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Title: Applied Acoustics Lab Overview

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Los Alamos
NATIONAL LABORATORY

Applied Acoustics Lab Overview

Cristian Pantea
Materials Physics and Applications, MPA-11

QCAM kick-off Meeting
NMSU, Las Cruces
Oct 7, 2021

LA-UR-21-30017

Applied Acoustics Team

http://www.lanl.gov/orgs/mpa/mpa11/AcousticsAndSensorsTeam

Cristian Pantea

Team Leader

Vamshi Chillara

Research Scientist

Electric Imp Spectr
Chevron)
Well Integrity Monitoring
CO_2 sequestration (DOE)
μarchitected Waveguides (LDRD-ECR)

John Greenhall

Research Scientist

Machine Learning
3DHEAT
Defects Thermoel Wafers
NDE weapons components
Electronics design

Craig Chavez:

Research Technologist

Mechanical and Electronics Design, and System Configuration

Eric Davis

Postdoc

Well Integrity Monitoring
CO_2 sequestration (DOE)
D_2O content in heavy water
3DHEAT
Acoustic Monitoring of Pu
NDE of weapons components

Hung Doan

Postdoc

Corn stover acoustics sensor
Well Integrity Monitoring

Dipen Sinha

Visiting Scientist

Defects Thermoel Wafers
Welding inspection
NDE of weapons components
Electronics design

Pavel Vakhlamov

Research Technologist

Mechanical and Electronics Design, and System Configuration

Milo Prisbrey

Postdoc

Machine Learning
Acoustic manipulation
Waveform inversion
**Joint w/ CCS-7*

Alan Graham

Research Associate

Defects detection in wafers
Welding inspection
NDE of weapons components

Sincheng Huang

Grad Student

Instrumentation development
LabView programming
D_2O content in heavy water

+ several students through Rockward's student programs

Our research - Applied Acoustics

Development of instrumentation, methods and sensors with a focus on difficult and challenging conditions (high pressure, high temperature, corrosive media, radiation, etc.)

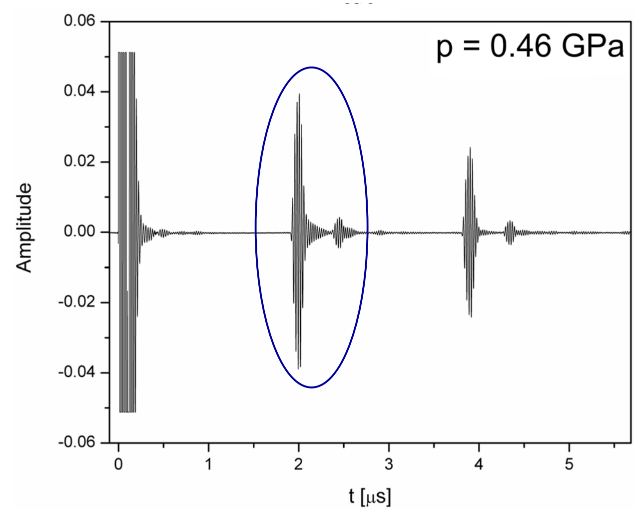
Sensing

Manipulation with sound

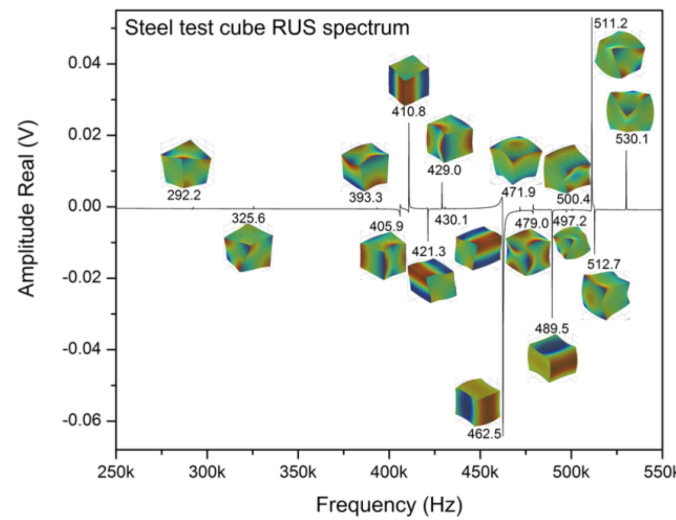
Elastic Properties Determination

In-situ Materials Characterization (Elastic Properties) at Conditions of High Pressure and High Temperature, Corrosive Media, etc.

