Experimental Techniques in Mechanical Performance Evaluation of Microsystems

Wei-Yang Lu
Sandia National Laboratories
Livermore, CA 94551-0969

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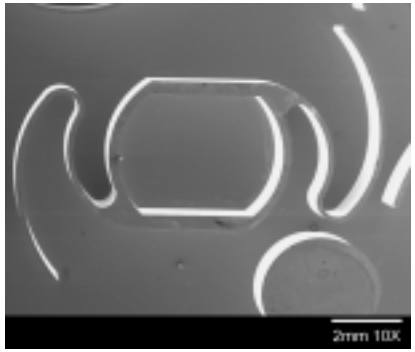
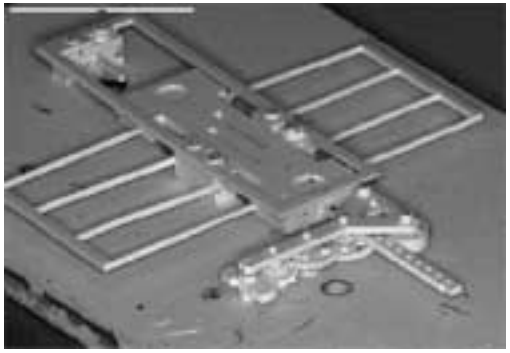
Outline

- **LIGA Microsystems**
- ***In-situ* SEM Experiment**
- **Deformation Field Measurement**
- **Dynamic Characterization**

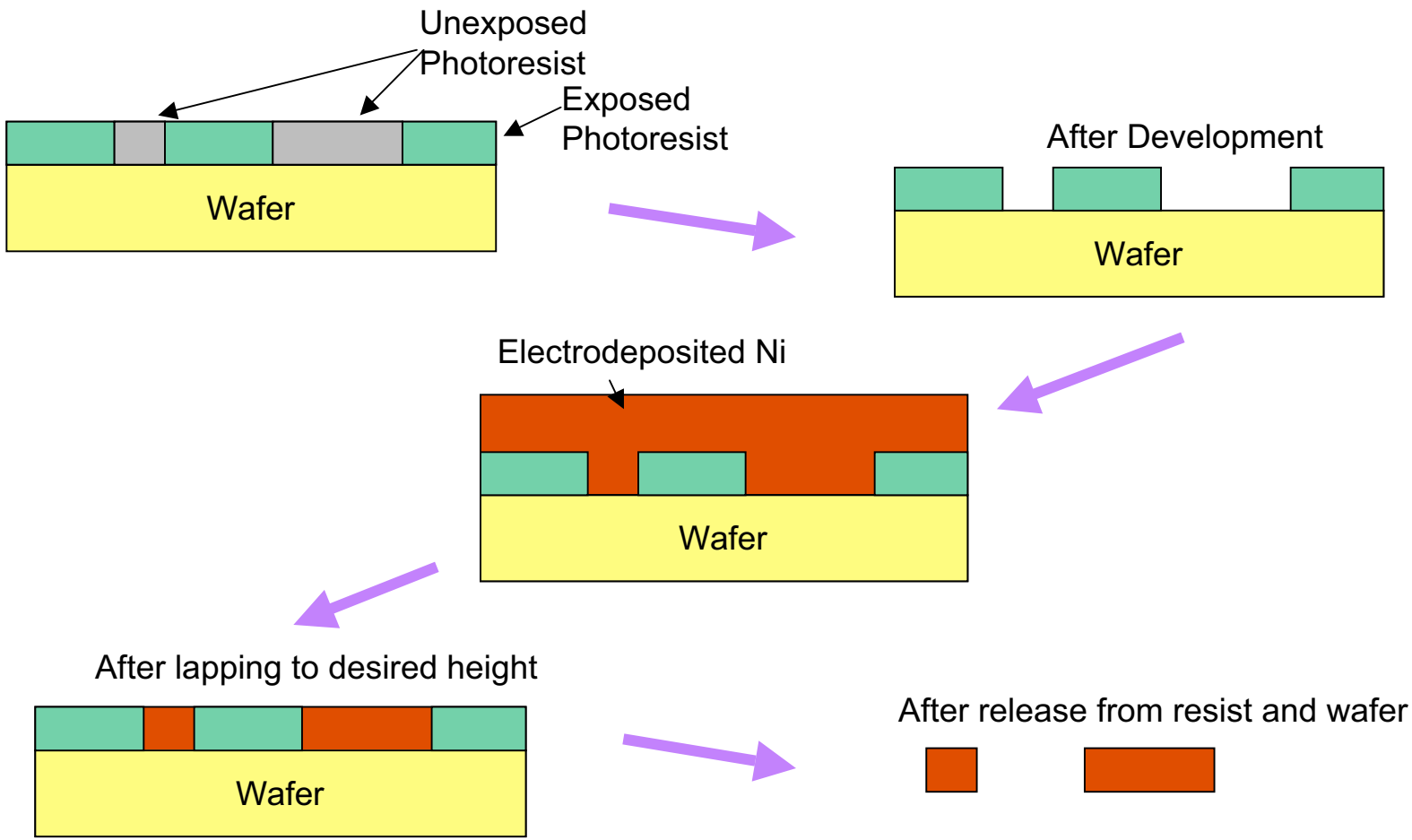
LIGA Process

- **LIGA stands for Li**thographie, **G**alvanoformung, **A**bformung **(German)**
  - **Lithography, Electroplating, Molding**
- **Free lateral shaping**
- **Large variety of materials**
- **Very high aspect ratio microstructures**





