Near-field Acoustic Holography and Drum Modal Vibrations

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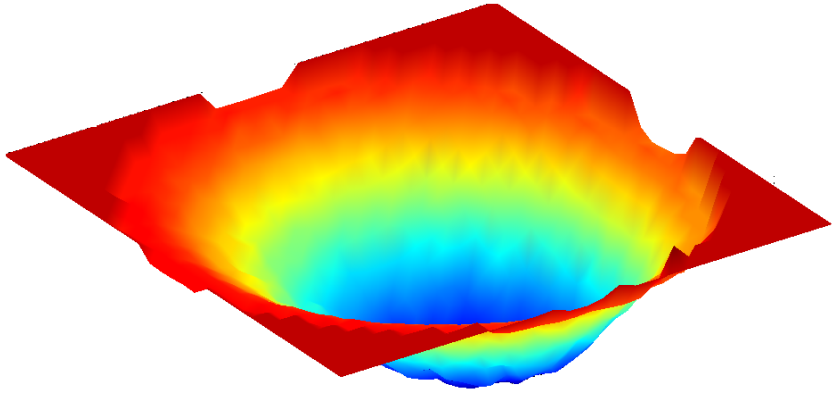
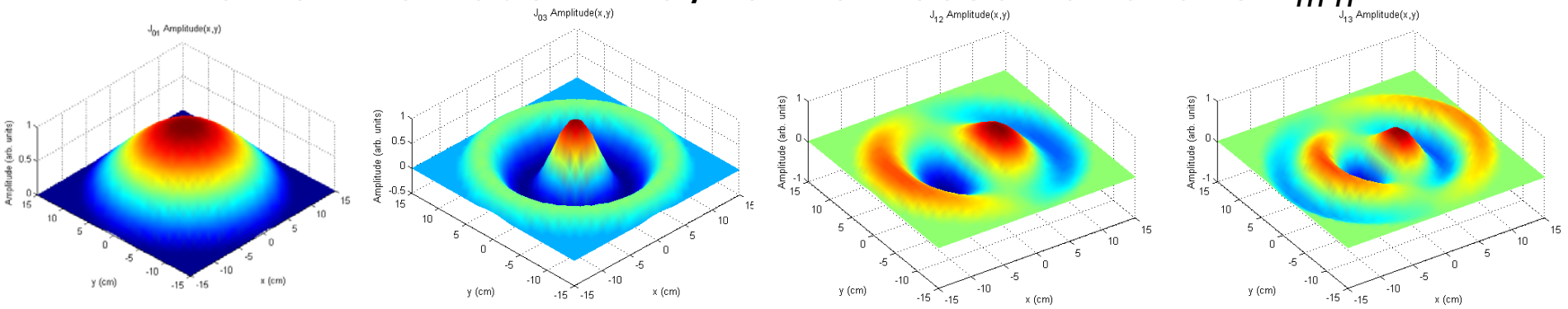
Physics 499