- *In-situ d*etermination of elastic constants:
  - Bulk Modulus
  - Shear Modulus
  - Young Modulus
  - Anisotropy
  - Poisson ratio
  - Acoustical Nonlinear Parameter β
  - Higher-Order Elastic Moduli



- Two experimental approaches:
  - Time-domain measurements
    - Pulse-echo
    - Pitch-catch
    - Digital Ultrasonic Pulse-Echo Method
  - Frequency-domain measurements
    - Resonant Ultrasound Spectroscopy
    - Acoustic Resonance Spectroscopy
    - Swept Frequency Acoustic Interferometry

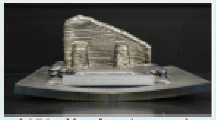


In situ Ultrasonic Monitoring of Additively Manufactured Structures

Blake T. Sturtevant, Cristian Pantea, Dipen N. Sinha
Materials Physics & Applications, Los Alamos National Laboratory

Background

- Stresses can arise during the AM build process
  - Large and fast (10^3-10^6 K/s) local thermal cycling
  - Can lead to deformation of part after release from build plate



Additive Manufacturing magazine

BAE Systems Advanced Technology

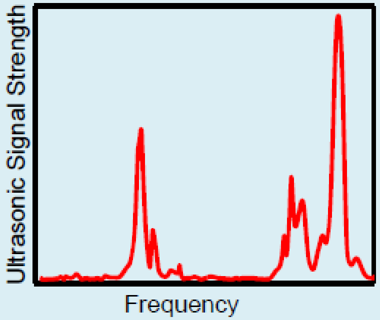
  - Residual stresses can lead to early and/or catastrophic part failure
- Defects (voids, microcracks, inhomogeneities) can also arise as a result of the build process
- Need techniques for monitoring for stresses and defects, *in situ*, during the build process, to enable adjustment or termination of build

Why Ultrasonics?

- Inherently non-destructive
- Can be performed non-invasively and even non-contact
- High temperature capabilities (>1000 °C)
- Ultrasonics probe the material properties that are most affected by defects and stresses
  - Mass density
  - Elastic moduli
  - Elastic nonlinearity
- Many complementary techniques can be performed with similar equipment & materials
  - Bulk acoustic waves – traveling and standing (bulk properties)
  - Surface acoustic waves (surface stresses and defects)
  - Nonlinearity studies (presence of defects)
- Can probe the bulk of metals and other optically opaque materials

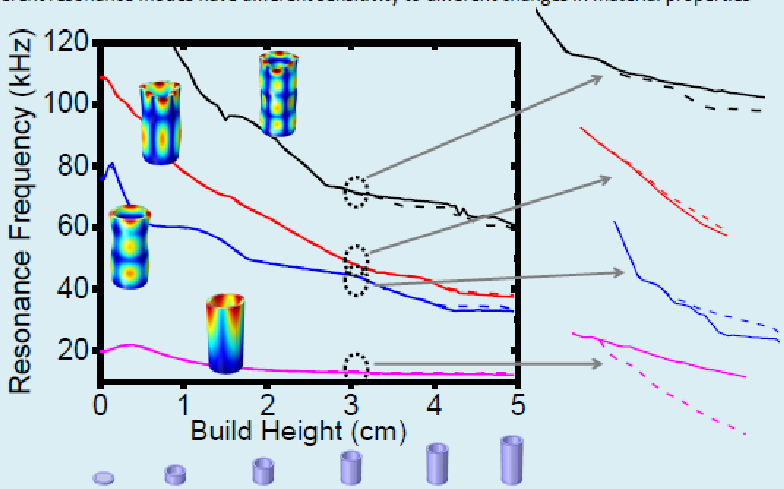
Structural Resonance Evolution During Build

- Every solid object has a unique resonance spectrum
- Resonance peaks (right) correspond to different structural vibration modes
- Can observe how individual resonance modes change frequency over the build process
  - Deviation from expected behavior indicates stress, defects, or damage



Finite Element Modeling

- Tracked individual resonance peaks throughout the build process
  - Build is of a 5 cm tall stainless steel hollow cylinder with an endcap
- At 3 cm, artificially changed elastic modulus of material (mimics residual stress)
- Observed resonance frequency shift from that of a "good" part (constant elastic modulus)
- Different resonance modes have different sensitivity to different changes in material properties

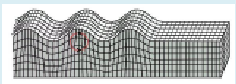


(dashed lines show how resonances change when elastic modulus changes @ 3cm)

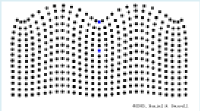
Can detect changes of <1% in elastic modulus

Rayleigh Waves

- Rayleigh waves (surface acoustic waves or SAWs) propagate on the surface of a structure
- Most of their energy is confined to within a few wavelengths of the surface (material deformation shown below)
  - Provides extreme sensitivity to surface defects or residual stress on surface



Rayleigh wave propagating left to right



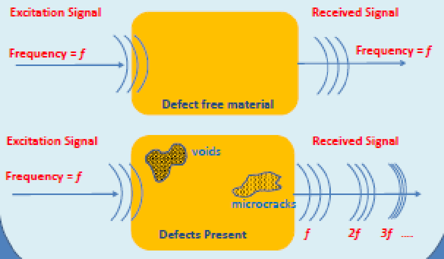
Local material deformation of a Rayleigh wave

$$c = \lambda f$$ (speed is constant)