LIGA Schematic



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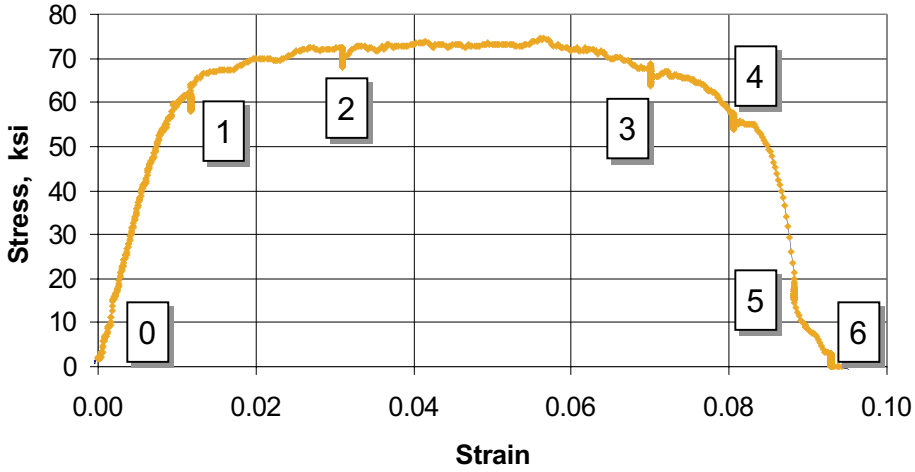
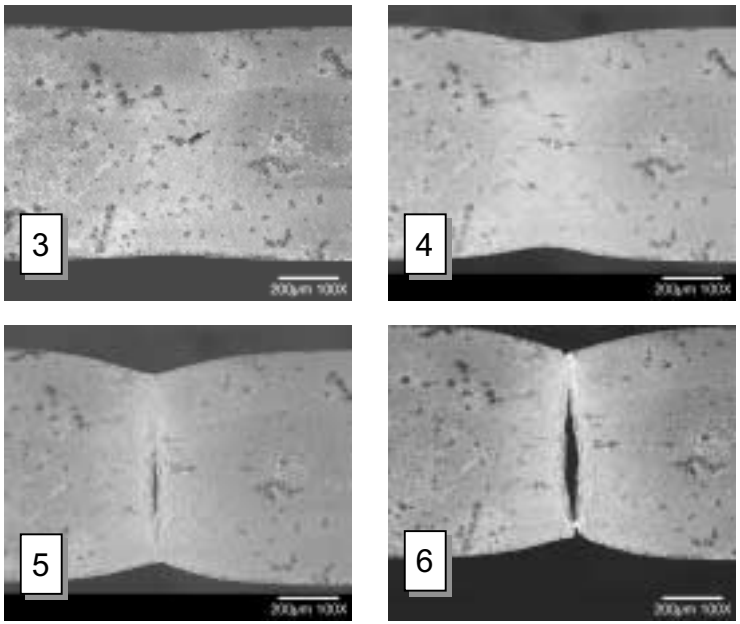
SEM Loading Stage

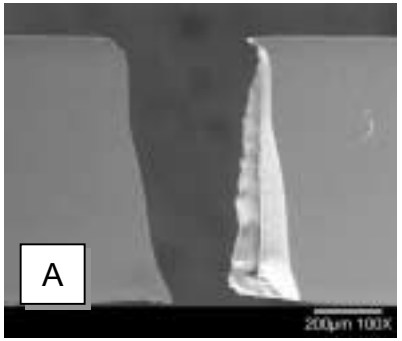
LabView Data Acquisition

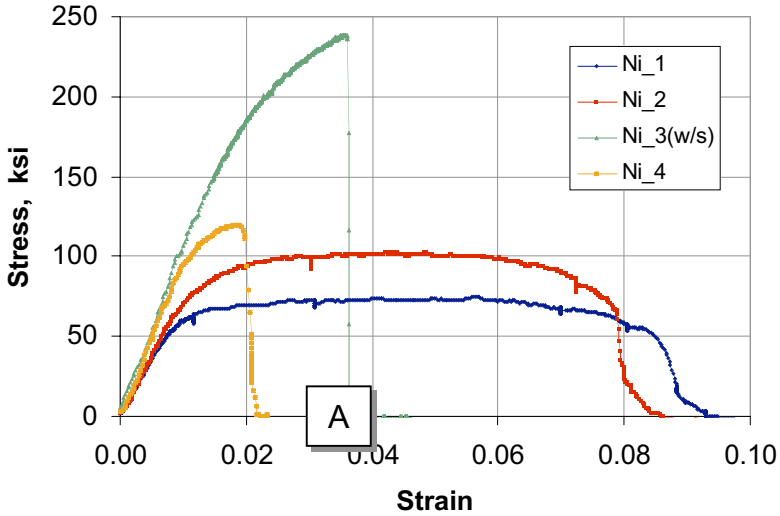
In-situ SEM Experiment





v = 0.000064 in/s (0.0016 mm/s)





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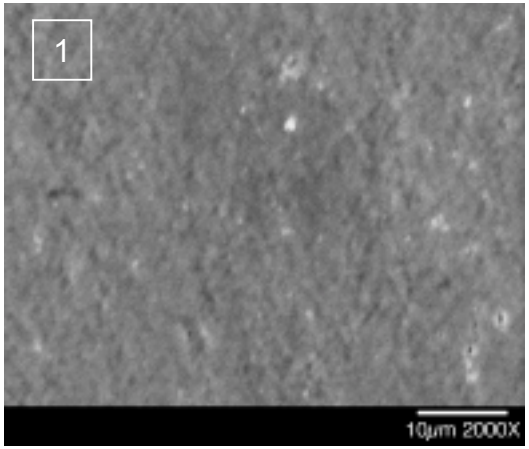
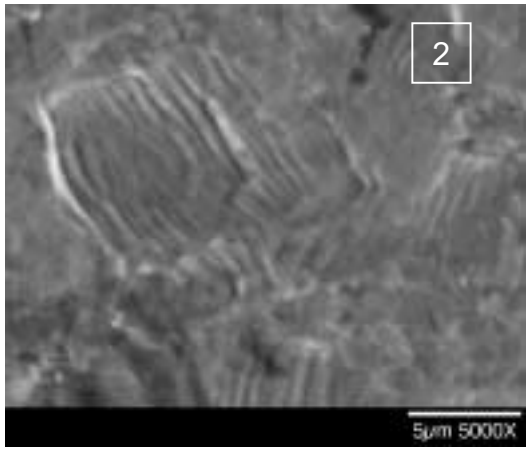
Specimens From Different Electroplating Tanks