Nov. 14, 2008



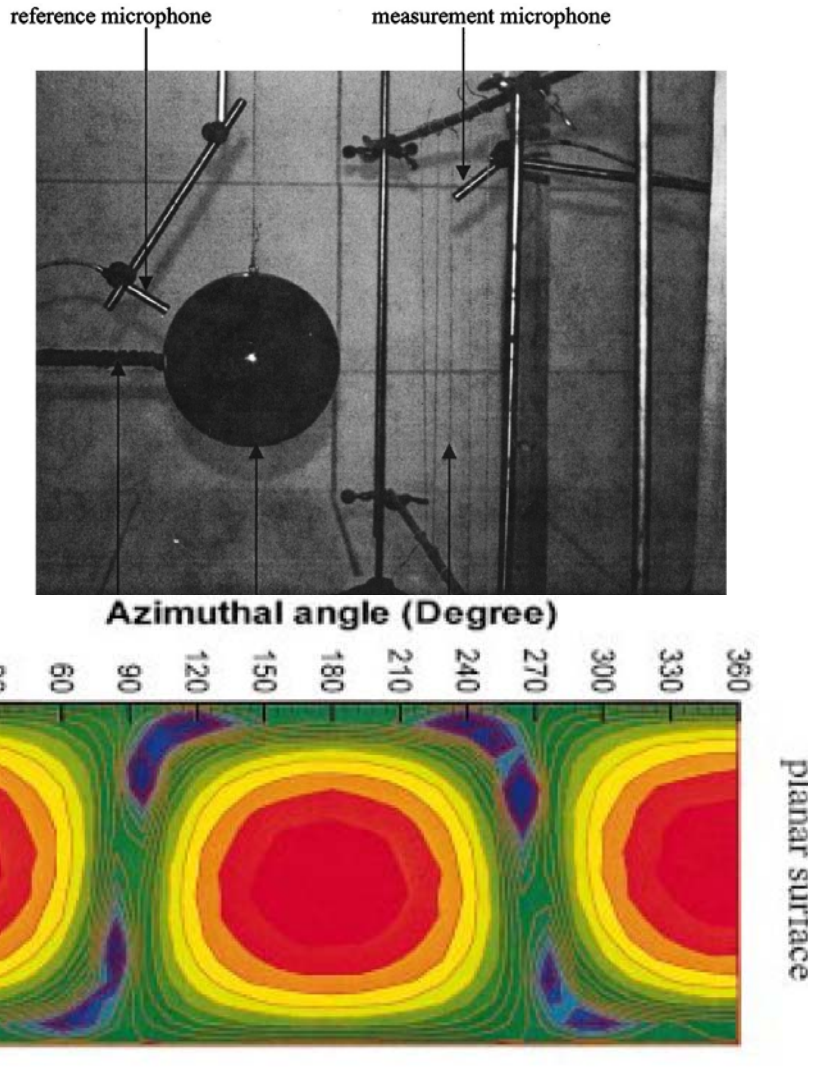
Overview

- Major goal: create an acoustic holography setup
  - *Acoustic holography*: imaging small vibrations on a surface using acoustical properties of vibrations
- Drumhead vibrations are a great case for testing the new setup
  - Two dimensional surface makes construction easier
  - The vibrations are already well researched using other methods – they're the Bessel functions $J_{m,n}$



Acoustic Holography

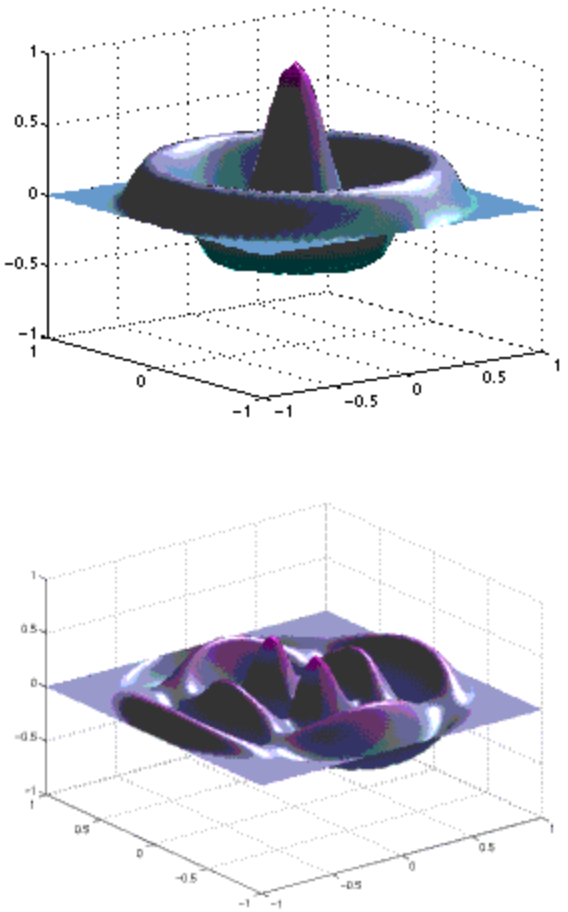
- Acoustic Holography is an efficient way to image surface vibrations
  - Does not perturb the system (when done correctly)
  - Allows for very precise measurements
- The general technique has used developed before
  - Never before this accurate or with phase sensitivity



Right: Acoustic holography of a bowling-ball. Taken from Wu et al., J. Acoust. Soc. Am., Vol. 109, No. 6, ????