- By varying frequency, can change the depth probed below the surface

Ultrasonic Nonlinearity

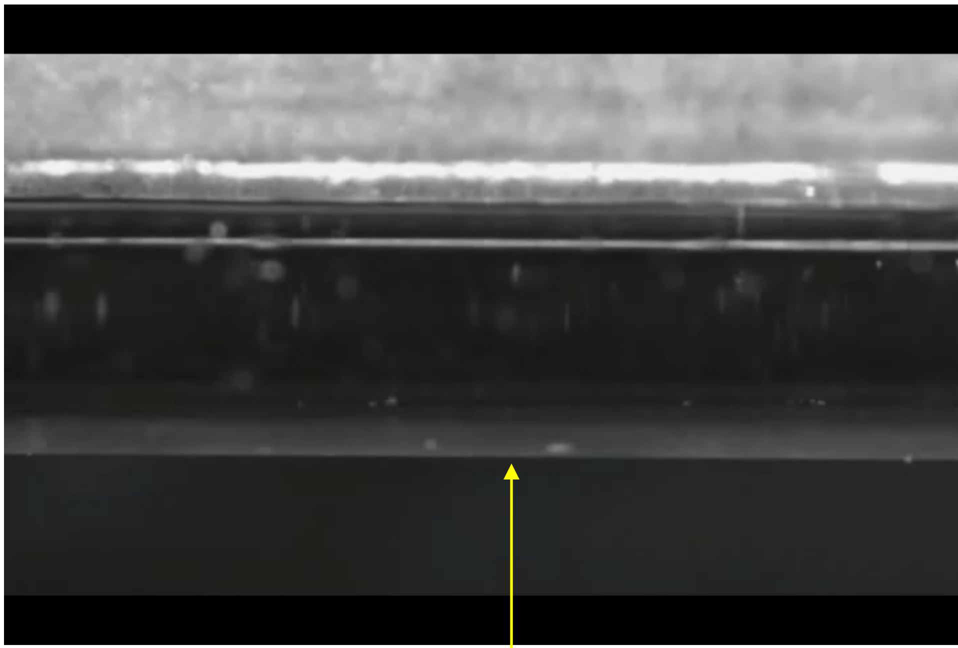
- Defects produce nonlinear acoustic signals
  - (microcracks, voids, inhomogeneities)
  - Higher harmonic (2*f, 3*f, etc) generation
- Strength of the harmonic signals (degree of nonlinearity) provides a way to quantify presence of defects



Concentration of Particles in a Tube

Sound field is turned ON and OFF.

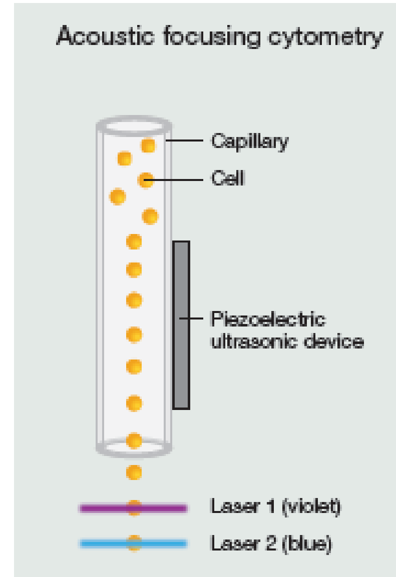
Piezoelectric Transducer @ 1.5 MHz



600 μm capillary, Flow~ 200 μL/min
20 μm polystyrene beads

Real Time Video

Acoustic Flow Cytometer

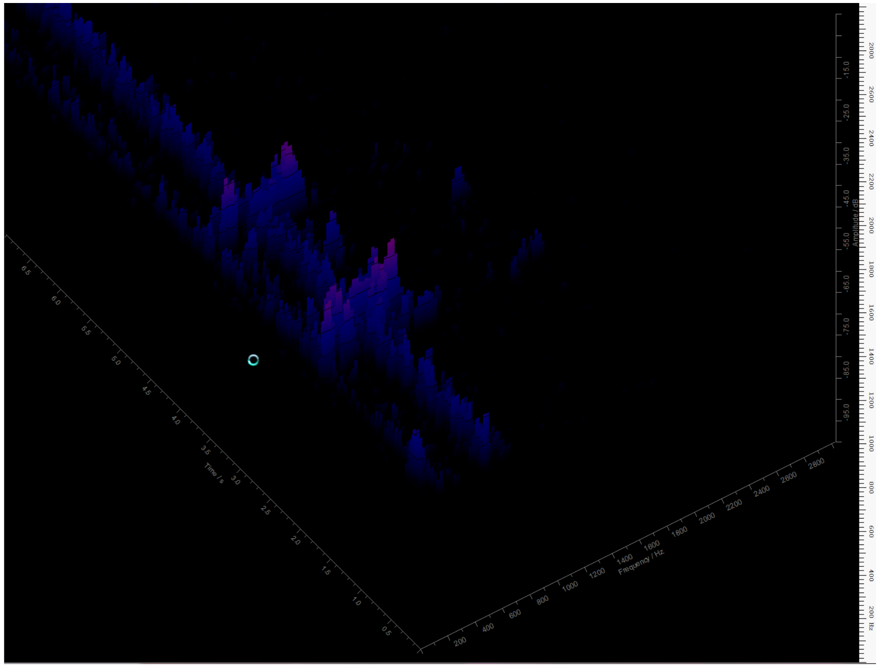


Biological cell analysis

Thermo Fisher Scientific

Applications of Acoustic Techniques

3. Detect and quantify particulate matter, liquid droplets, and gas bubbles in flowing media through Doppler Spectroscopy



