Aerospace Engineering at Universidad del Valle – More tan 10 year of challenges and achievements.

Joao Luis Ealo C. Ph.D

School of Mechanical Engineering

Universidad del Valle

Cali - COLOMBIA

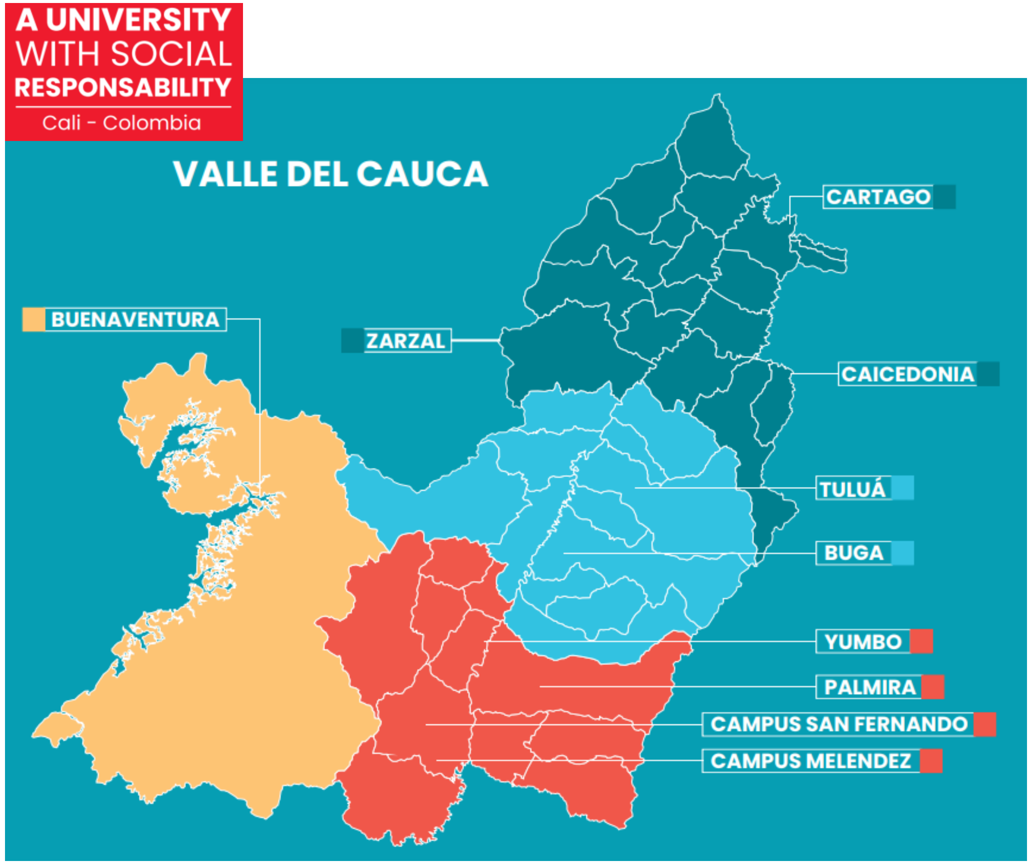
30th Virtual UNISEC – Global Meeting

OUTLINE

- Brief presentation of the Universidad del Valle and its Faculty of Engineering.
- Graduate Program in Aerospace Engineering.
  - Numbers and projects.
- Research line: Acoustic Technologies for aerospace applications
  - High-power vortex beams for angular momentum transfer (acoustic radiation torque).

Universidad del Valle in Numbers

- Institutional video (www.univalle.edu.co)