Drumhead Motion

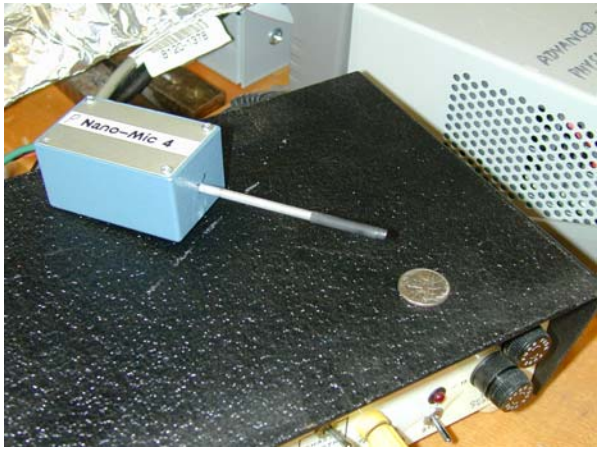
- Arbitrary drumhead motion can be described as a superposition of its **eigenmodes**
  - Just as a wavefunction ψ can be described as a superposition of its eigenfunctions
- Mathematically, these eigenmodes are simply the Bessel functions Jmn
  - At the corresponding eigenfrequency, the drumhead's motion is a Bessel function!
- This makes a drumhead great for testing the acoustic holography setup
  - Once the eigenfrequency is known, just do a spatial scan to image the drumhead.



Above: Modal Vibrations Animations. Taken from http://web.mat.bham.ac.uk/C.J.Sangwin/Teaching/CircWaves/waves.html

Measuring Complex Pressure (*p*) and Particle Velocity (*u*)

- By measuring complex pressure *(p)* and particle velocity *(u)*, any information on the soundfield can be calculated
  - Acoustic Impedance, $Z = p / u$
  - Intensity Factor $I = p\, u^*$
  - Displacement $ds = \int u\, dt$
  - Acceleration $a = du / dt$

