Centre for Industrial Ultrasonics Meeting
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Advances in Flexural Ultrasonic Transducers for Optimal Industrial Impact (Part 1)

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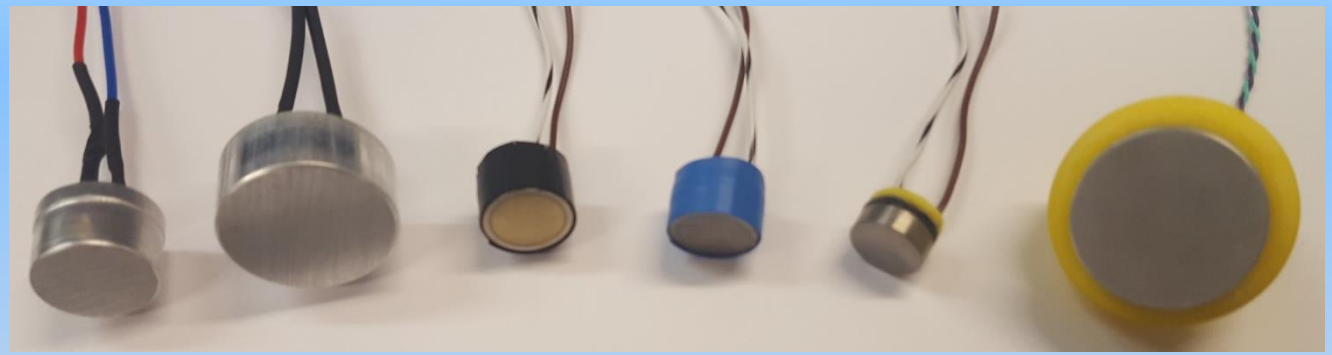
WARWICK

Overview of Our EPSRC Research

EPSRC
Engineering and Physical Sciences Research Council

Grant Number EP/N025393/1

- Adaption of the flexural ultrasonic transducer (FUT)
- Piezoelectric driver bonded to a metal cap
- Vibration of the piezoelectric induces plate modes of membrane
- Efficient coupling to low-impedance media