Universidad del Valle

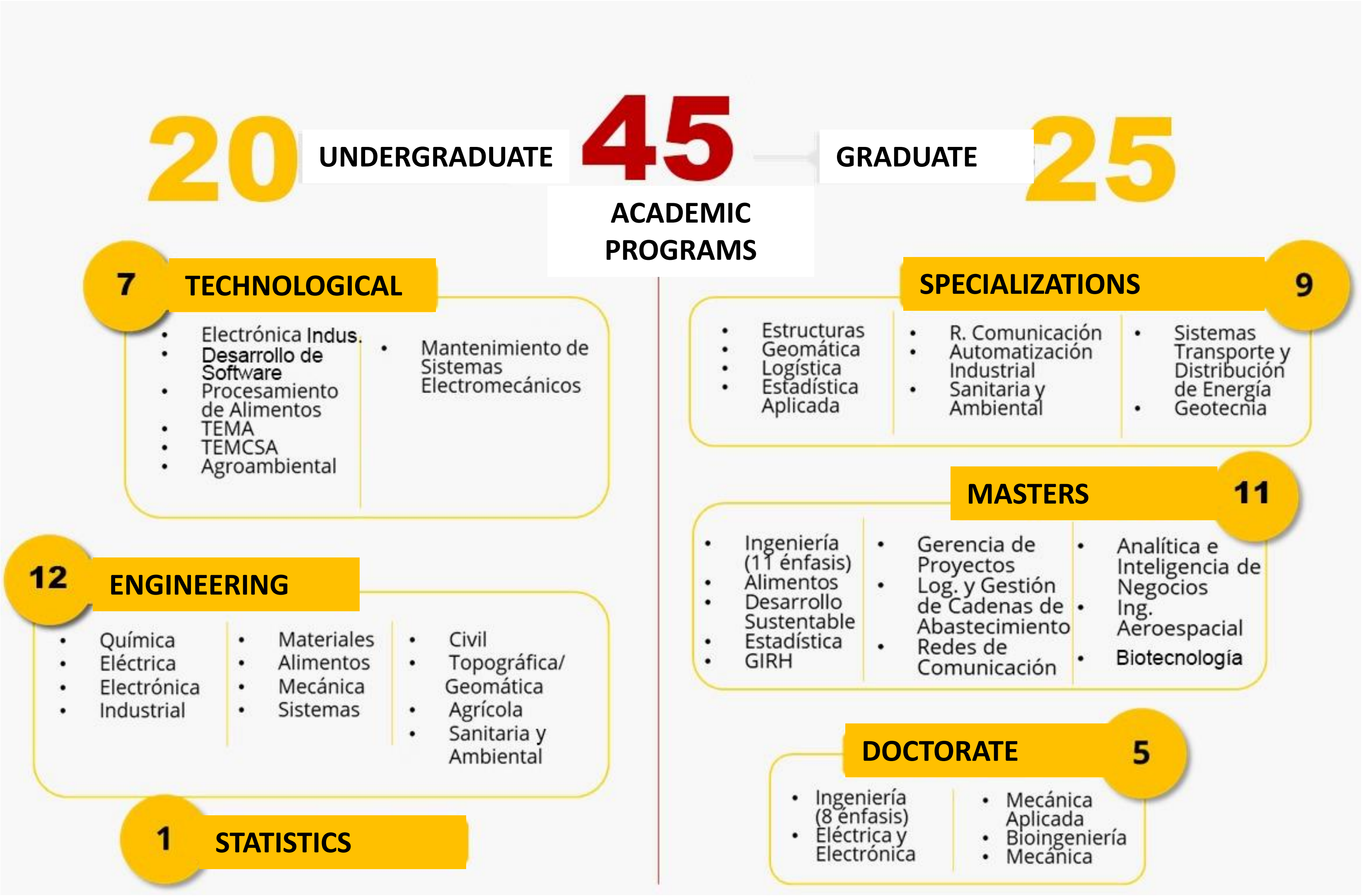
10 Años Acreditación Institucional de Alta Calidad 2014 - 2024

Enrolled Students	**32450**
Level of Education	
Undergraduate	**29512**
Technological Level	4866
University Level	24646
Graduate	**2938**
Specialization	427
Medical & Surgical Specialities and Master Degree	1953
Doctoral Degrees	558

Academic programs	**348**
Cali	**205**
Undergraduate	**76**
Technological Degrees	9
University Degrees	67
Graduate	129
Specialization	26
Medical & Surgical Specialities and Master Degree	83
Doctoral Degrees	20

Professors	
Dedication TCE	
Complete	876
Partial	123
Professors	999
Men	666
Women	333

Faculty of Engineering in Numbers



STUDENTS

- 152 PhD students
- 399 master students
- 71 specialization students
- 9695 undergrads

(93% from low income families)

- 10 engineering schools
- 1 research institute
- 30.000 alumni
- 48 research groups
- 195 professors (tenured)
- 73 laboratories

Master Program in Aerospace Engineering.