20-50 micron sand particles moving through mineral oil in a vertical metal pipe

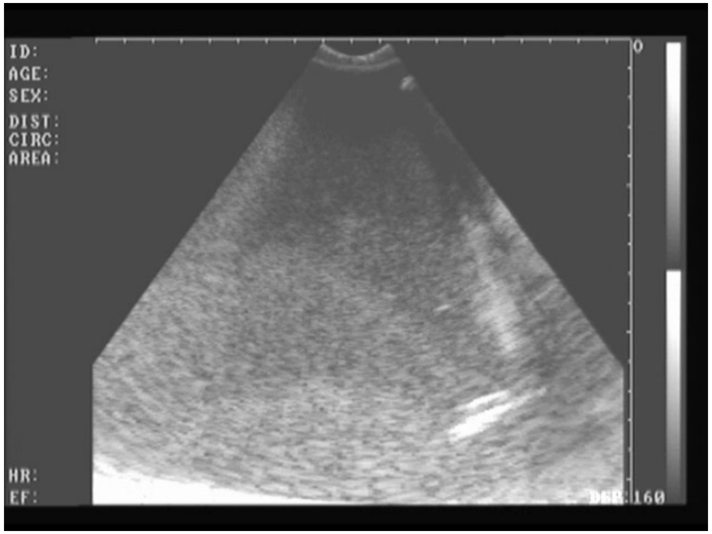
Doppler Spectroscopy

The spectrum contains information about particle size and concentration

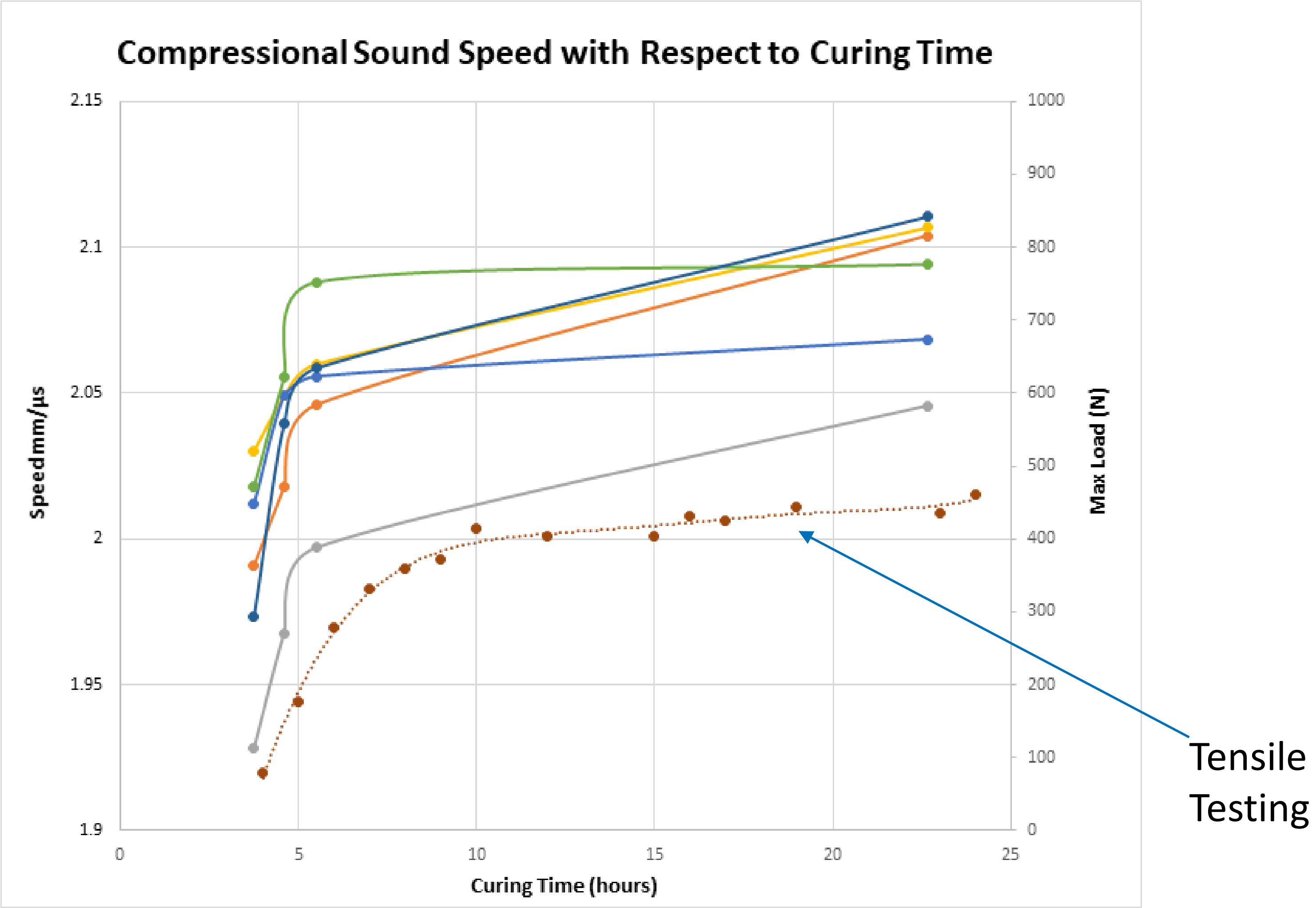
Detection Sensitivity: ~ 5 grains of sand