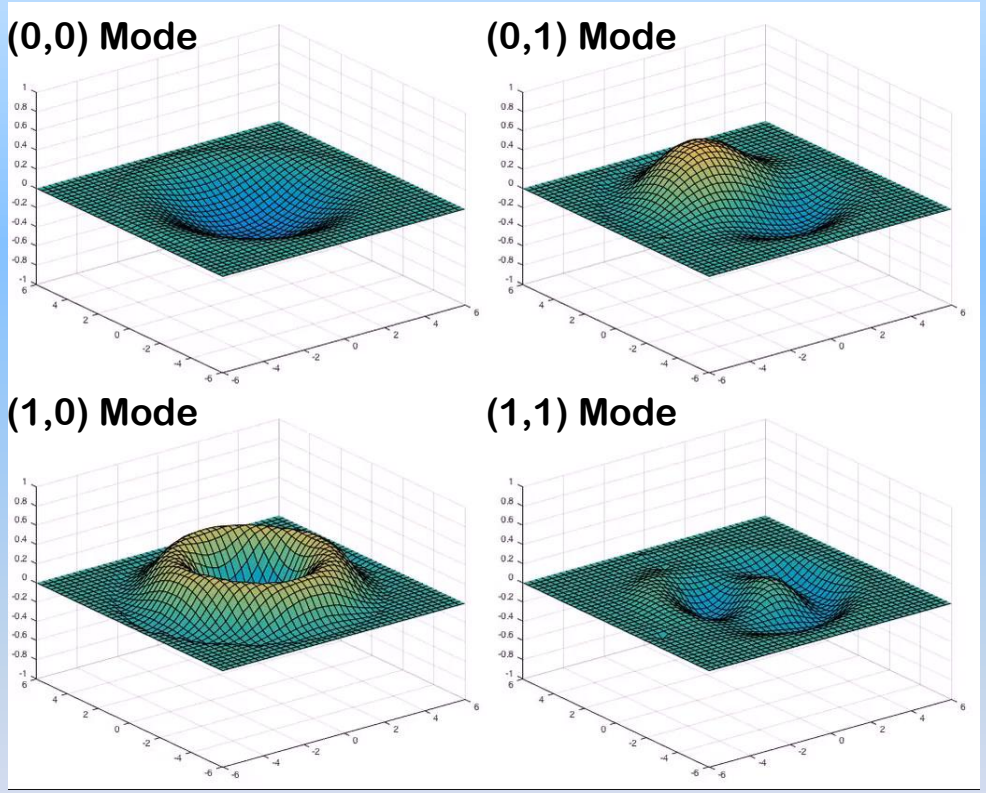


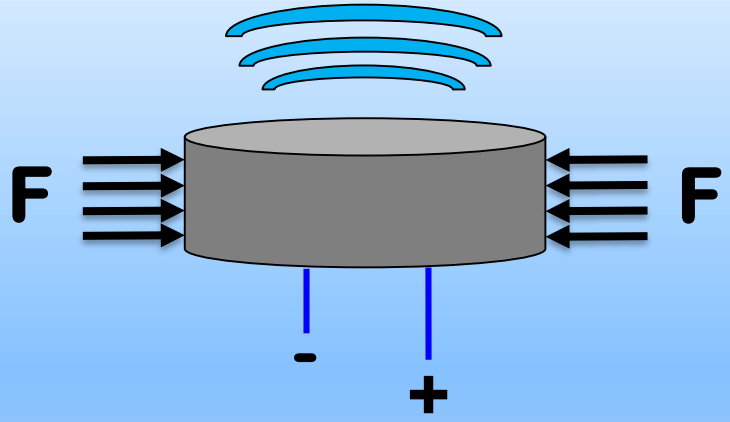
Target Applications and Environments

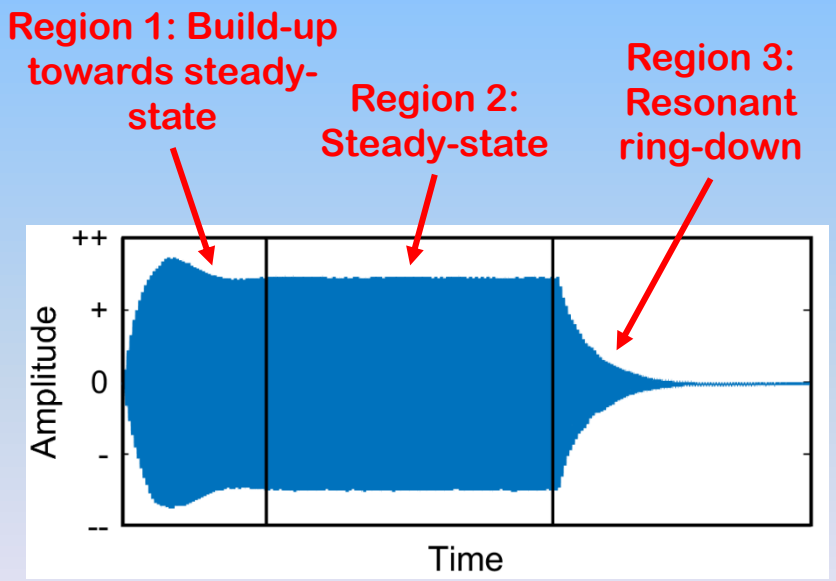
Application	Example Pressure (bar)
Domestic water meters	20
Industrial gas meters	300
Industrial flow meters	300+

Environment	Example Temperature (°C)
Oil production	120
District heating	250
Petrochemical	350-450
Power plants	560