Tank #14

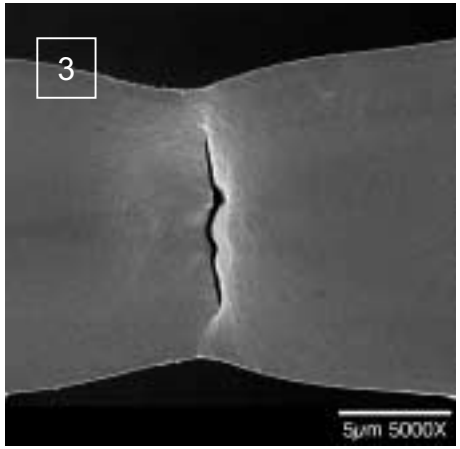
Hardness:
Vicker 330
Texture:
plating dir 001

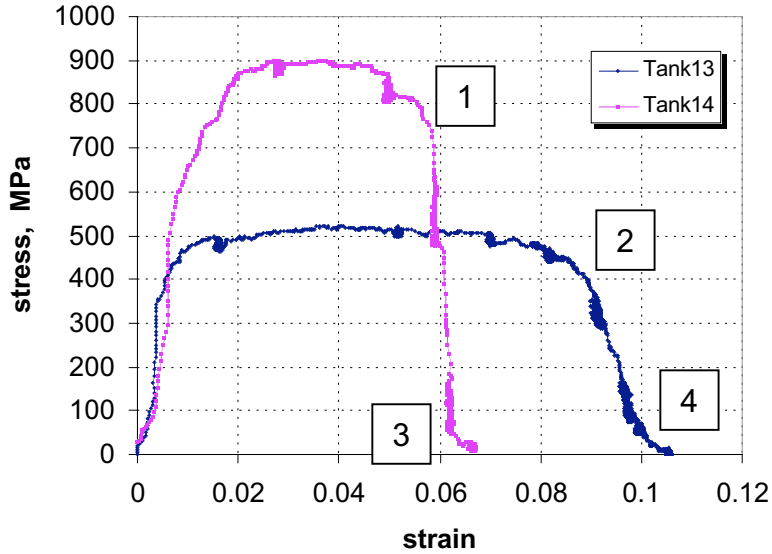


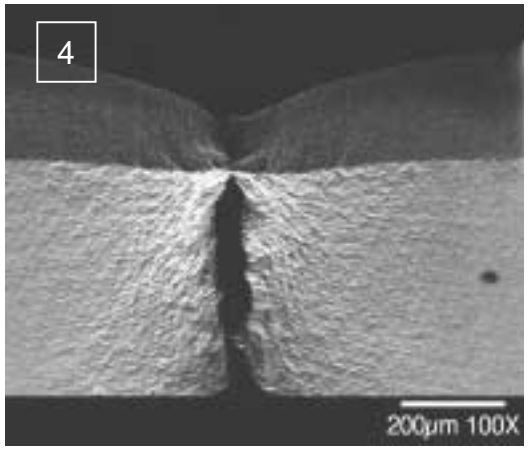


Tank #13

Hardness:
Vicker 210
Texture:
Plating dir 110







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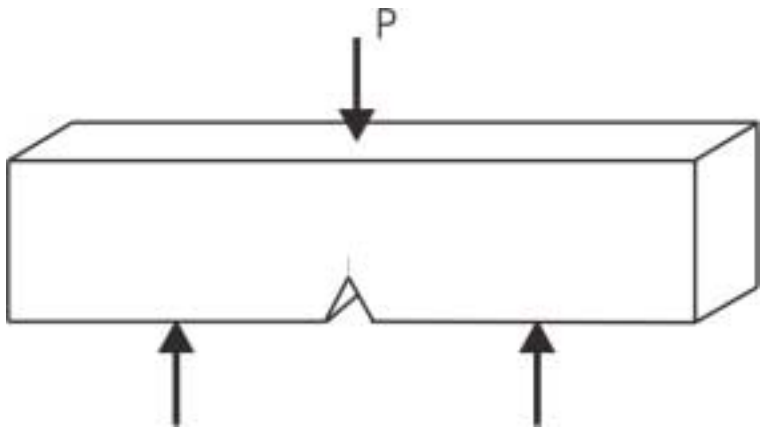
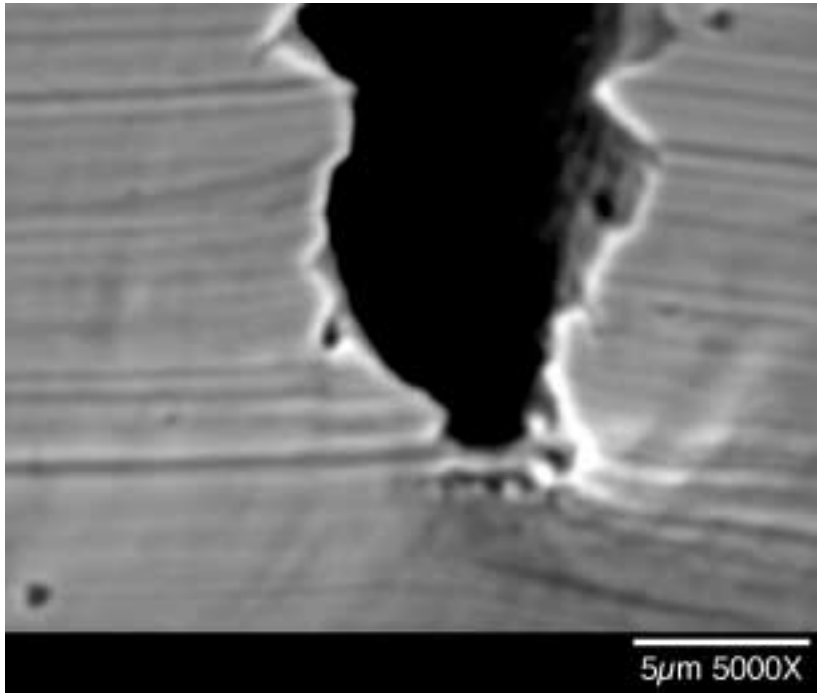
Fracture Mechanism



