# Acoustic Microscopy Imaging of Cu Samples

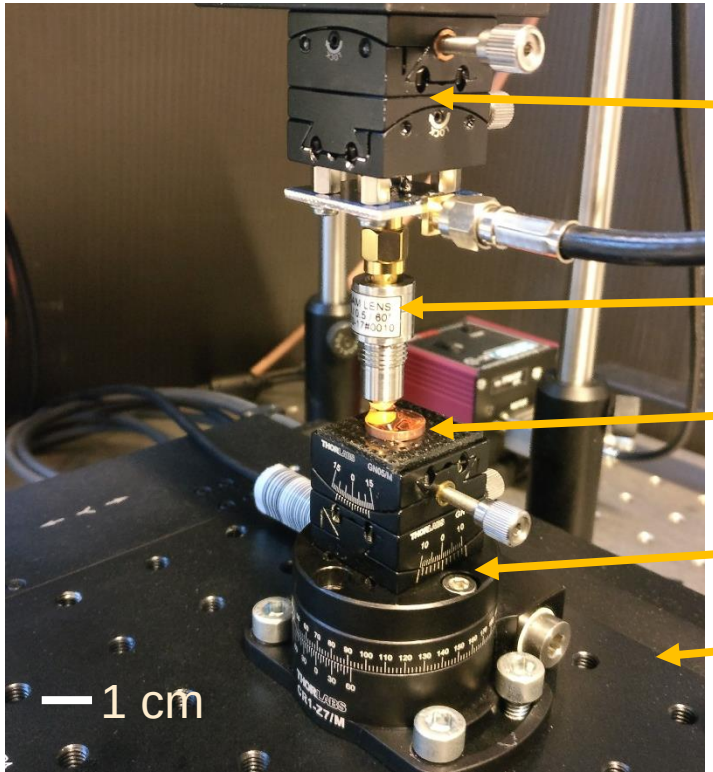
Antti Meriläinen[1,2], Ivan Kassamakov[1,2], Markus Aicheler[2], Kenneth Österberg[1,2] and Edward Hæggström[1]