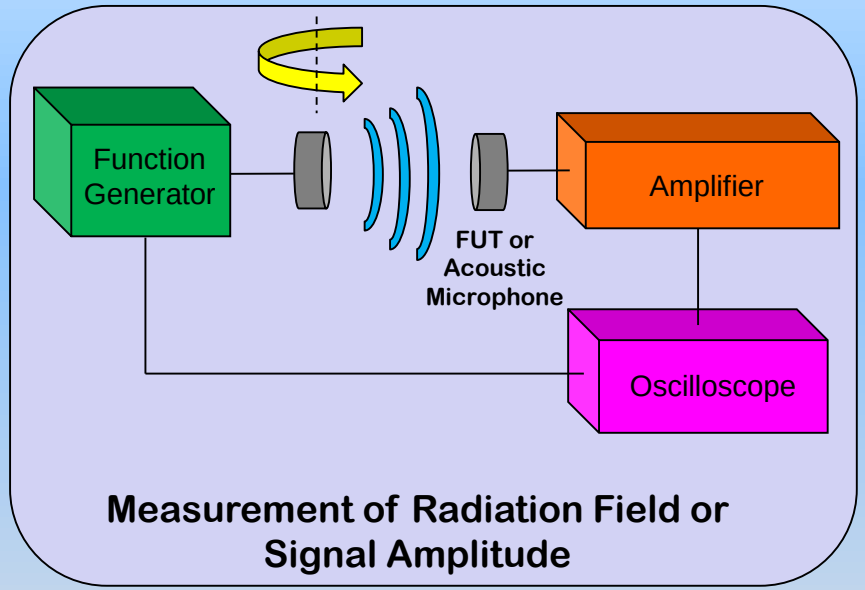
Fundamental Operating Characteristics



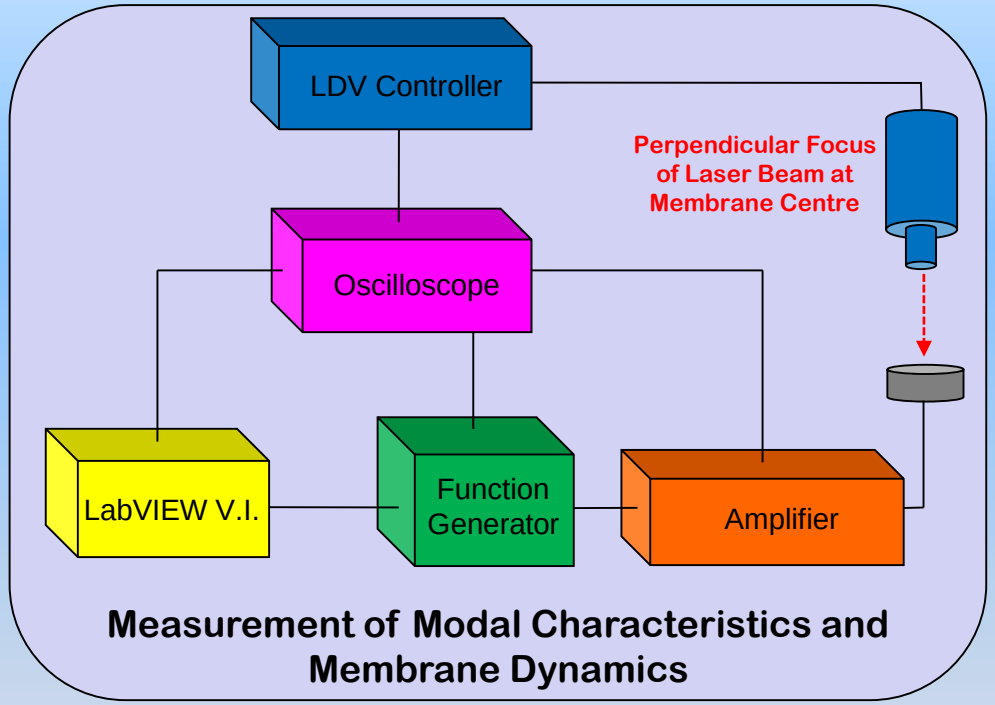




Measurement Methods



Measurement of Radiation Field or Signal Amplitude



Measurement of Modal Characteristics and Membrane Dynamics

Limitations and Opportunities

- FUTs are designed for ambient conditions and low ultrasonic frequencies, up to approximately 50 kHz
- Conventional FUTs used in only a limited number of applications, such as flow measurement and proximity sensing

<u>Factors to consider:</u>

- FUT dynamics at different displacement amplitudes or excitation voltages
- Modifications of the FUT design
- Measurement at high pressure
- High frequency operation
- Operation at high temperatures

Dynamics at Different Amplitudes: Nonlinearity

Displacement

Stress (σ) Coefficient

Drive Frequency

Excitation

$$x = acos(\Omega t - \gamma) + \frac{1}{2}\epsilon\alpha_2\omega_0^{-2}a^2[-1 + \frac{1}{3}\cos(2\Omega t - 2\gamma)] + O(\epsilon^2)$$