Size range: 1 – 100 micron

Ultrasonic Visualization of sand in water

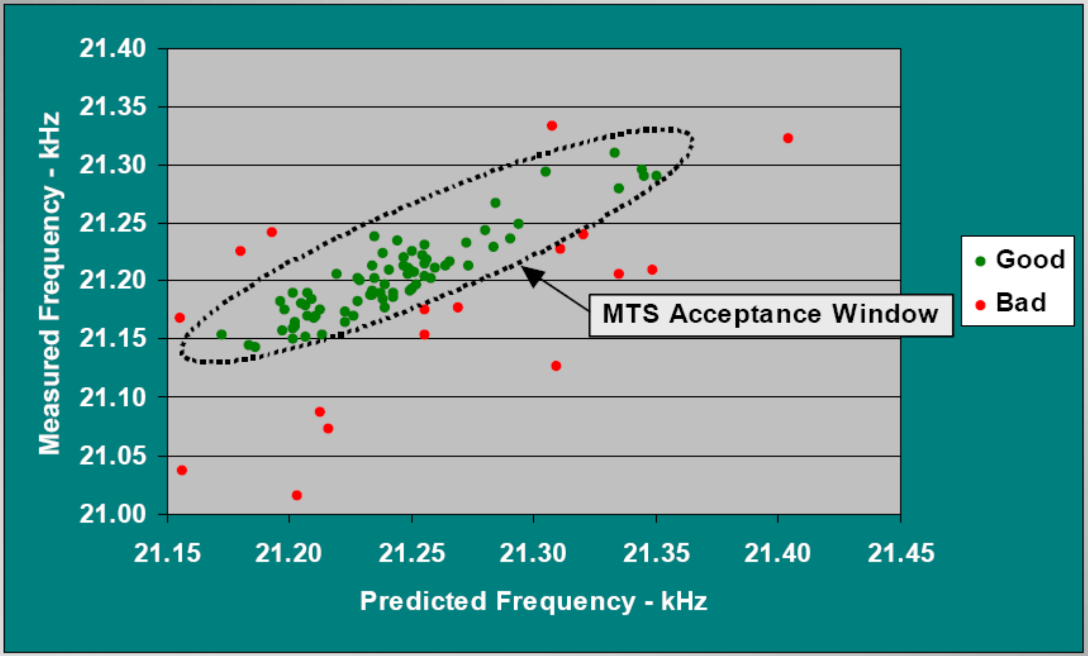


Two parts adhesive curing monitoring with ultrasound
Summer project with FIU - Gonzalo Seisdedos



Quasar International (Albuquerque)