1) Department of Physics, University of Helsinki

2) Helsinki Institute of Physics

# 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




Goniometer tilt stage

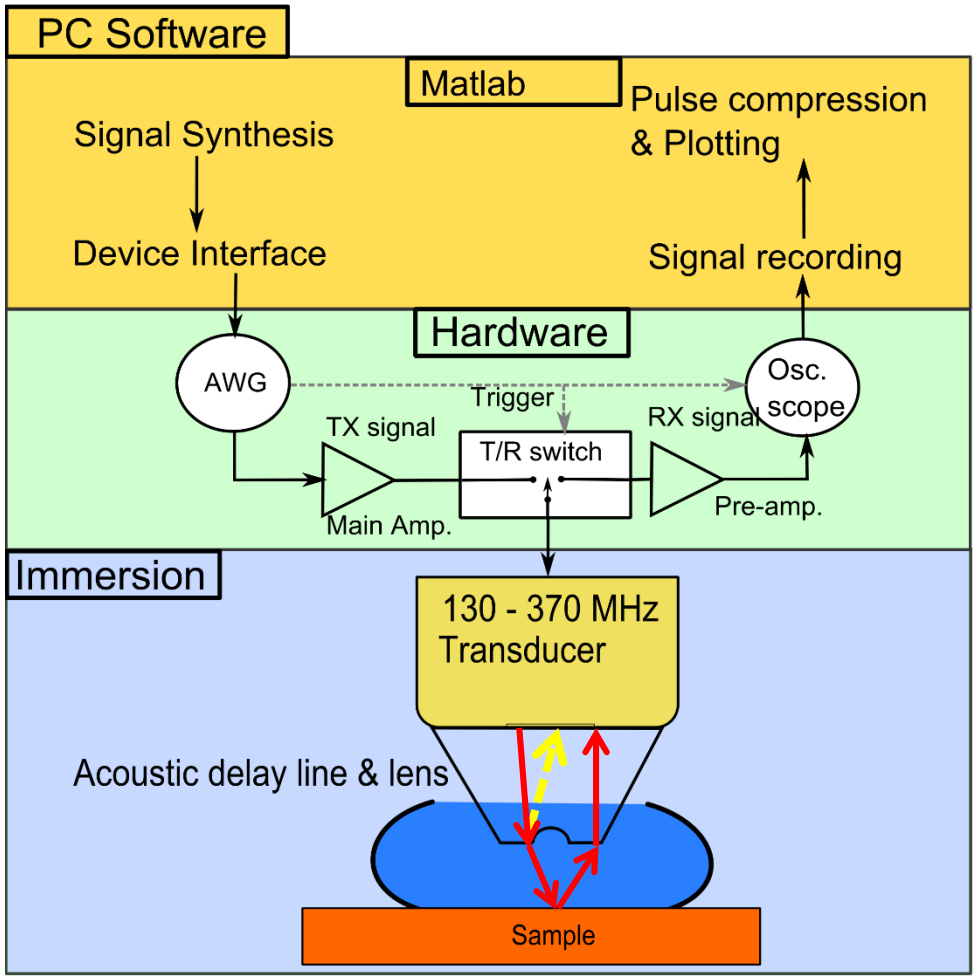
Ultrasound transducer

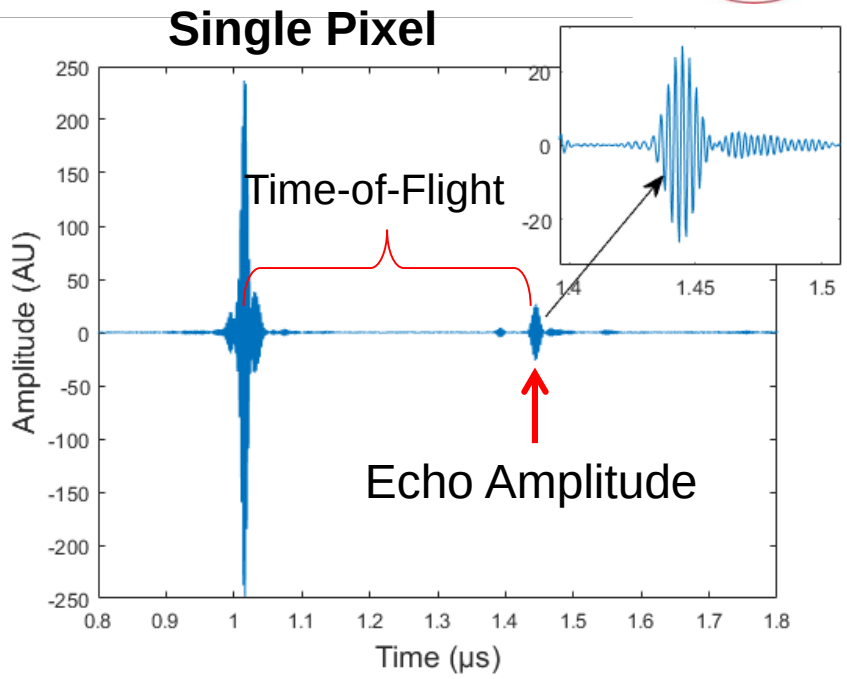
Sample

Goniometer tilt stage

XY Stage

# 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**

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

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

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

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

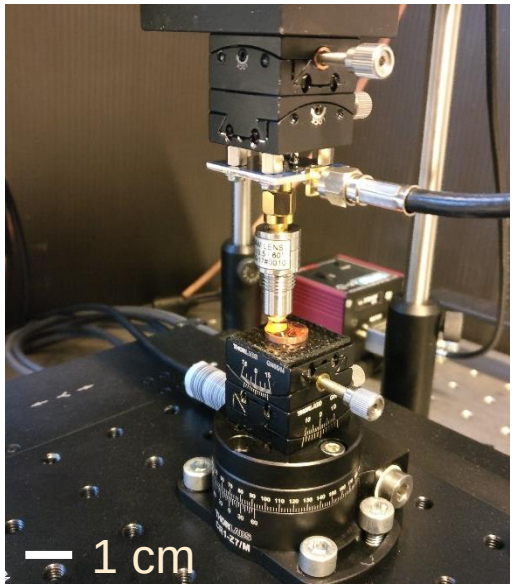
$$\boxed{Z_{Cu} = \frac{\boldsymbol{K_{Cu}} + \frac{4}{3}\boldsymbol{G_{Cu}}}{C_{Cu}}}$$

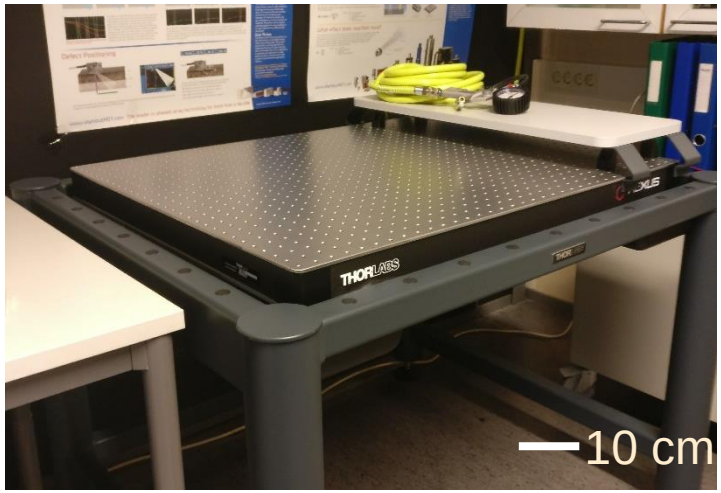
$A = Echoes'\ Amplitude$

***K is Bulk Modulus***

***G is Shear Modulus***

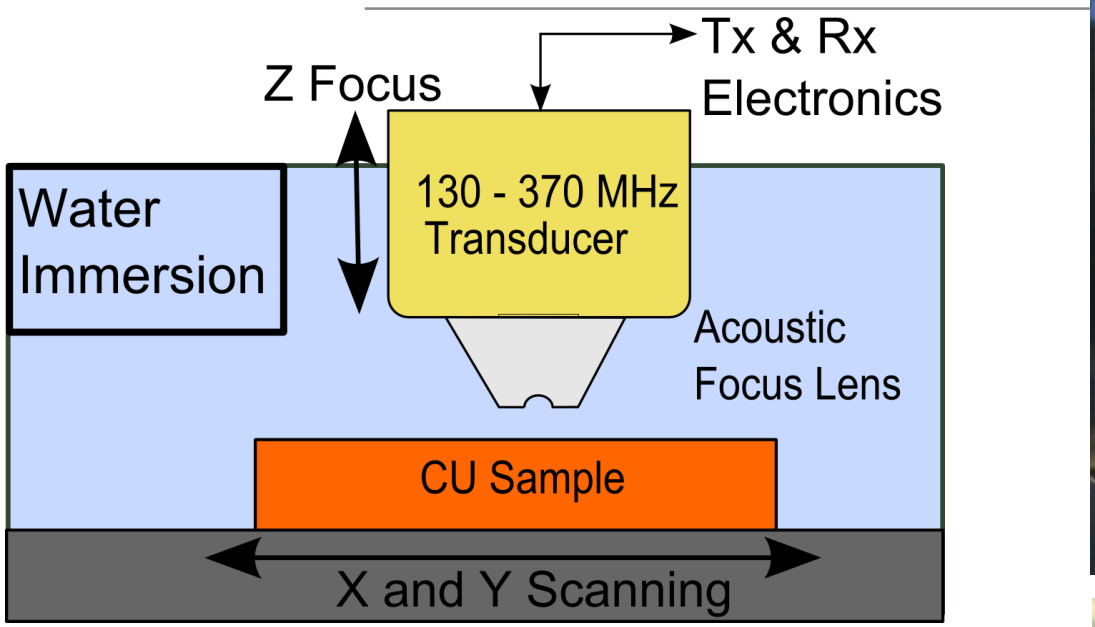
# Acoustic Microscope Upgrades (Rebuild the setup)