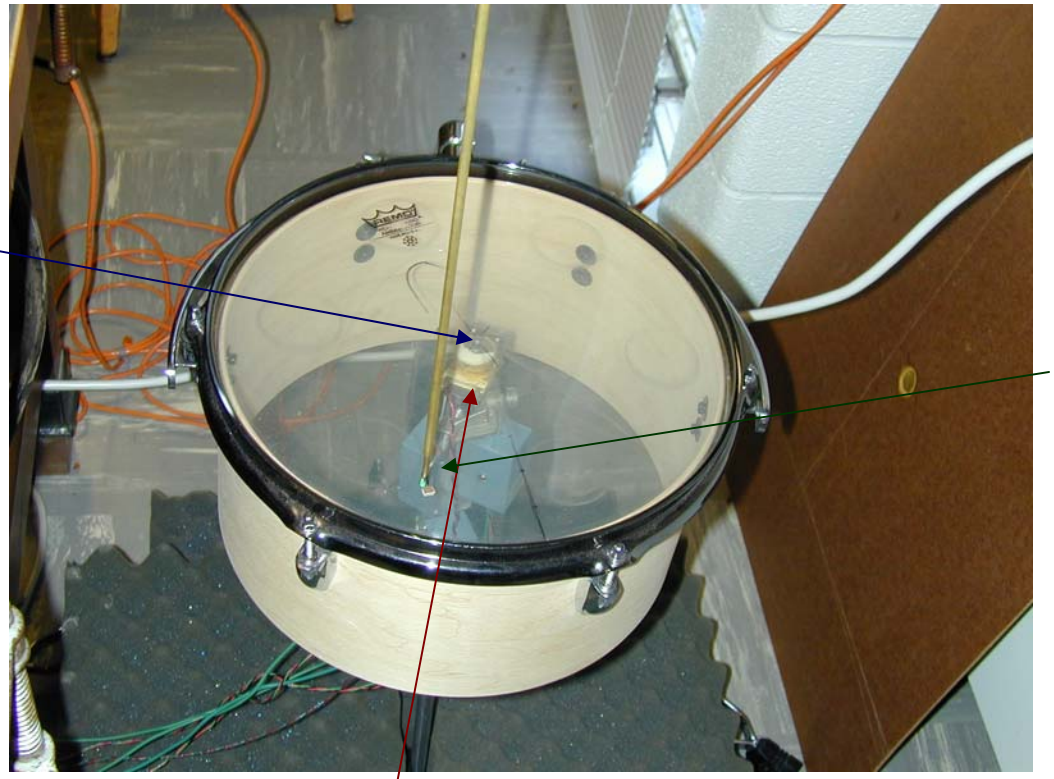


- Both *p* and *u* are measured by their own phase-sensitive microphone
  - Each of the above quantities also has phase information
  - See D. Pignotti's senior thesis for more on the microphones

Exciting the Drumhead for Measurements

1) Small magnets are placed on the drumhead. The magnets create an anti-node, so only some modes are accessible at a given radius.

$\Rightarrow$ Change radial excitation point ρ to access other J_{mn} modes.

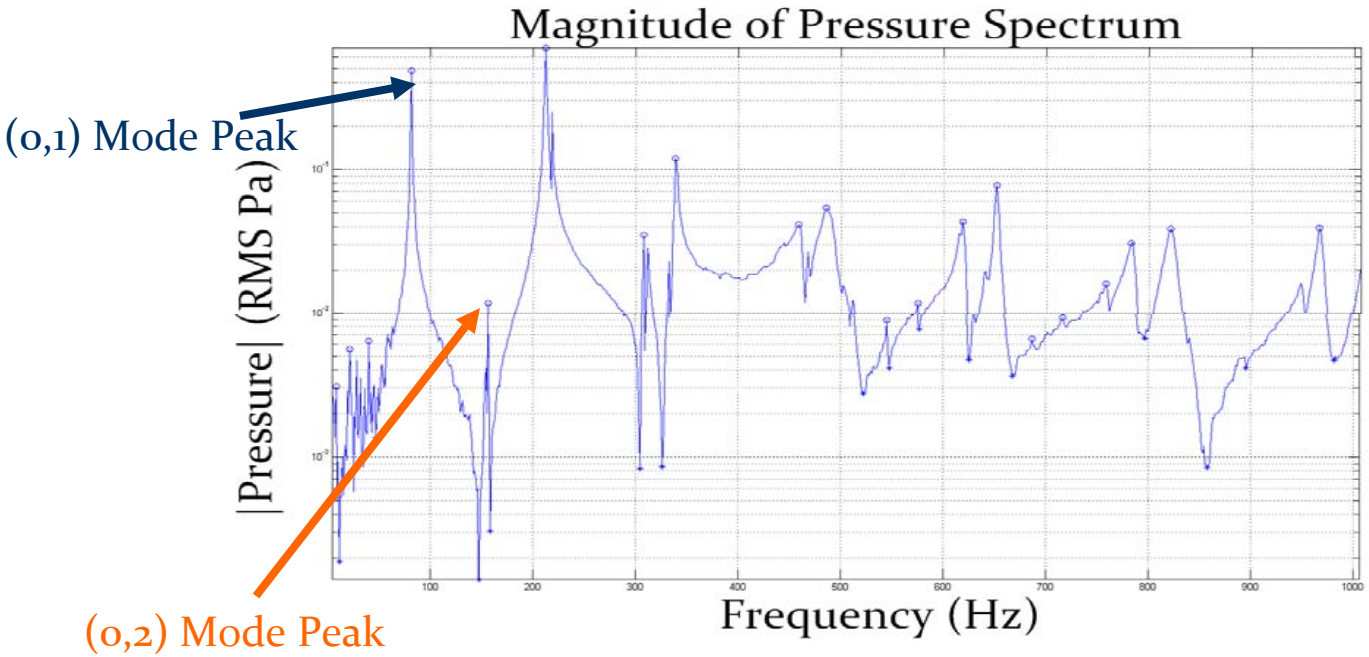


3) Once the drumhead is vibrating on a resonant eigen-frequency, the p/u microphones can be scanned over the drumhead