- Graphical Illustration -
Part Sorting Using Pattern Recognition



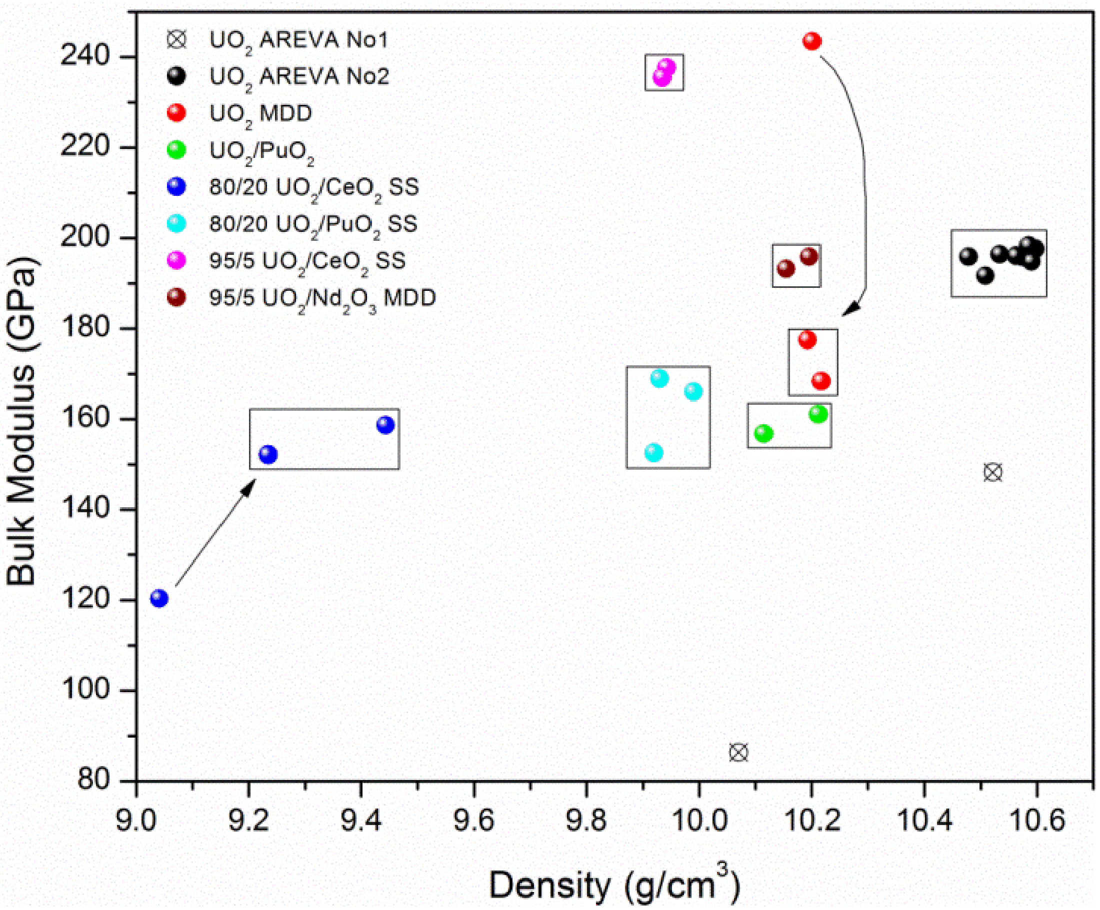
Measured & Predicted Resonant Frequencies for 200 Aluminum Master Cylinders

MTS = Mahalanobis Taguchi System

Quasar's VIPR program computes MTS Compensation Equations

Elastic Moduli vs. Density

- RUS - a nondestructive, very difficult to spoof, well-tested measurement method.

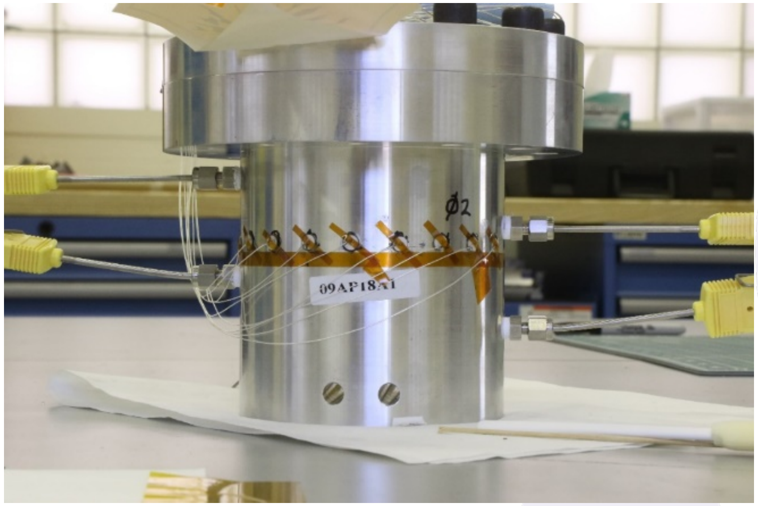


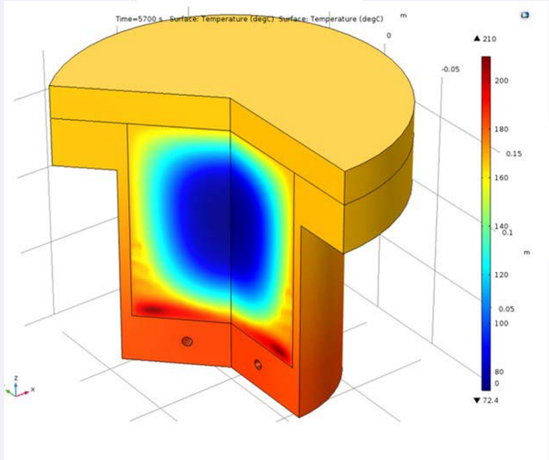
Good correlation between the elastic moduli and density for samples of different compositions/origins.

Able to identify nuclear material composition, fabrication method and source by measuring its RUS properties.

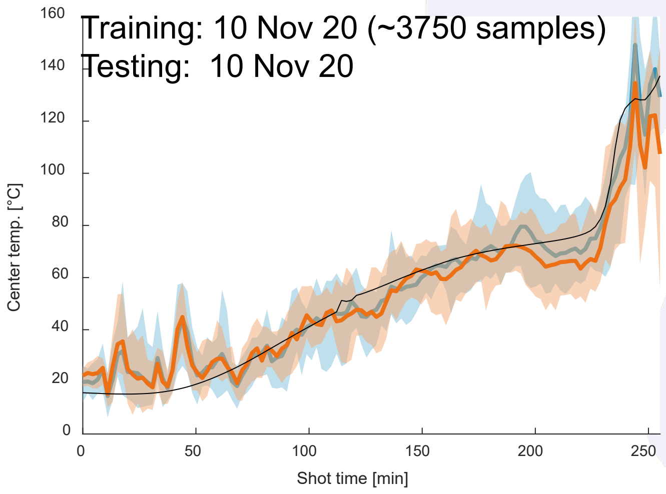
3DHEAT (3 dimensional high explosive acoustic temperature)