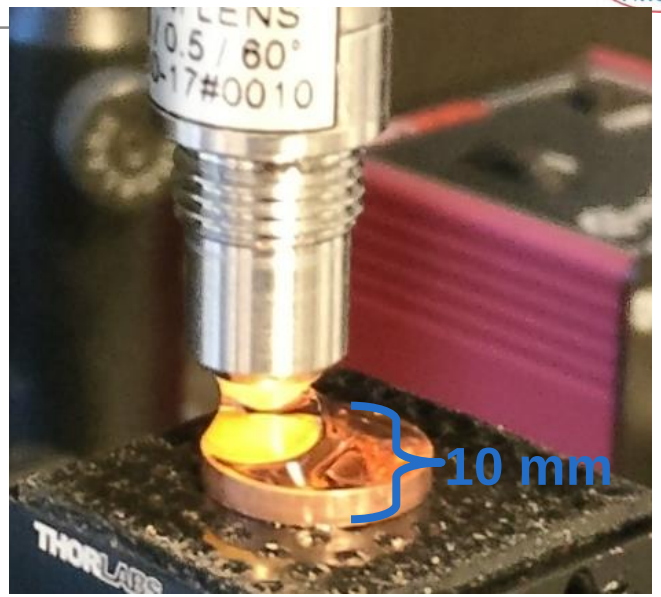


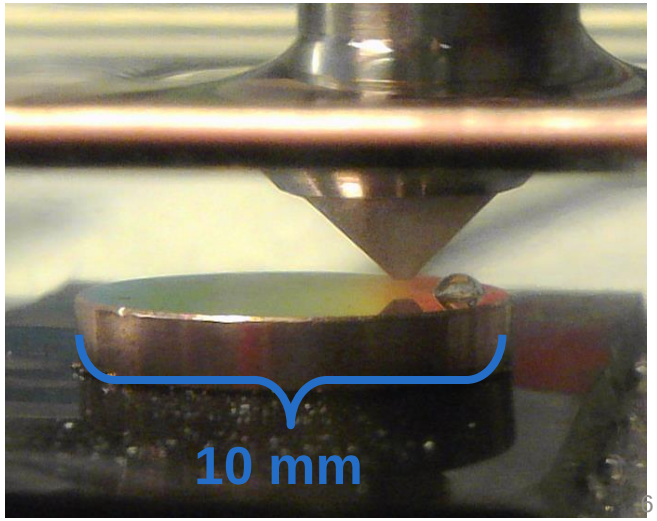




- Fast imaging of large area
  - Time of 1 $mm^2$ is 1 minute (It was 1 hour)
  - New components:
    - XY & Z-Stages
    - PCIe Oscilloscope
    - Custom build trigger electronics
    - Software
- Stable mechanics (Less artefacts)
  - Proper Alignment
  - Steady and smooth movement
  - Robust