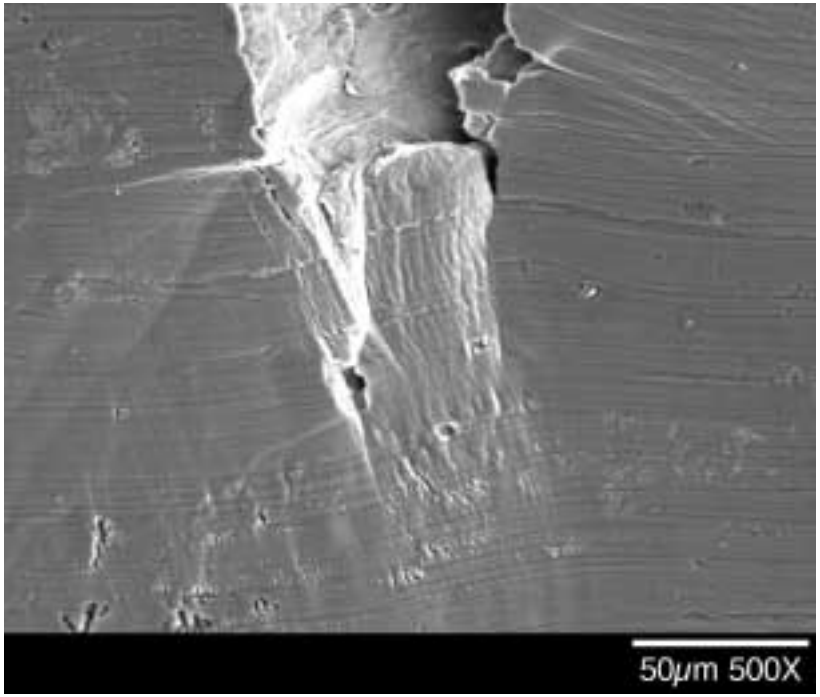
SS304L



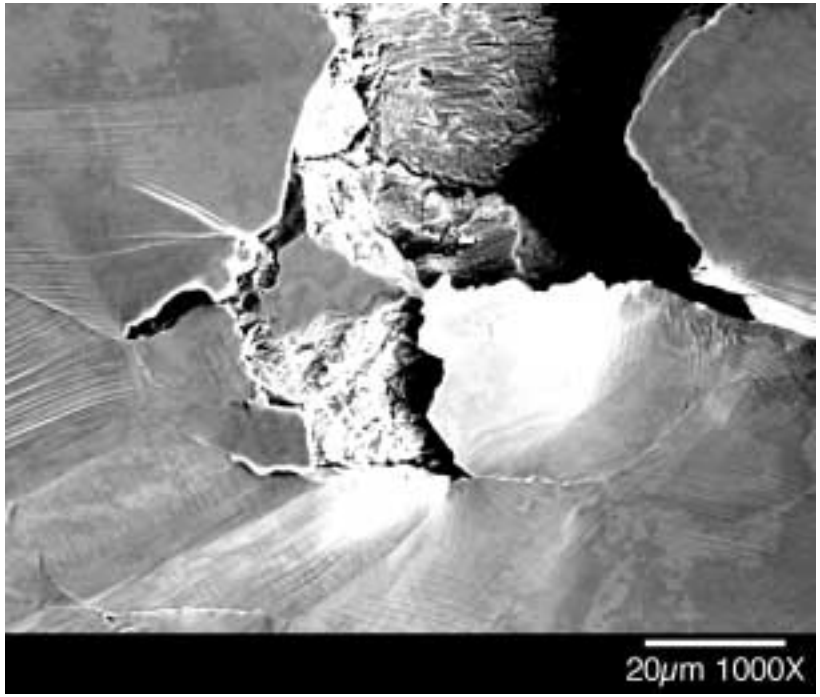
(Bonnie Antoun & Sam Mcfadden)