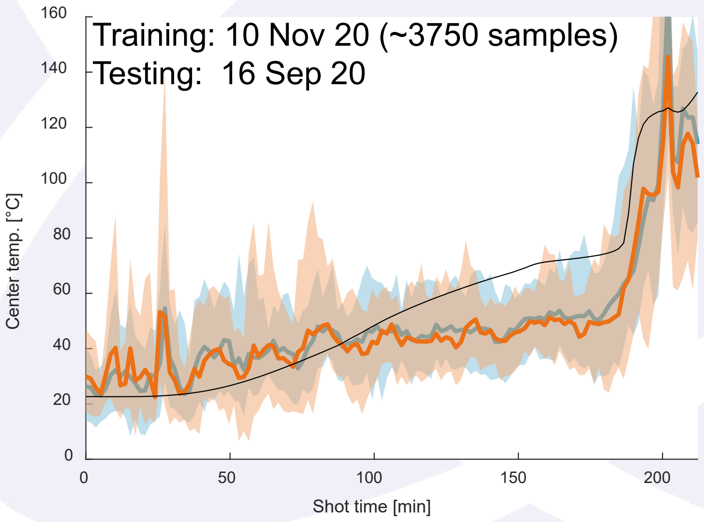
Acoustics diagnosis of thermal damage in Pentolite





Machine learning, CNN (convolutional neural network)

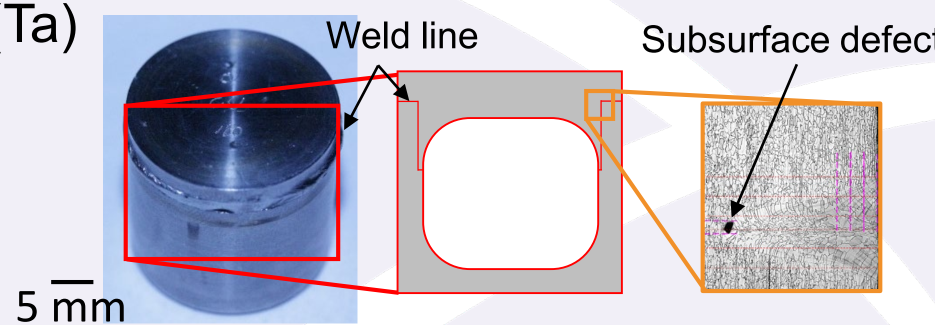




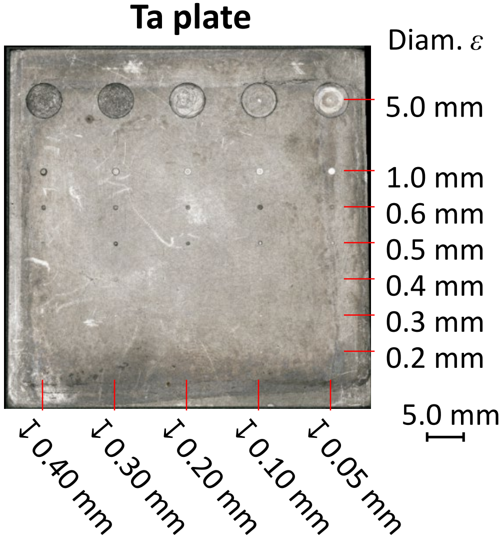
Applications of Acoustic Techniques

Acoustic weld defect detection

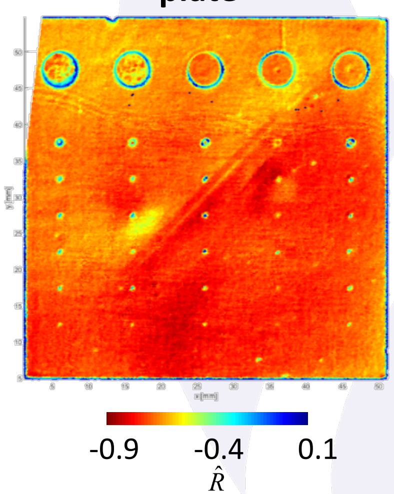
- Weld detection in dense materials (Ta) challenging for radiography
- Solution: scanning acoustic microscopy