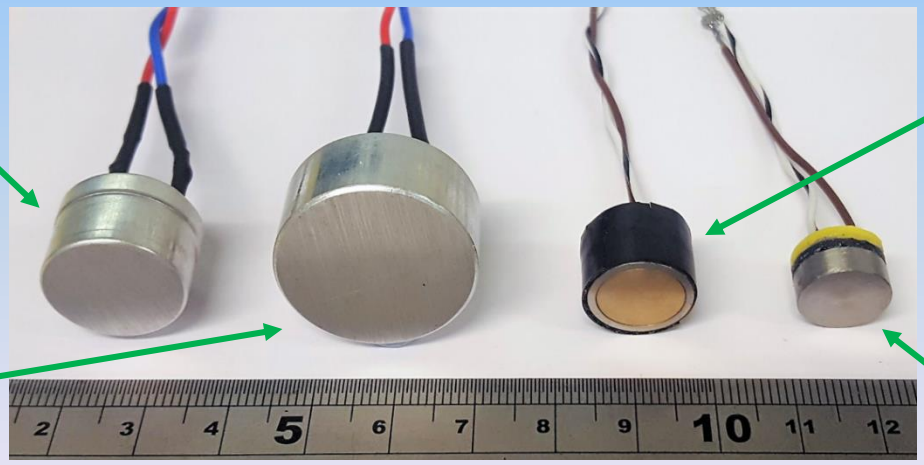
Amplitude

Phase

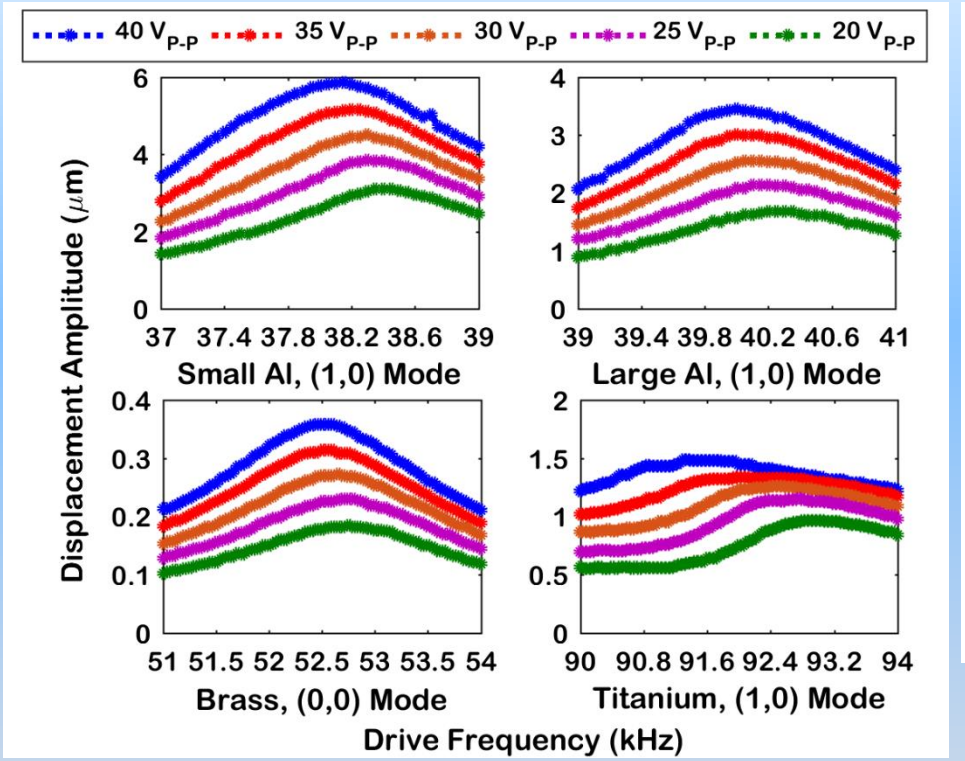
Resonance Frequency

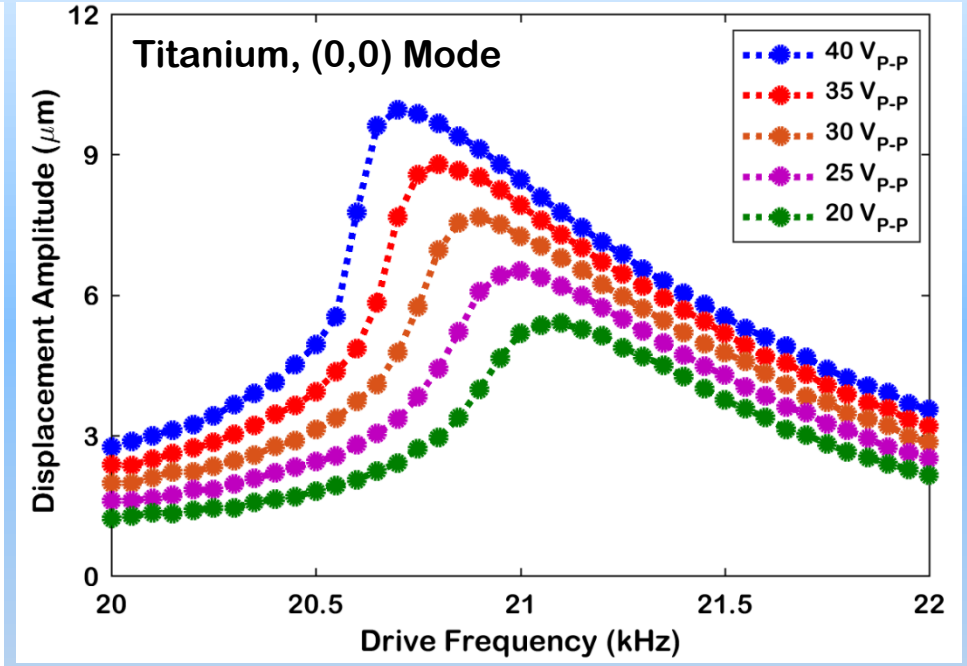
Time

Perturbation Parameter



Dynamics at Different Amplitudes: Nonlinearity



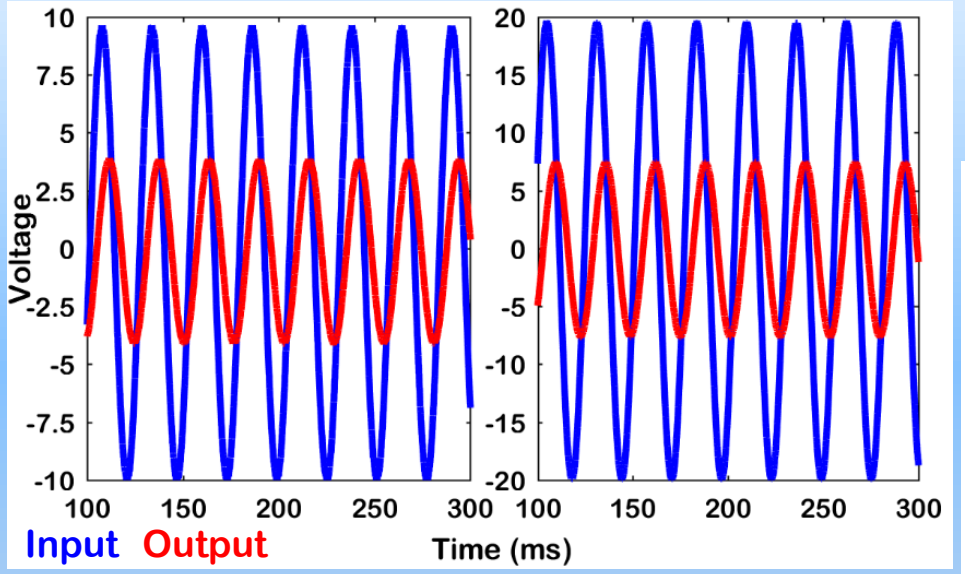


$$a = \frac{1}{\sigma}\left(\frac{9\alpha_3\omega_0^2 - 10\alpha_2^2}{24\omega_0^3}a^3 - \frac{A}{2\omega_0}cos\gamma\right)$$