Fracture Mechanism

Al6061

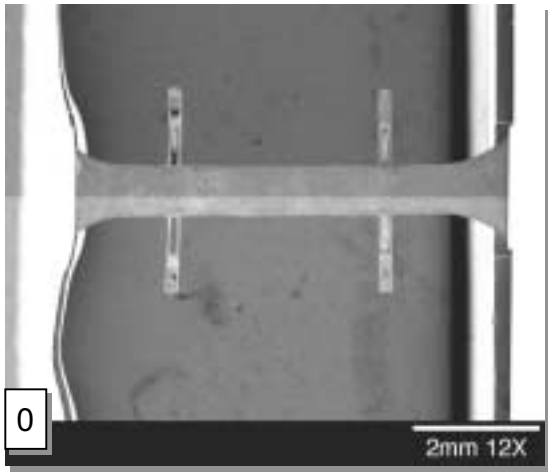


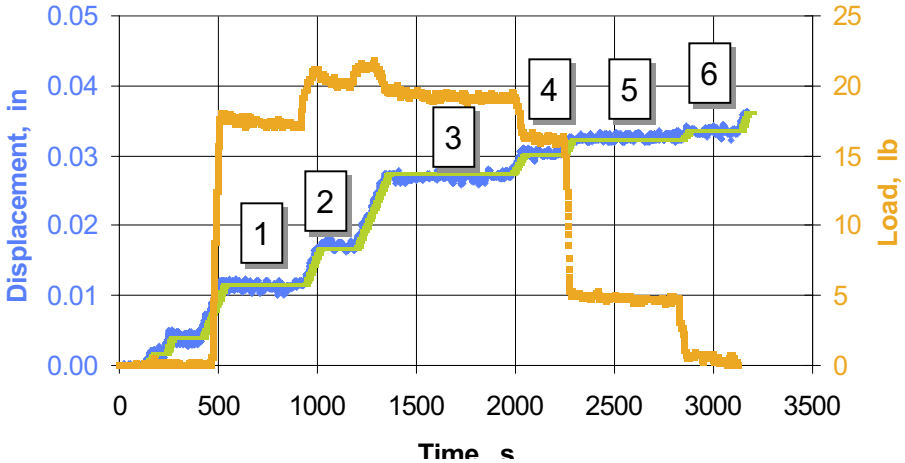
Cu

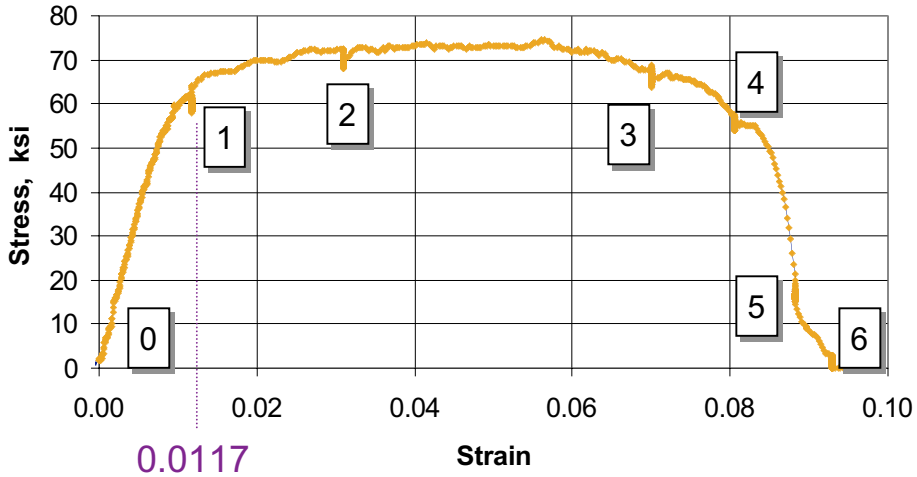


(Bonnie Antoun & Sam Mcfadden)

LIGA Tensile Specimen: Ni_1







v = 0.000064 in/s (0.0016 mm/s)

Preliminary results:

σ_y = 60 ksi (414 MPa)

σ_u = 75 ksi (517 MPa)

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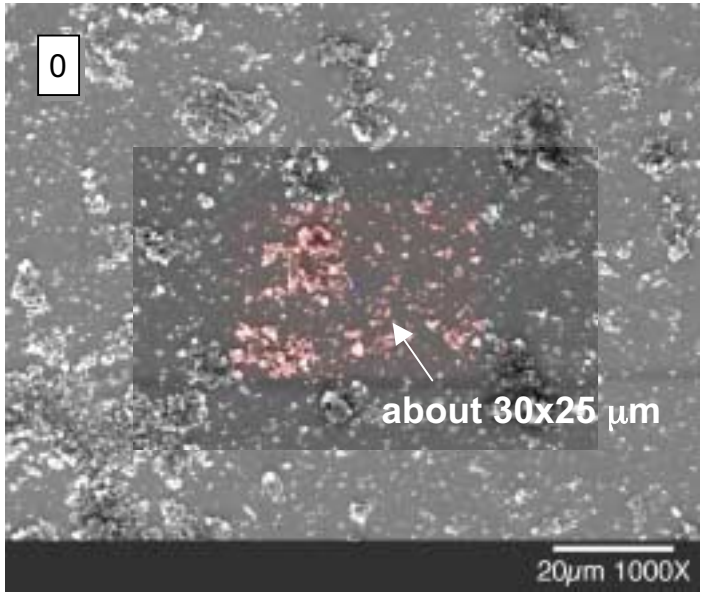
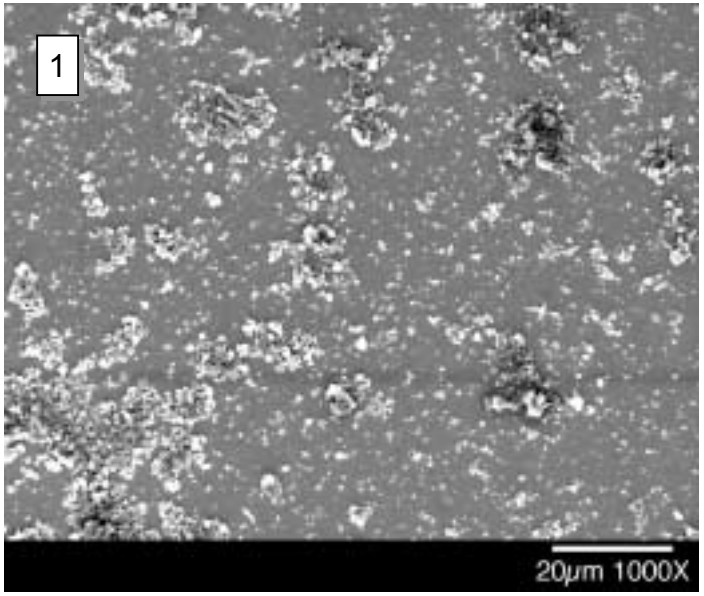
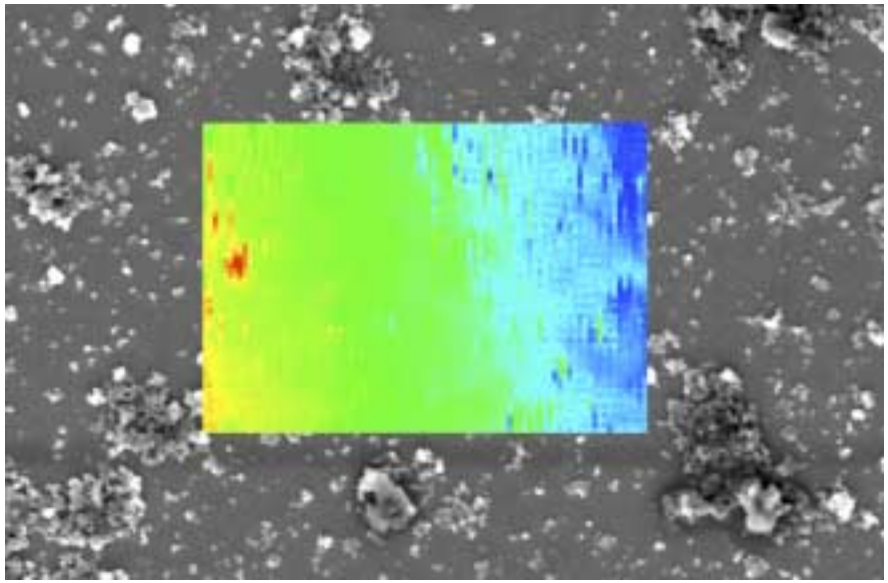
Displacement Field Measurement