# Scanning Acoustic Microcopy

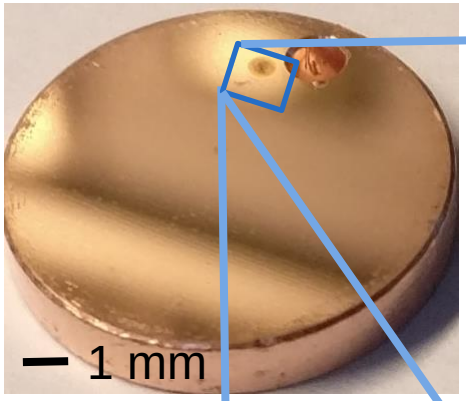


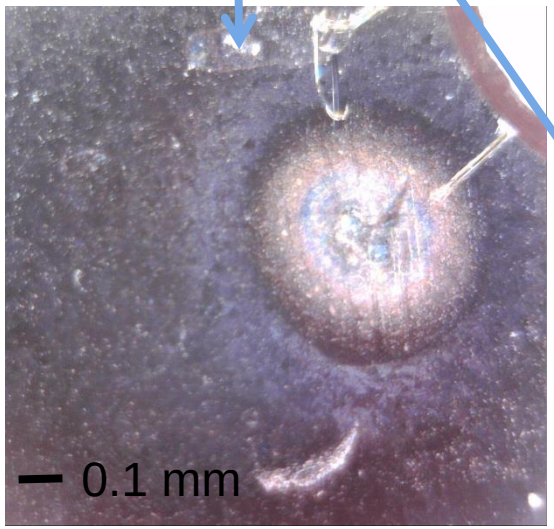



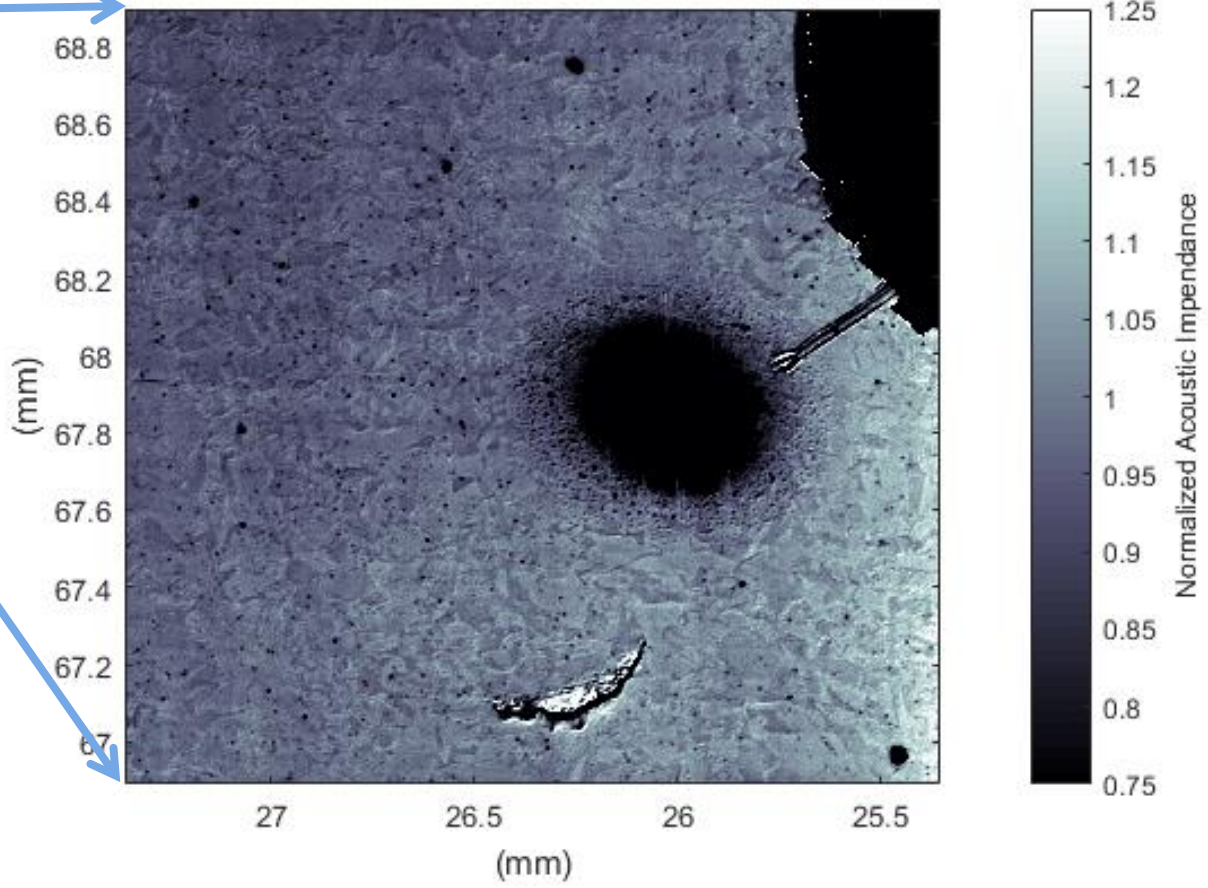




- Frequency range: 130 – 370 MHz
- Pixel-by-Pixel Imaging
- Areas 1 mm * 1 mm
  - Stepping 3 µm
- Focus size: less than 3.5 µm
- Imaging time: ~1 min/mm$^2$