2) A coil is placed underneath the drumhead and driven by a sinusoidal current. This creates a sinusoidal B-field, which causes the magnets to move

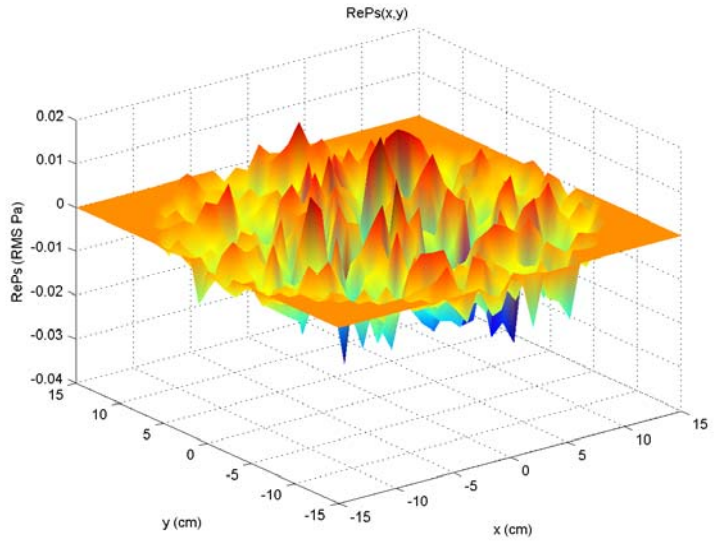
Finding the Eigenfrequencies

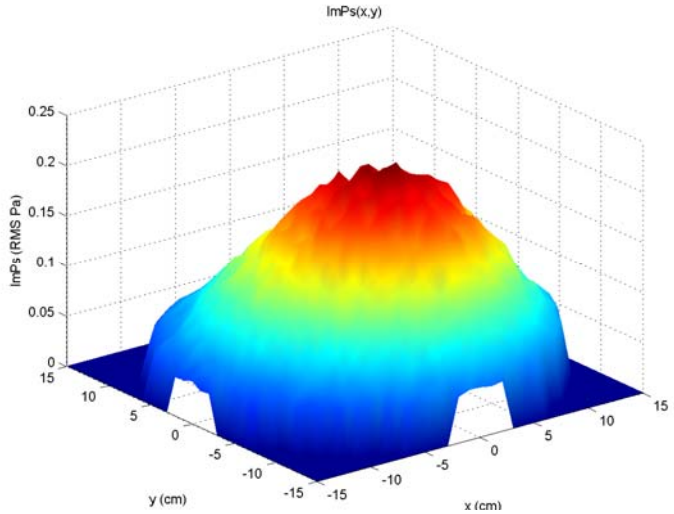
- To find the eigenfrequencies, hold the microphone at a constant location and sweep the frequency the magnets move at



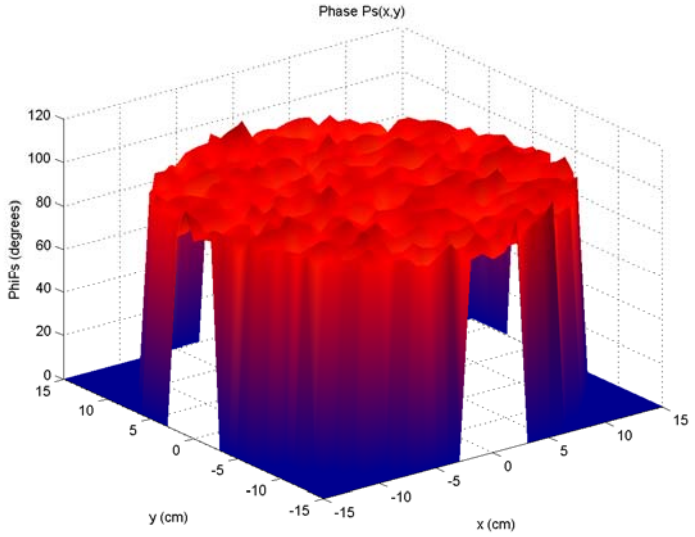
Left: A typical pressure spectrum. This scan was taken with the magnet at the center, so only (0,n) modes are accessible. The peaks correspond to eigenfrequencies of the drumhead.