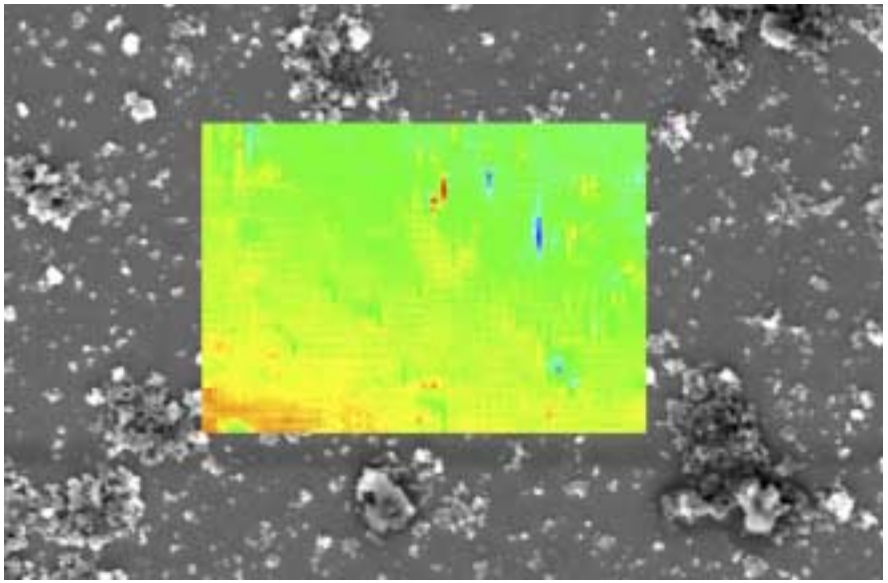
- Using digital image correlation method to analyze SEM images of samples under stresses.