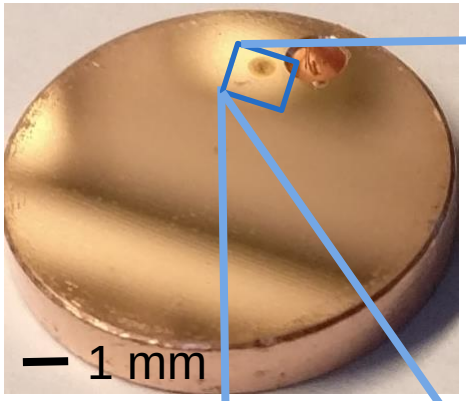
# Copper Sample ID5 #495 Spark Spot

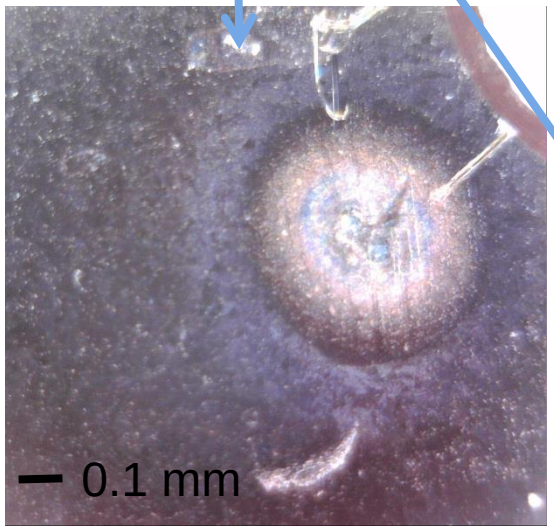


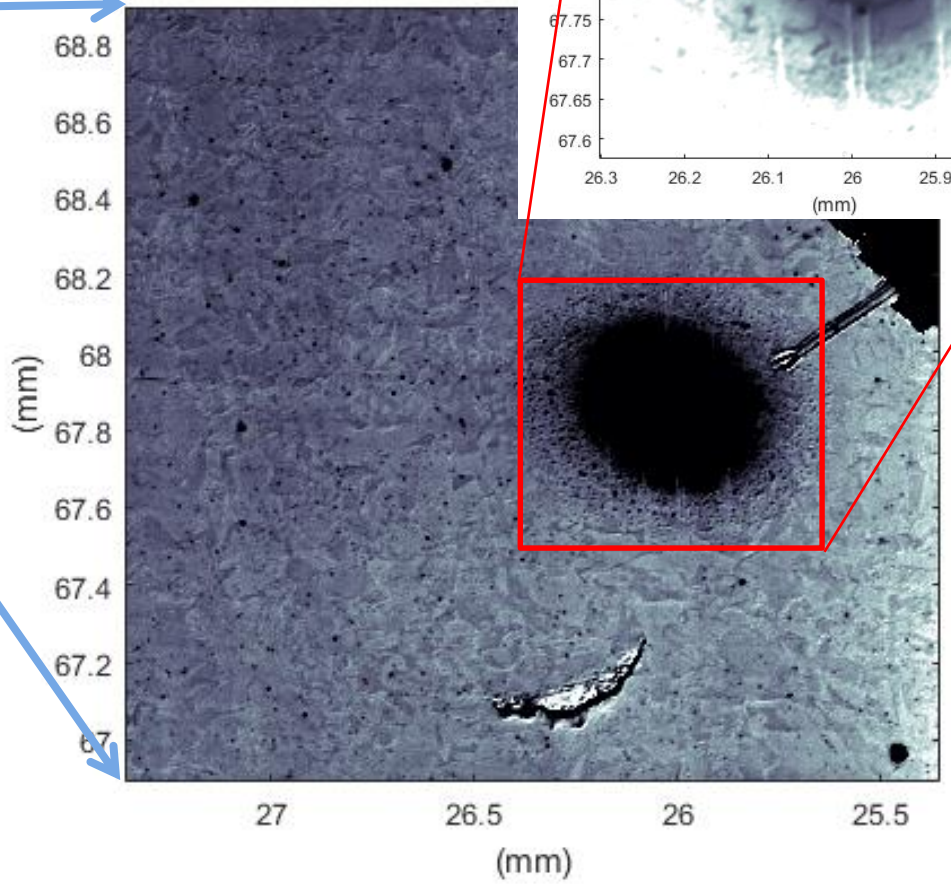



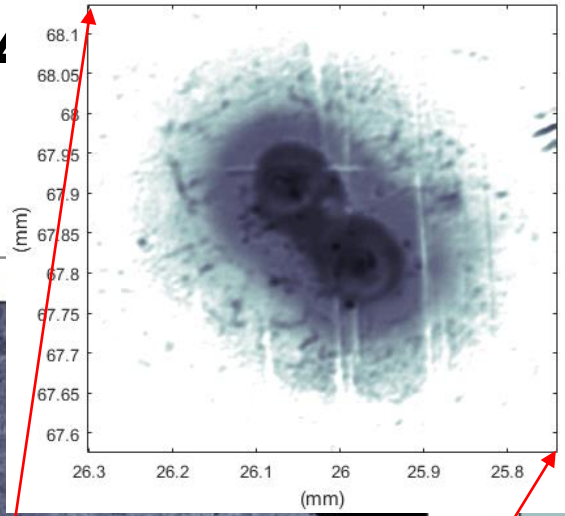



