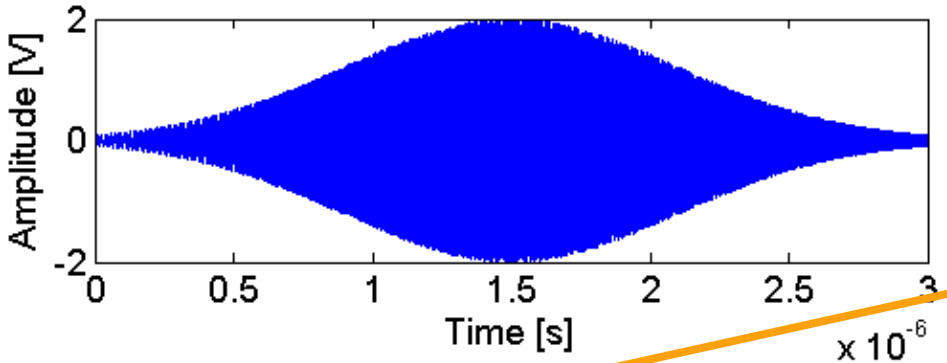
Questions and Comments

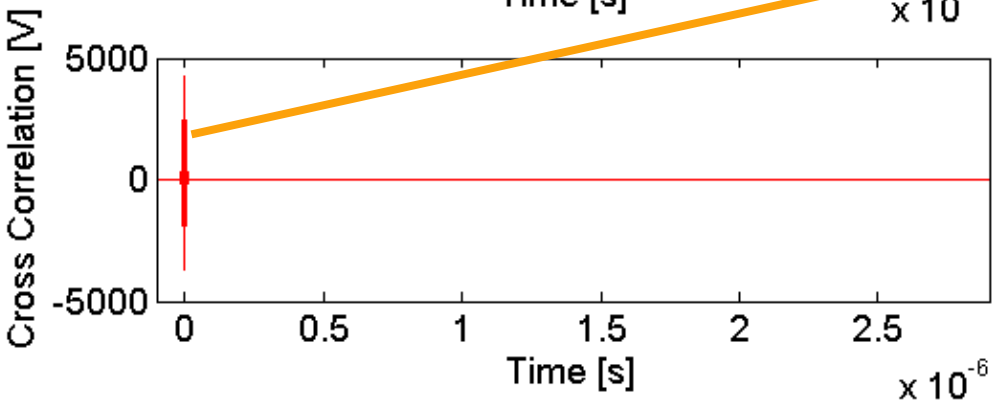
Thank You!

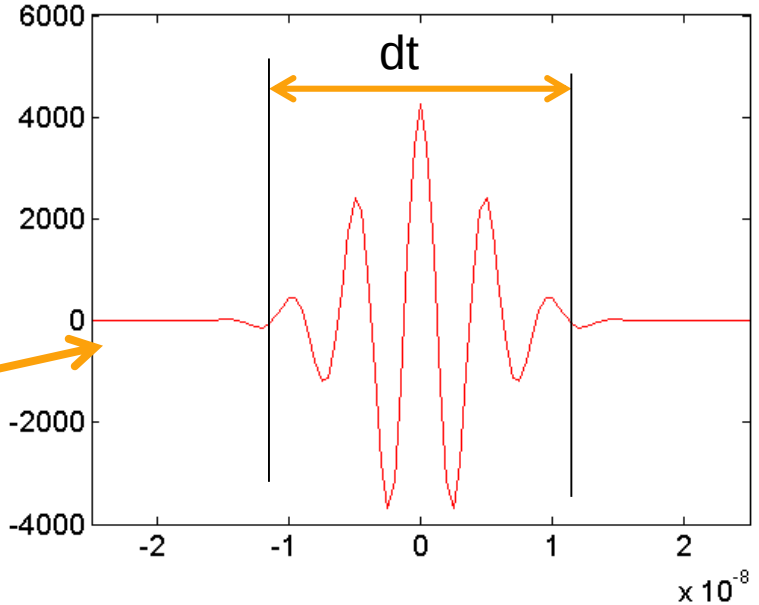
Pulse Compression
Cross Correlation

$$(f \star g)(t) \stackrel{\text{def}}{=} \int_{-\infty}^{\infty} f^*(\tau)\ g(t+\tau)\, d\tau$$

dt descript depth resolution
dt depends on bandwidth







$$dt = \frac{1}{\Delta f} \qquad dz = \frac{c}{2\Delta f}$$

Coded Signal and SNR