Nonlinear Softening Condition

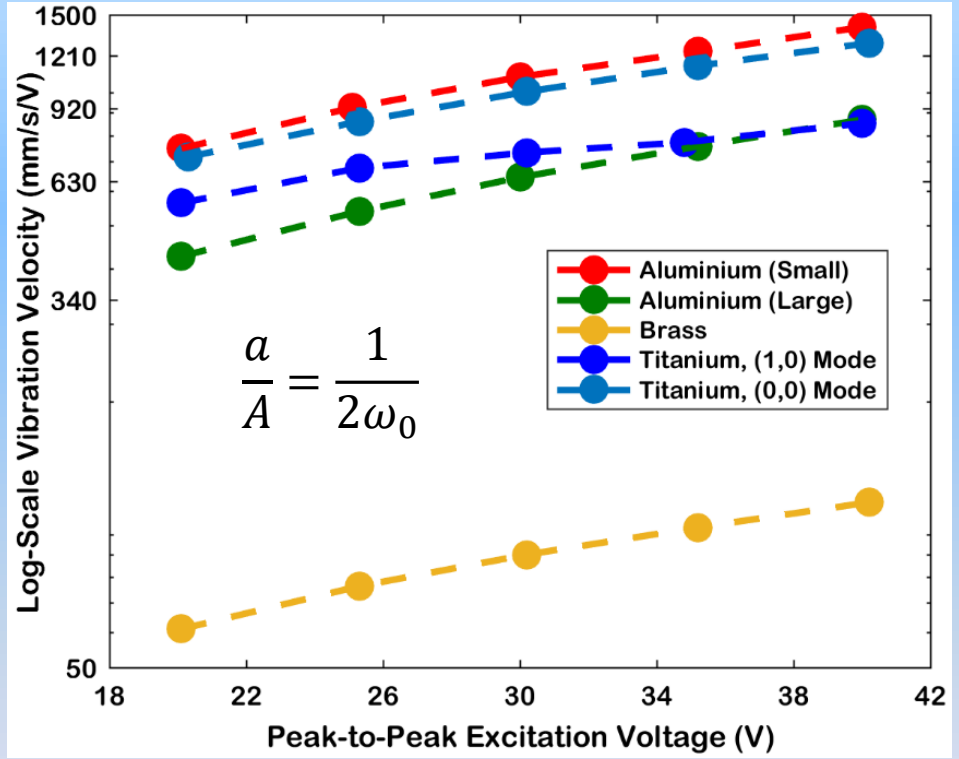
$$9\alpha_3\omega_0^2 < 10\alpha_2^2$$

Dynamics at Different Amplitudes: Nonlinearity



φ = 56.6° → φ = 64.5°

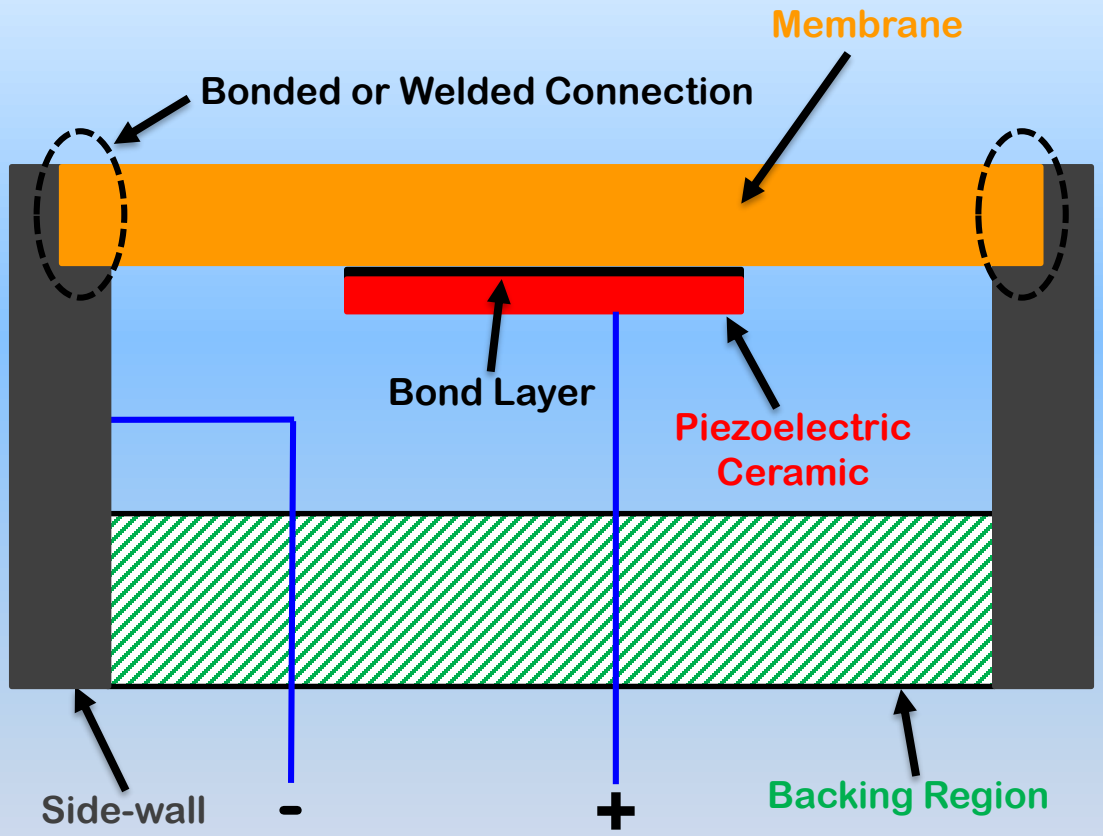
Small Al, (1,0) Mode



$$\mu a = \left(\frac{A}{2\omega_0}\right) sin\gamma$$

$$a = \frac{1}{\sigma}\left(\frac{9\alpha_3\omega_0^2 - 10\alpha_2^2}{24\omega_0^3}a^3 - \frac{A}{2\omega_0}cos\gamma\right)$$