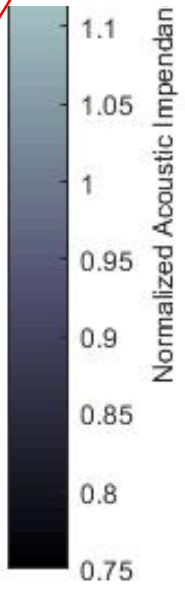
# Copper Sample ID5 #4 Spark Spot



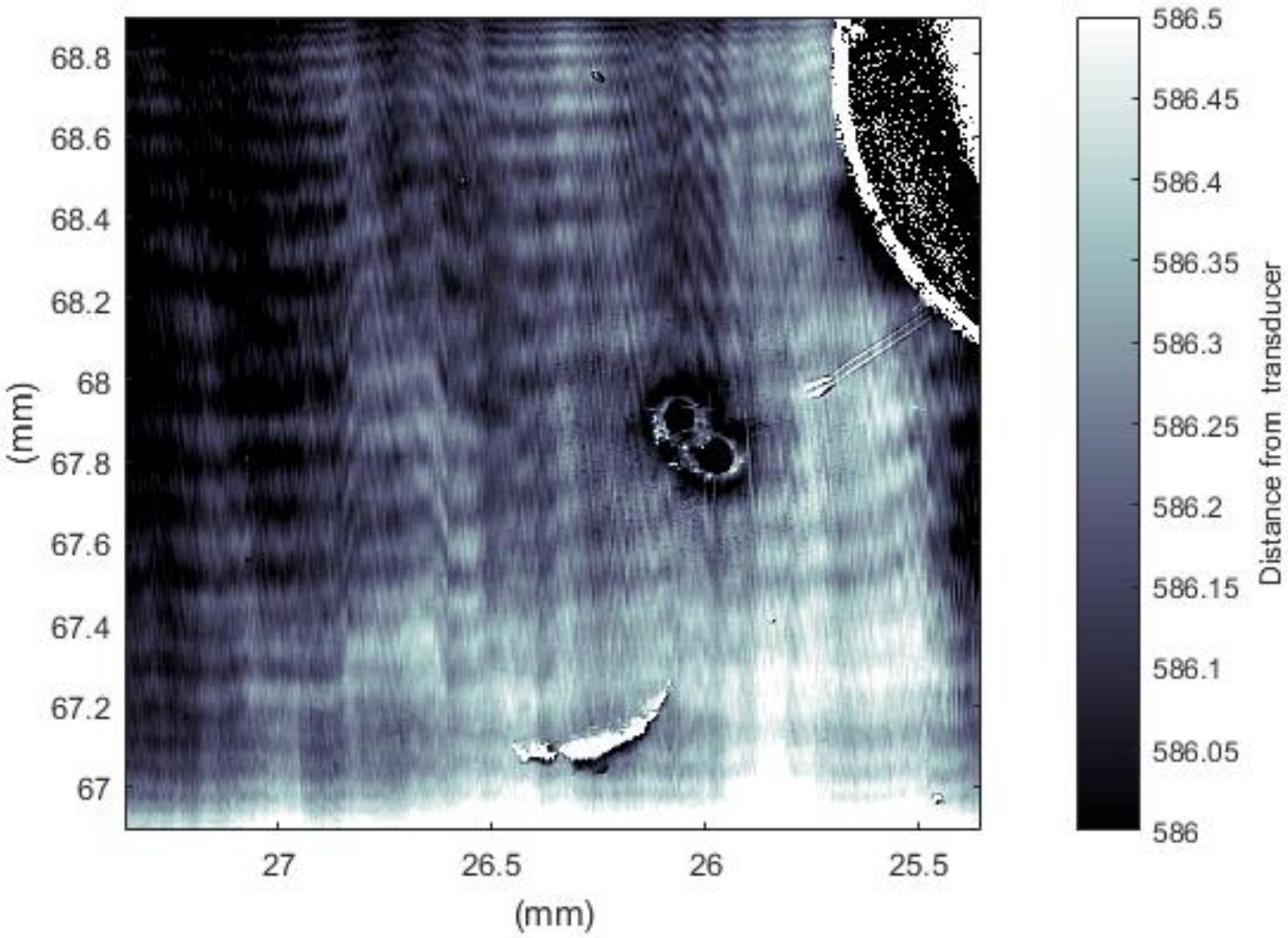



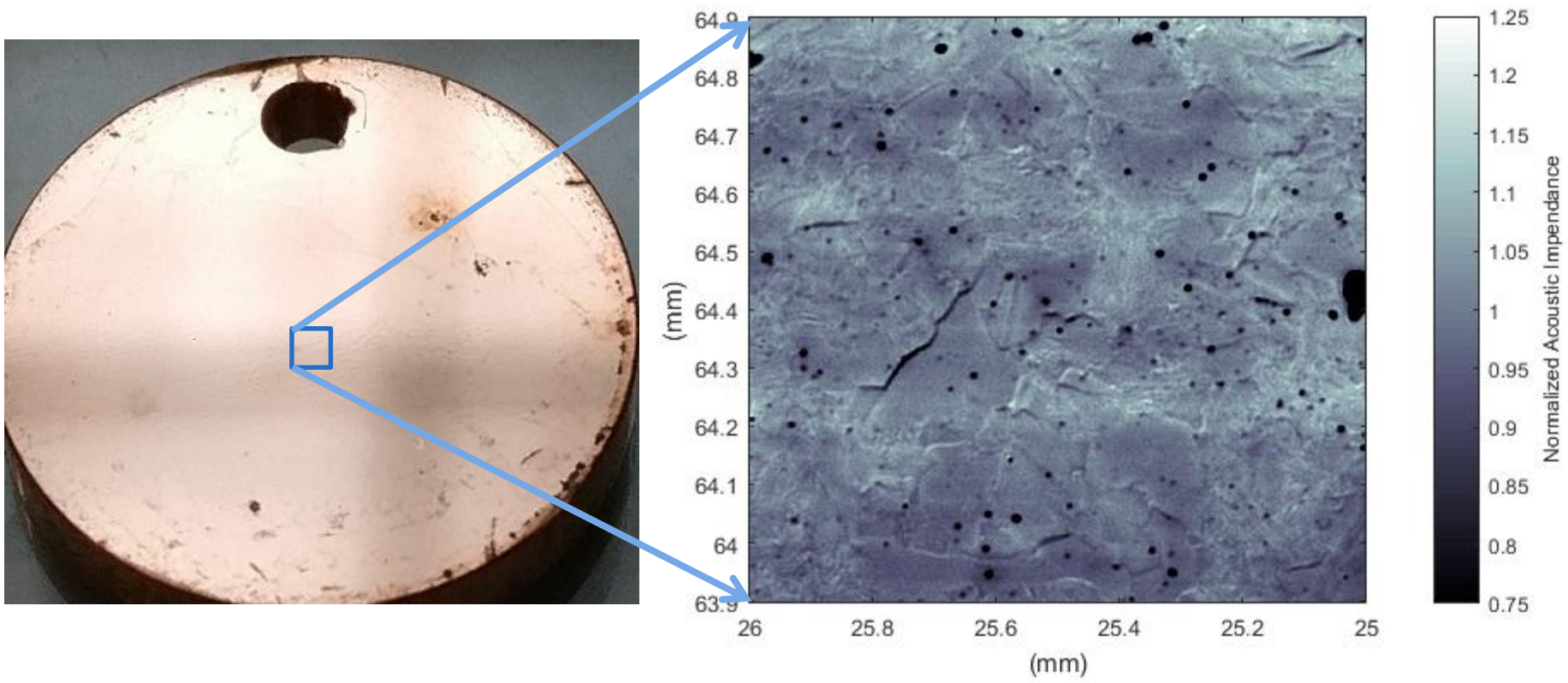



# Topology of Copper Sample

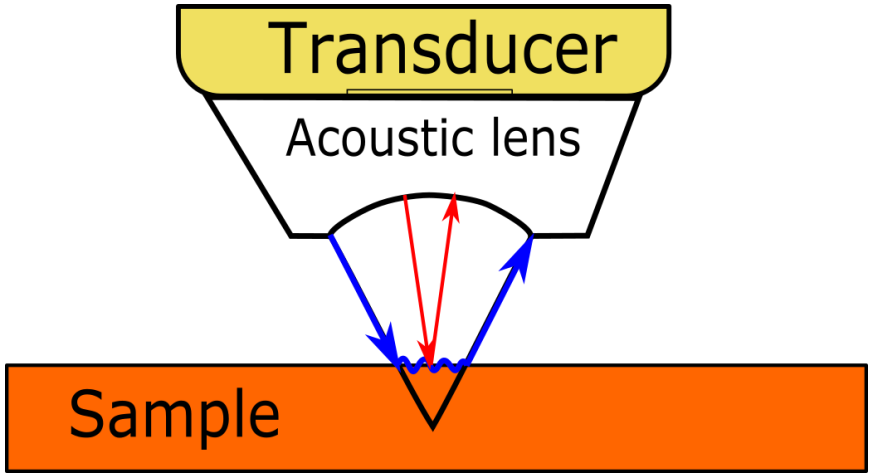