Scanning the Drumhead on the (0,1) “Breathing” Mode





- Pressure is largely imaginary in this mode, with the real part just being largely noise
- The pressure across the drumhead is entirely in-phase and 90° out of phase with the function generator



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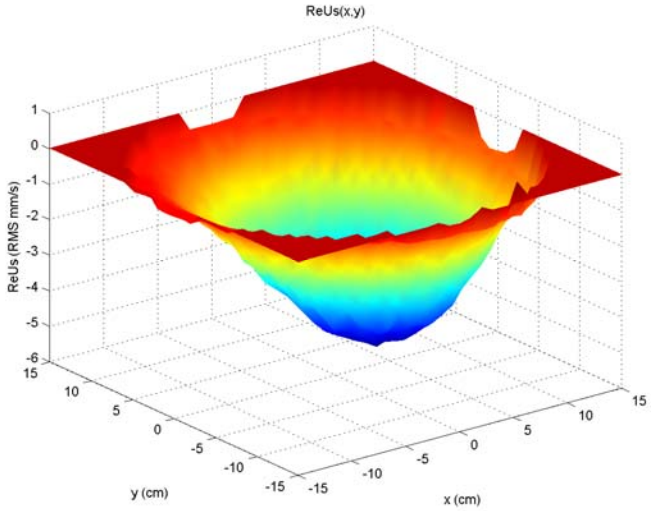
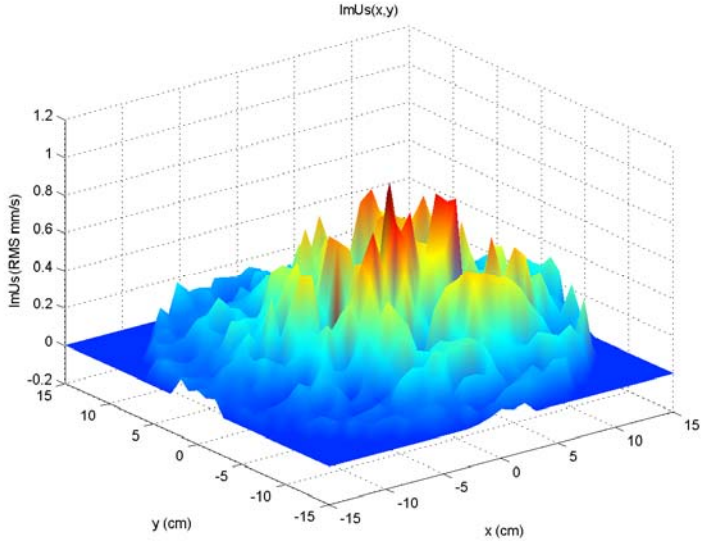
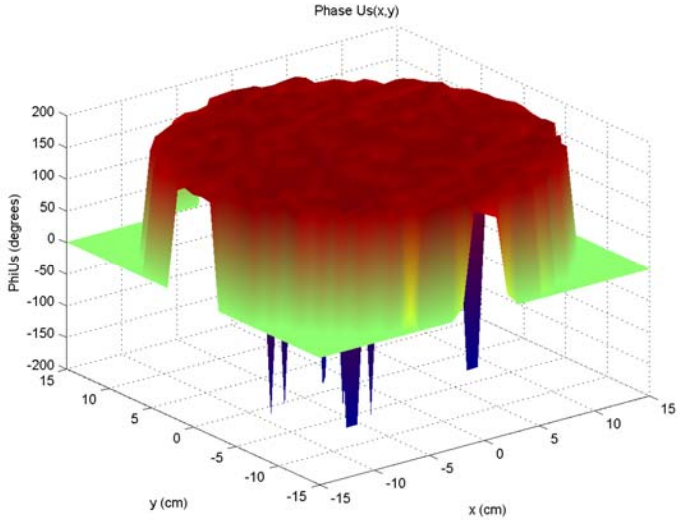