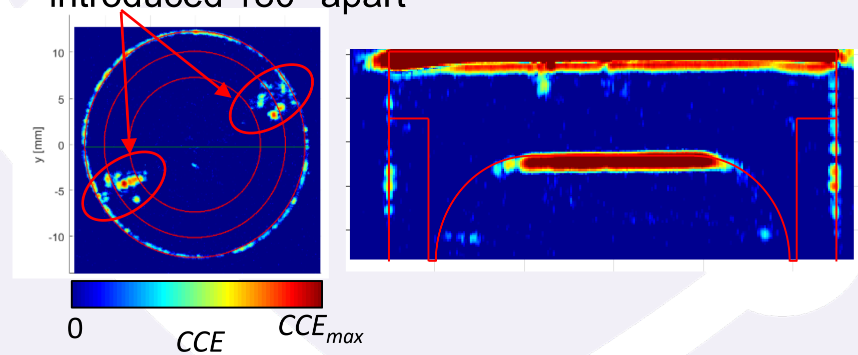
Optical microscopy of Ta plate

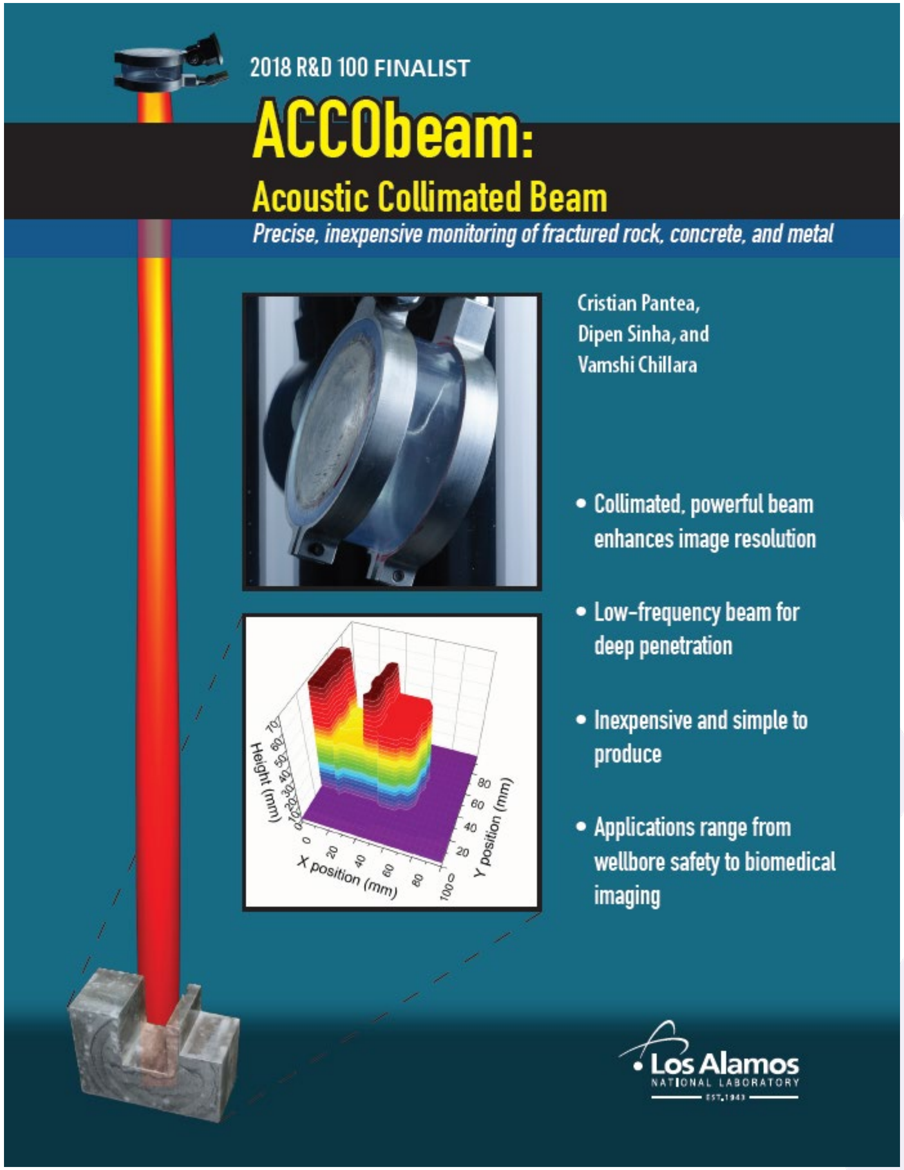


Acoustic microscopy of Ta plate



Inclusions intentionally introduced 180° apart




2018 R&D 100 FINALIST
ACCObeam:
Acoustic Collimated Beam
Precise, inexpensive monitoring of fractured rock, concrete, and metal
Cristian Pantea,
Dipen Sinha, and
Vamshi Chillara
• Collimated, powerful beam enhances image resolution
• Low-frequency beam for deep penetration
• Inexpensive and simple to produce
• Applications range from wellbore safety to biomedical imaging
Height (mm)
X position (mm)
Y position (mm)
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EST.1943


FLC
Mid-Continent Region
2021 R&D 100 JOINT ENTRY
Los Alamos National Laboratory and
Jenike & Johanson
2021
R&D 100
FINALIST
Integrated
Chutes and Sensors
Making Biorefineries Commercially Viable
Apply acoustic sensors to measure moisture content of feedstock in real-time
Integrage sensors and "smart" chutes to discard unacceptable material
Minimize biorefinery downtime and reduce operating costs
Enhance the commercial viability of biorefineries
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