# Copper Sample ID5 #23
# Dark Current Field

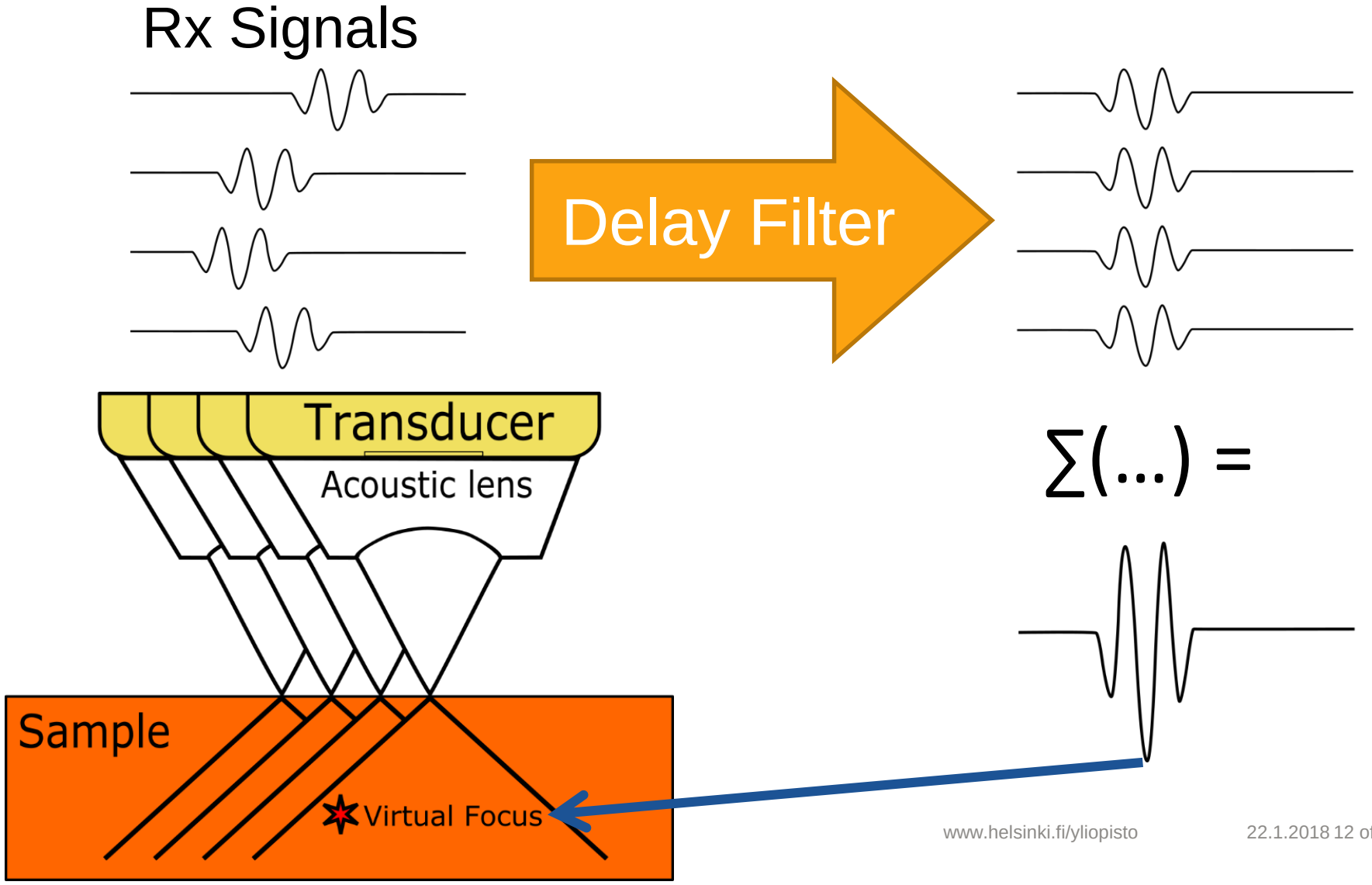


# Future Work

- Surface elasticity (GPa)
  - 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
  - Synthetic aperture focusing technique