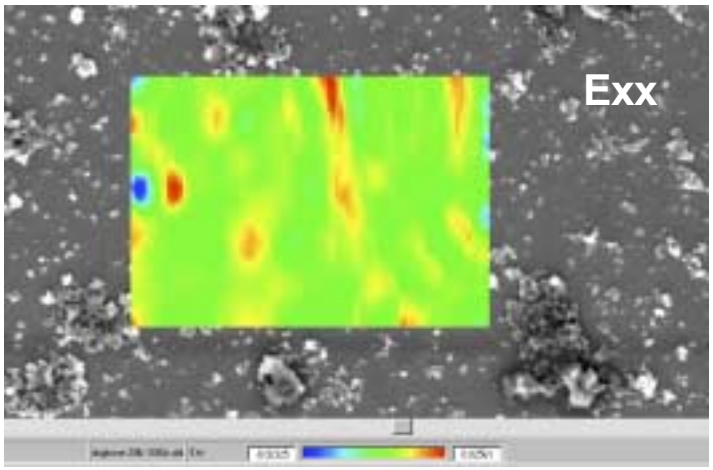


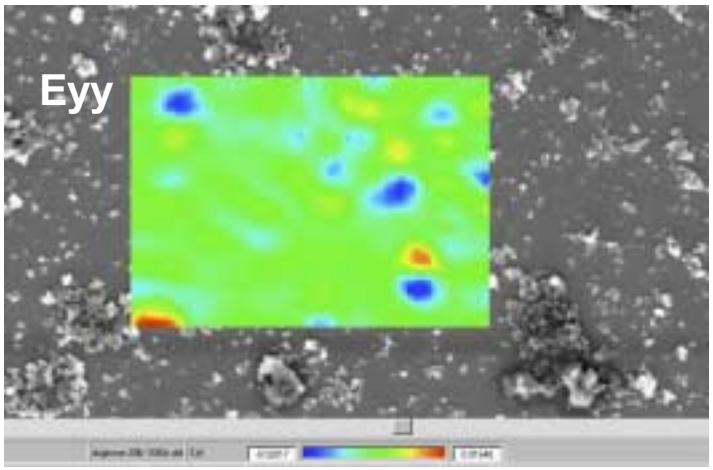
Displacement Field

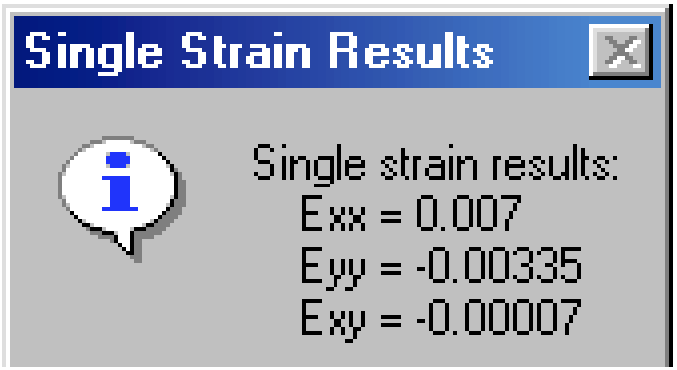




Summary of SEM Field Technique





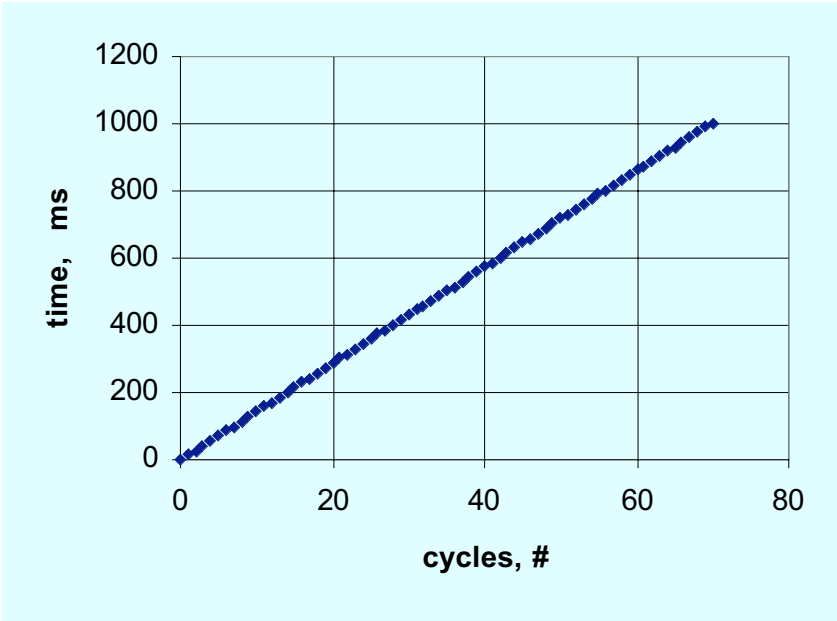


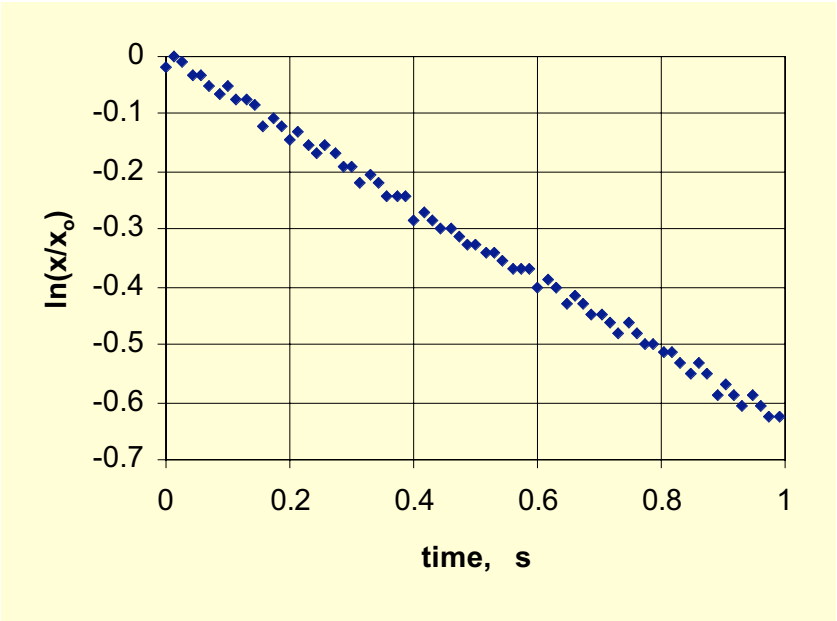
- **Preliminary results show the technique is promising.**
- **Specimens for non-uniform strain field have been designed for further investigation.**

Vibration of LIGA Structure

- Use high speed camera to capture the vibration and to verify the mode of deformation.
- Period and amplitude of oscillation are measured.
- Use oscillating amplitude to estimate the damping of the system.
- ⇐ Sampling rate: 1000 fps, display rate: 10 fps.
- 35-340 Ni Watts/sac

System Damping





- **Free vibration period, τ_d = 0.0144 s,** $1/\tau_d = f_d = f_n(1 - \zeta^2)^{1/2}$**.**
- **Damping factor ζ = 0.0014 ,** $ln(x/x_o)=-\zeta w_n t$ **, which is negligible.**
- **E = 20.4 Msi (141 Gpa),** using the designed beam dimension.

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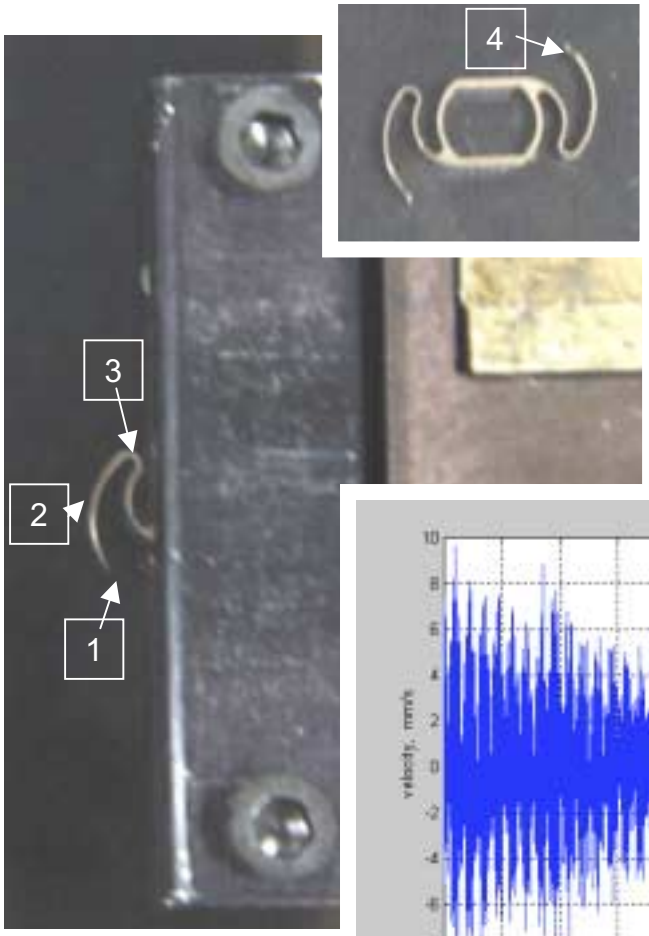
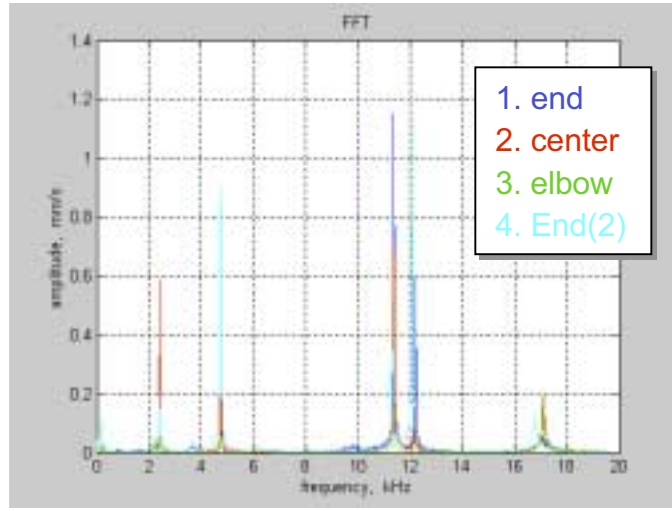
Error Analysis