- Created in 2009 as an initiative from Colombian AirForce - FAC.
- Duration: 4 semesters
- 14 Professors (11 Ph.D, 3 M.Sc) and 4 engineering schools involved.
- Aimed to aerospace, aeronautical, mechanical and electronic engineers and similar academic backgrounds.
- Research lines:
  - Aerodynamics and Propulsion
  - Aerospace materials and structures.
  - Navigation and Automatic Control.
- Research Groups/Team:
  - IDEXA – Prof. Jairo Valdés
  - Industrial Improvement (**GIMI**) – Prof. Fernando Casanova
  - G7 – Prof. Peter Thomson
  - Remote Perception (**GIPER**) – Prof. Francisco Hernández
  - Energy conversion and propulsion revolution (Impetus Indomitus) – Prof. Guillermo Jaramillo
  - Industrial Control – Prof. Esteban Rosero

IMPETUS INDOMITUS
Research Team in energy conversion & propulsion revolution

Equipo IDEXA
Equipo de Investigación en Desarrollo y Exploración Aeroespacial

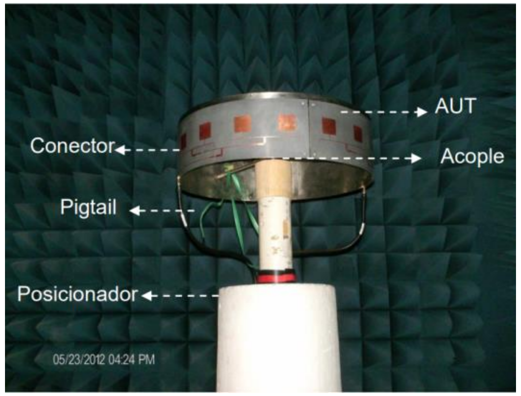
GICI
Grupo de Investigación en Control Industrial

Master Program in Aerospace Engineering.

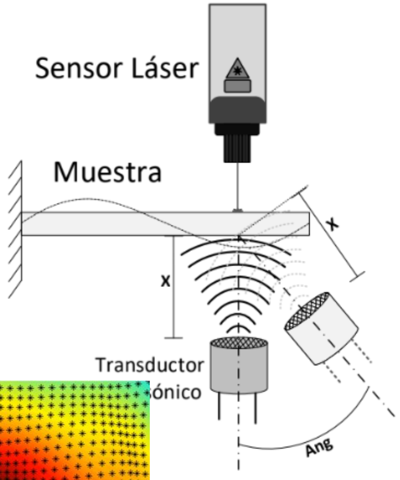
- 16 graduates, 5 current students.
- Alumni: 3 Ph.D, 2 current PhD students, 4 at Colombian Air Force - FAC. Most of them working in research and development, 1 independent consultant.

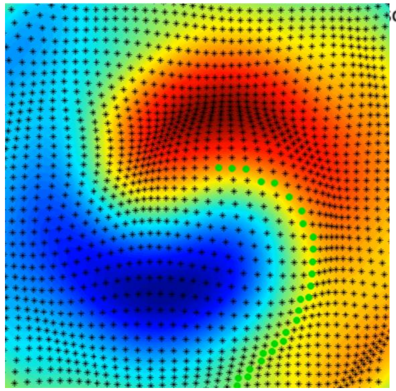
COLLABORATORS and PARTNERS

Some master's thesis titles.



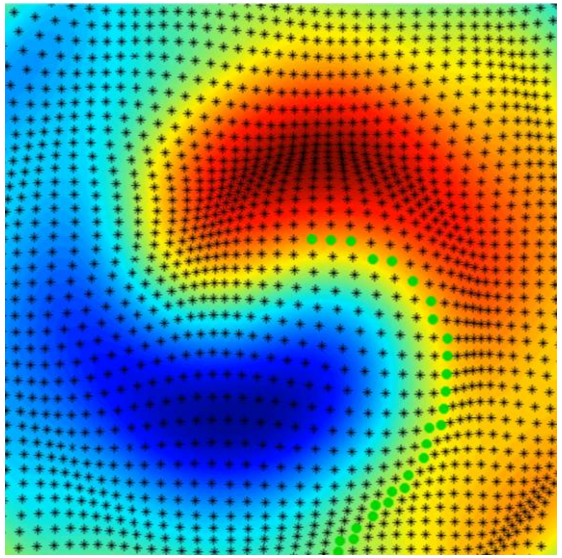
1. Angular momentum estimation transferred by an acoustic vortex beam
2. Defect detection in composite materials using Lamb waves.
3. Geostationary orbit for the satellite FACSAT 1.
4. Determination of an operational commercial orbit for the satellite mission FACSAT 2.
5. Numerical Modeling of the combustion process for hybrid rocket engines
6. Design of high-power vortex beam using ultrasonic vibrations.
7. The Ultrasonic Radiation Force and its potential for modal analysis.
8. Implementation of the random vibration standard test for environmental verification of micro satellites (NASA-GEVS).
9. Design and evaluation of Nonlinear control strategies for attitude control of a CubeSat in orbit.
10. Design and implementation of an omni-directive microstrip antenna with circular polarization for rocketry applications.