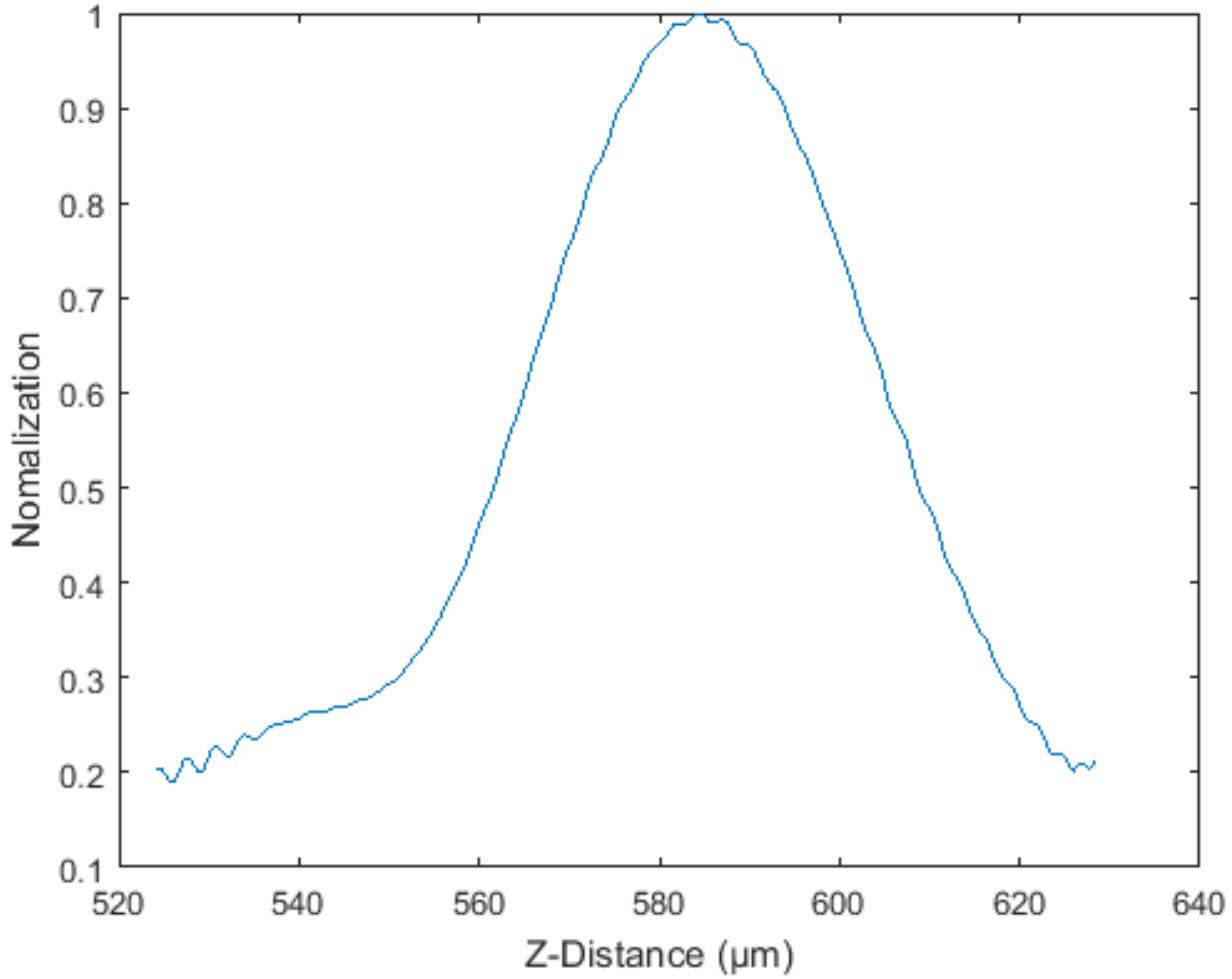
# Synthetic Aperture Focusing Technique



# Questions and Comments

Thank You!

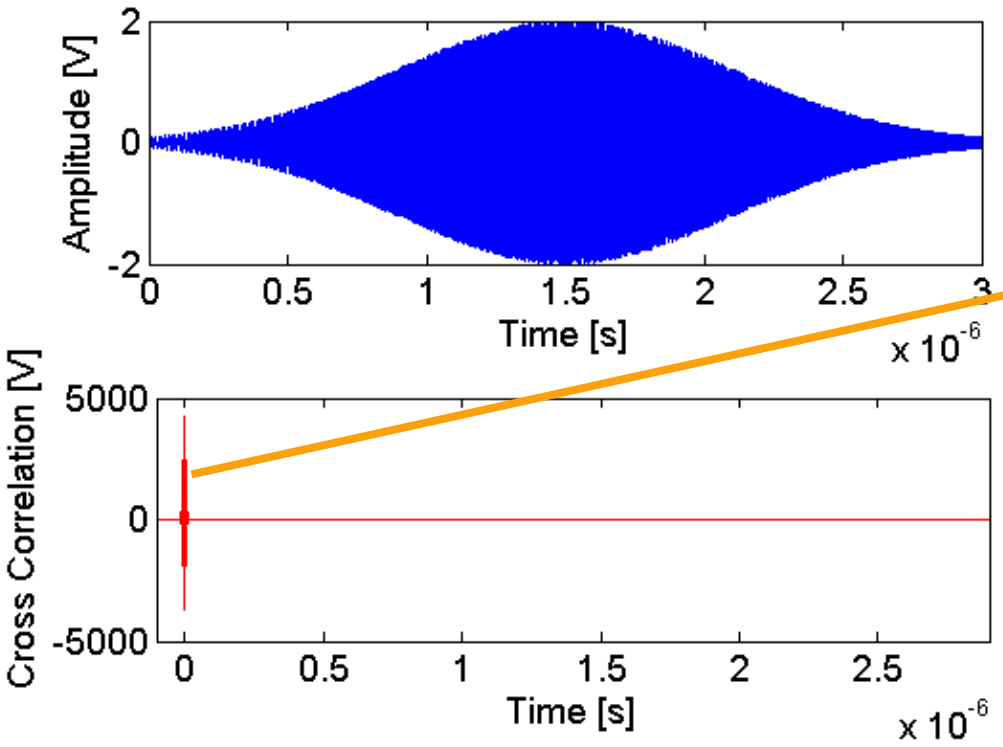
# Z-Focus vs Amplitude

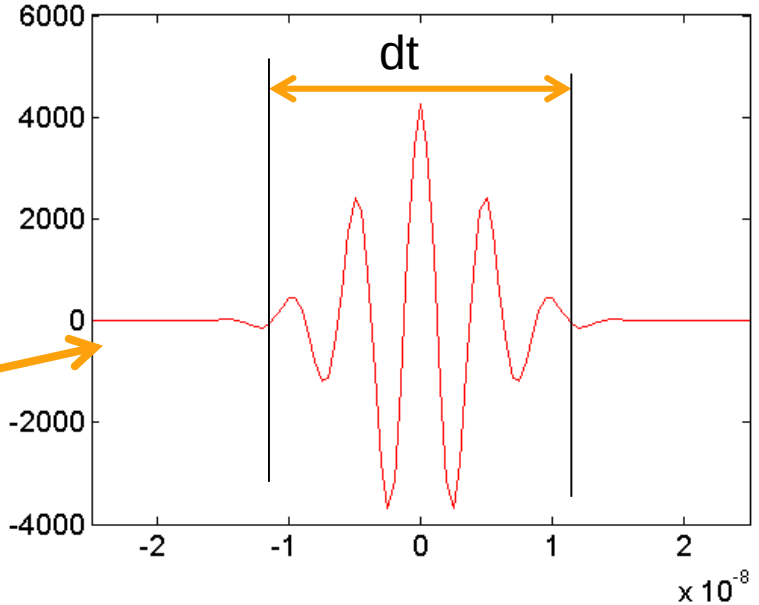


# Pulse Compression
# Cross Correlation

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

dt descript depth resolution
dt depends on bandwidth




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

# Coded Signal and SNR