Cantilever Parameter	Typical value		Measurement Uncertainty			Error in E
length L	7000	μm	1	μm	0.01%	<0.1%
depth b	250	μm	1	μm	0.40%	0.4%
→ width h	25	μm	1	μm	4.00%	12.0%
density ρ	8486	kg/m^3	100	kg/m^3	1.18%	1.4%
period τ_d	0.0144	s	0.0001	s	0.69%	1.4%
damping factor ζ	0.0014		0.0001		7.14%	<0.1%
modulus E	20.4	Msi				~15%

Free Vibration of Electrical Contact Spring Arm

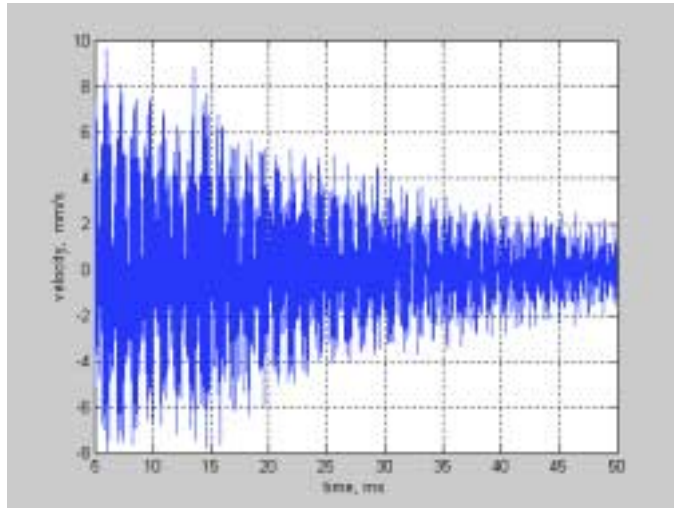


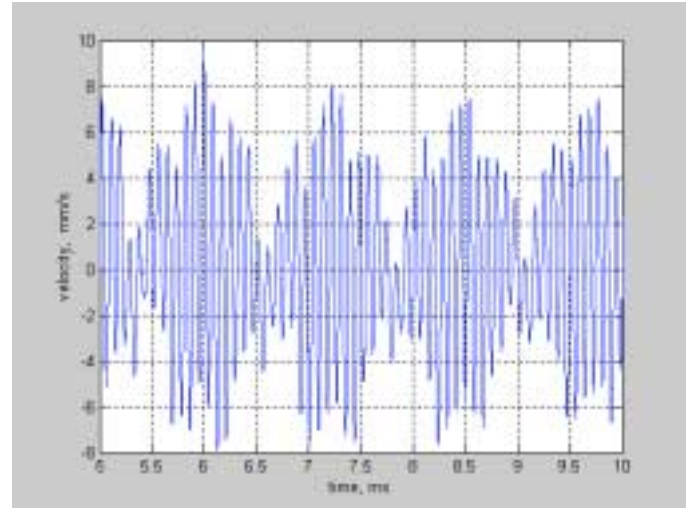


- **Laser vibrometer**
- **Impulse loading**
- **Preliminary results**

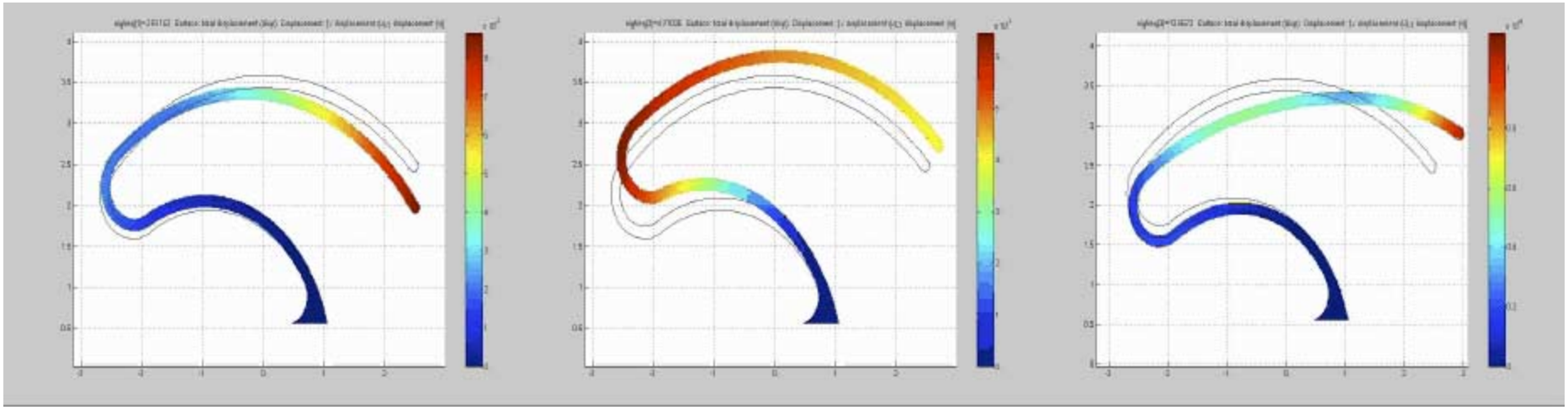
resonant frequencies:

2.4 kHz
4.8
11.4
12.2
17.0





Preliminary 2D Simulation Results



F = 2.6 kHz F = 4.7 kHz F = 13.7 kHz

- **Consider plane strain analysis**
- **Modal frequencies measured experimentally: 2.4, 4.8, 11.4, 12.2, 17.0 kHz**