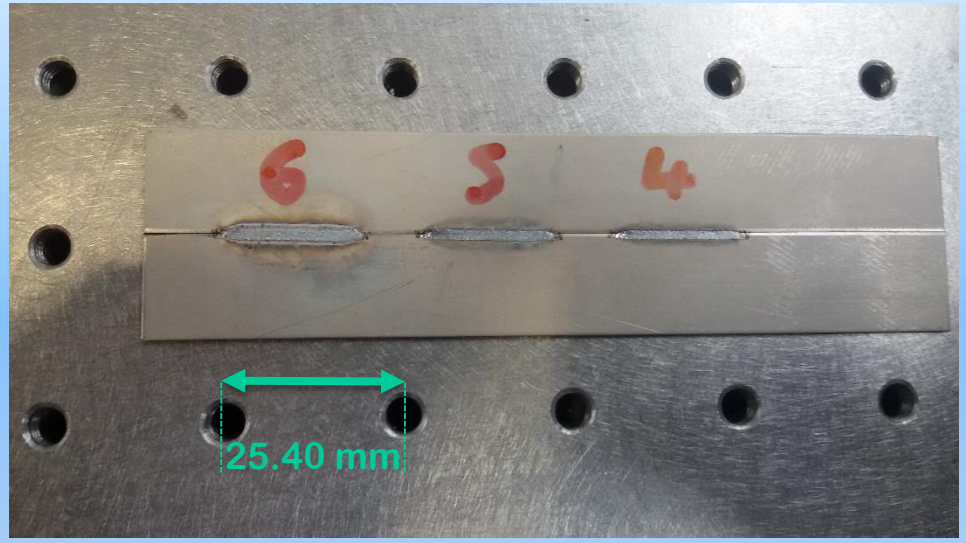
New Fabrication Techniques

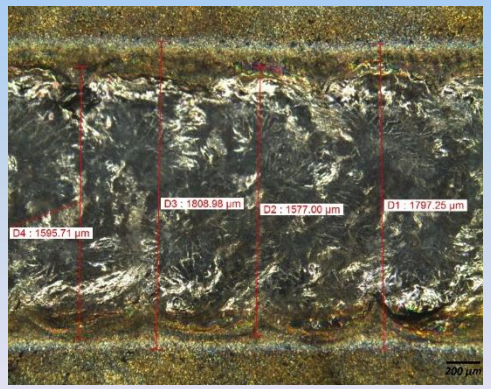


Novel Cap Fabrication

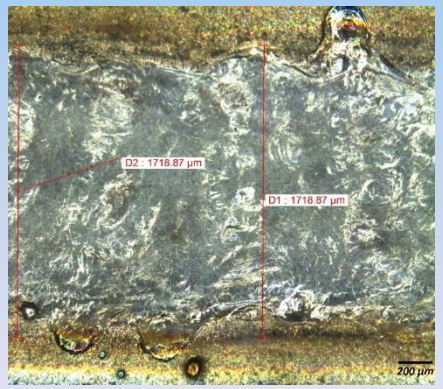
New Fabrication Techniques

- Laser welding
- Laser spot size: ~ 0.30 mm
- Convex HAZ profile can be modified to be flat
- Optimum welding parameters under investigation
- HAZ widths: 1.50 – 1.80 mm
- Titanium welding trials