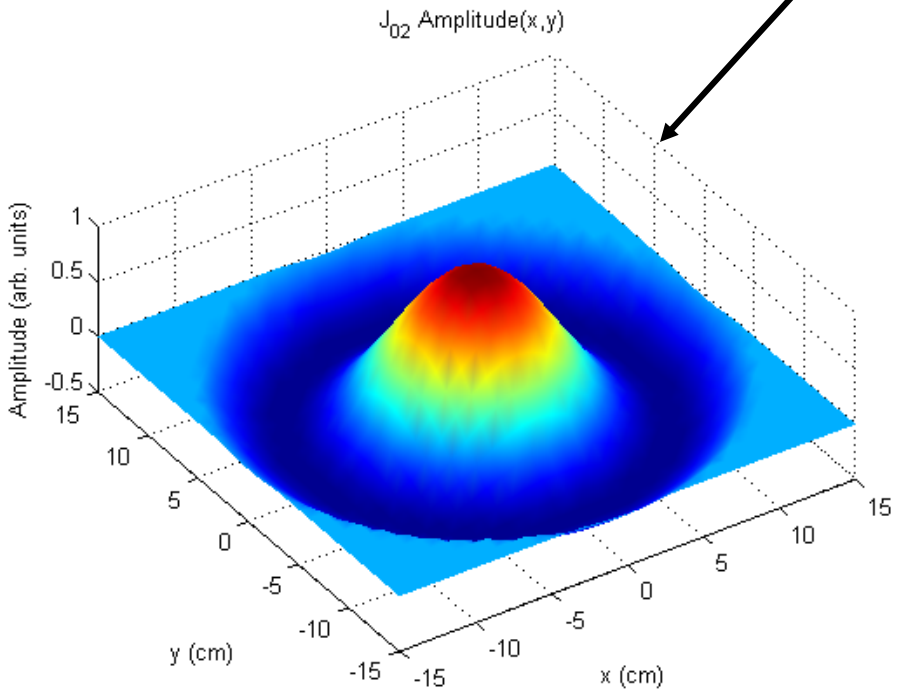




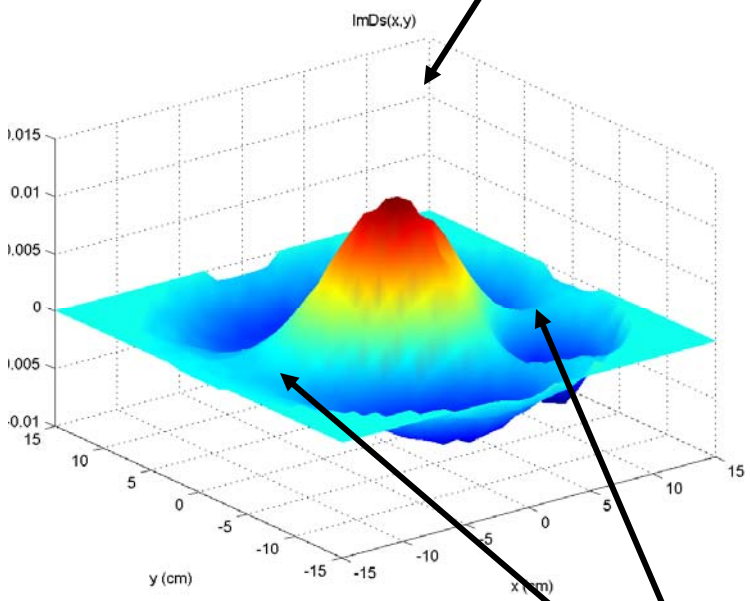
- Particle velocity is largely real in this mode, unlike the pressure
- The pressure across the drumhead is entirely in-phase and 180° out of phase with the function generator

Test of Precision: The (0,2) Mode

Theory says the plot should look like this…



But we found this…



Overall, they're pretty consistent, but why do the measured values have those bridges running to the center?

Very Slight Changes in the Drum Cause Drastic Changes to its Vibrations

- We found that these bridges led directly to the grommets supporting the drum.
  - The support structure must have been damping the vibrations
- Relieving the drum of some of the grommets' pressure removed the bridges