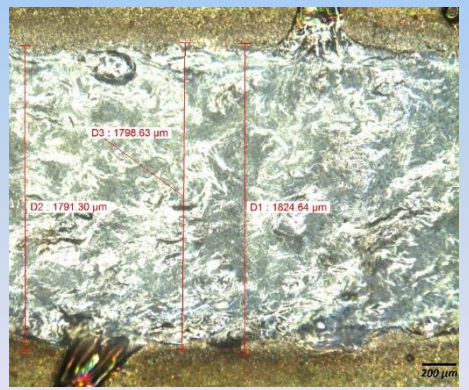




Sample 4

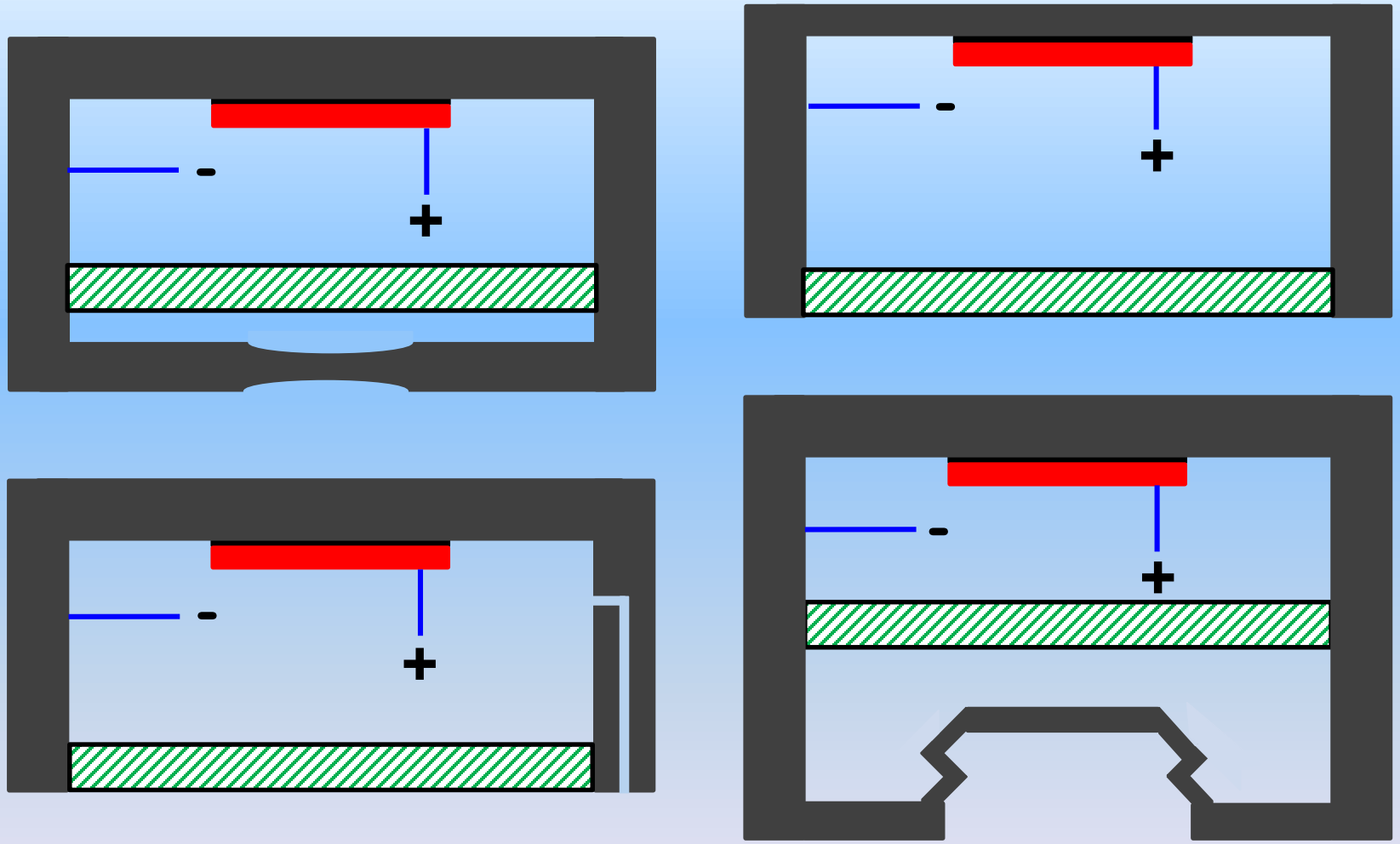


Sample 5



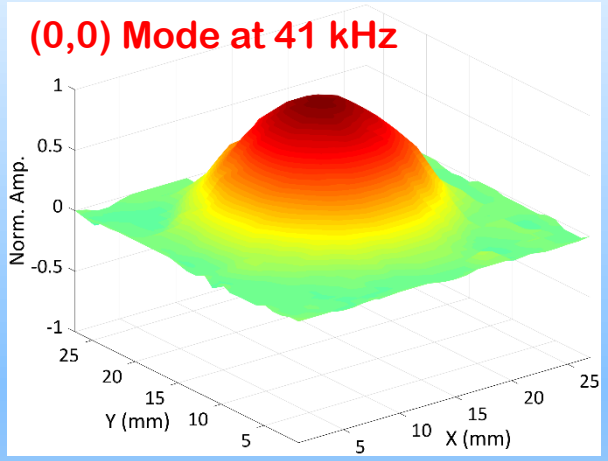
Sample 6

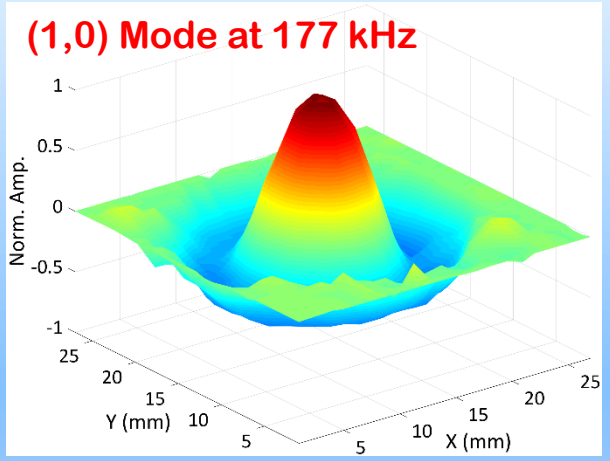
Measurement at High Pressure

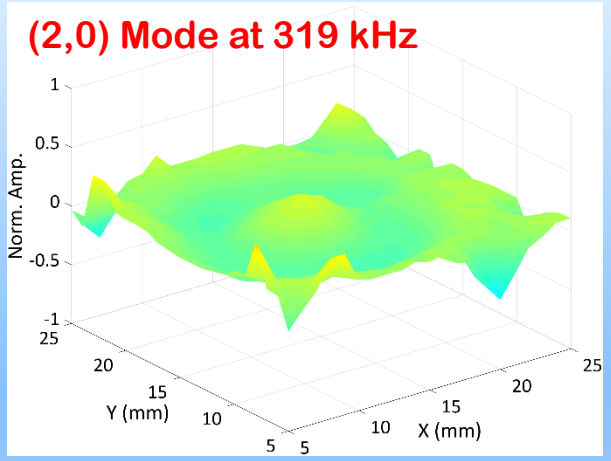


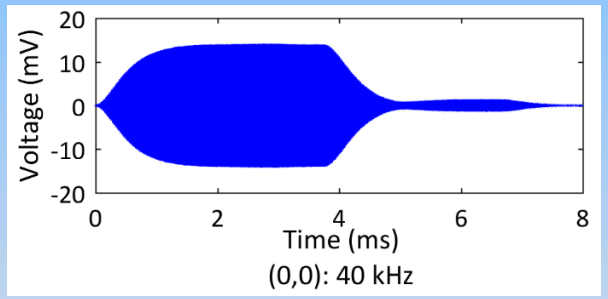
Measurement at High Pressure

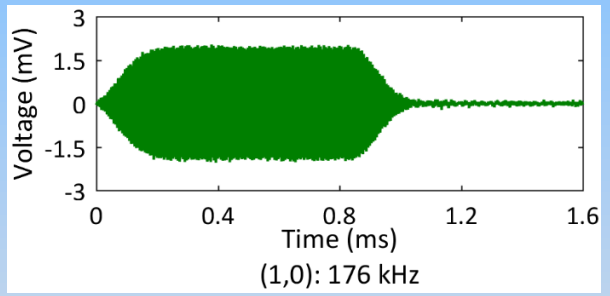
High Frequency Operation

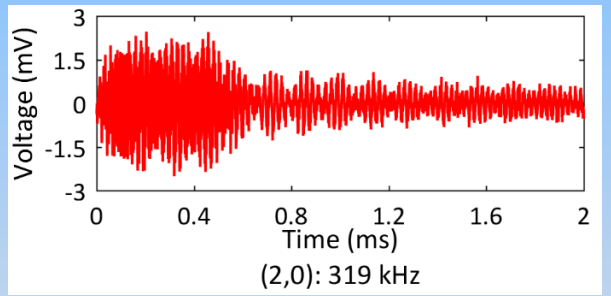


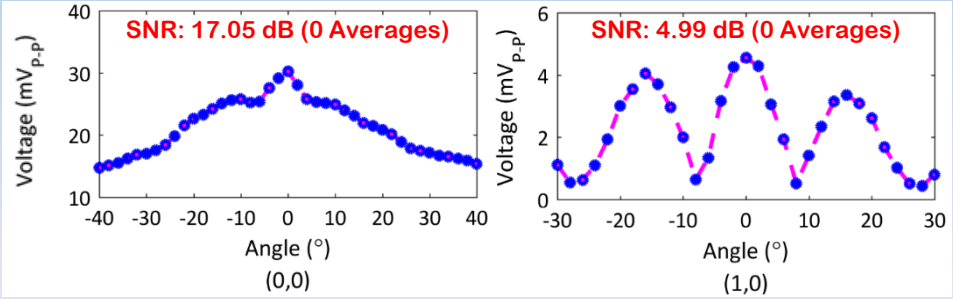












- Aluminium FUT
- One FUT as Transmitter
- One FUT as Detector
- Excitation: 20 V_{P-P}
- D = 500 mm

Any Questions?