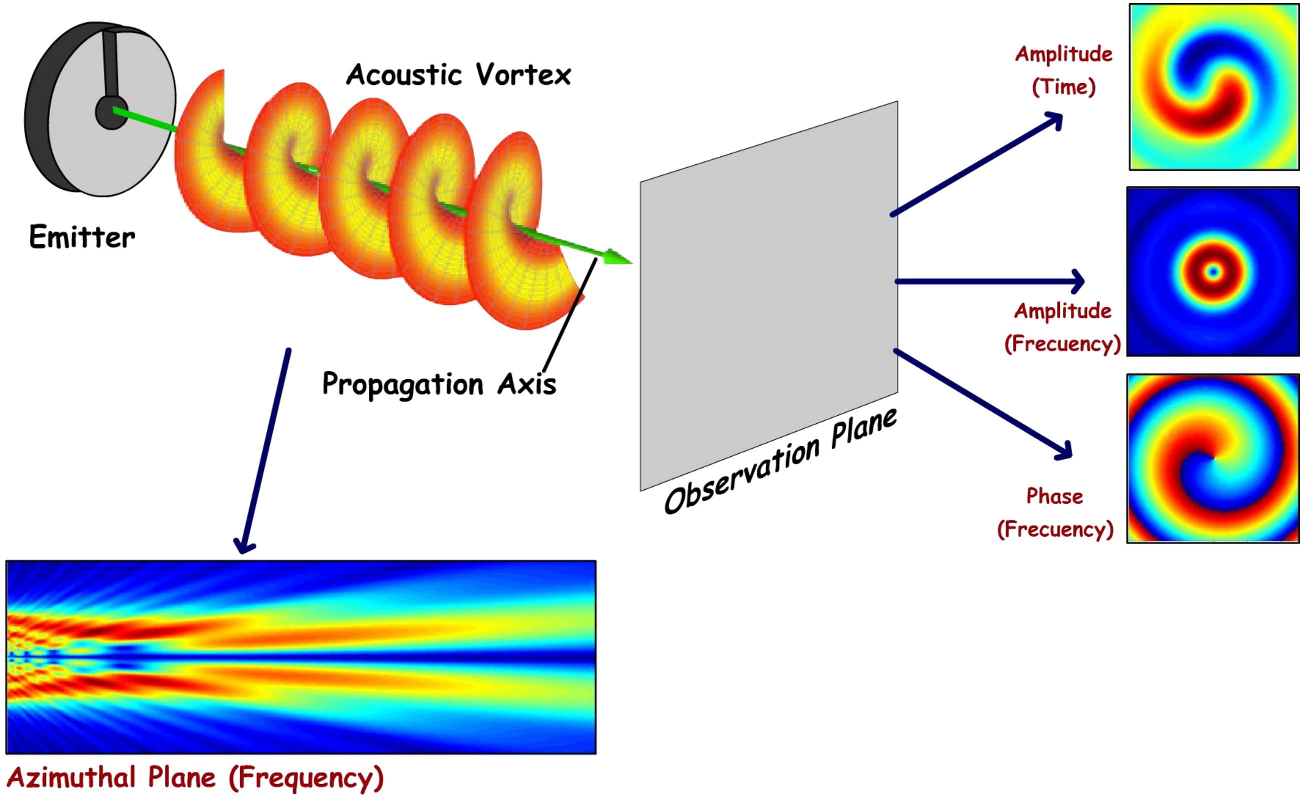
Acoustic Technologies for aerospace applications: vortex beams for angular momentum transfer

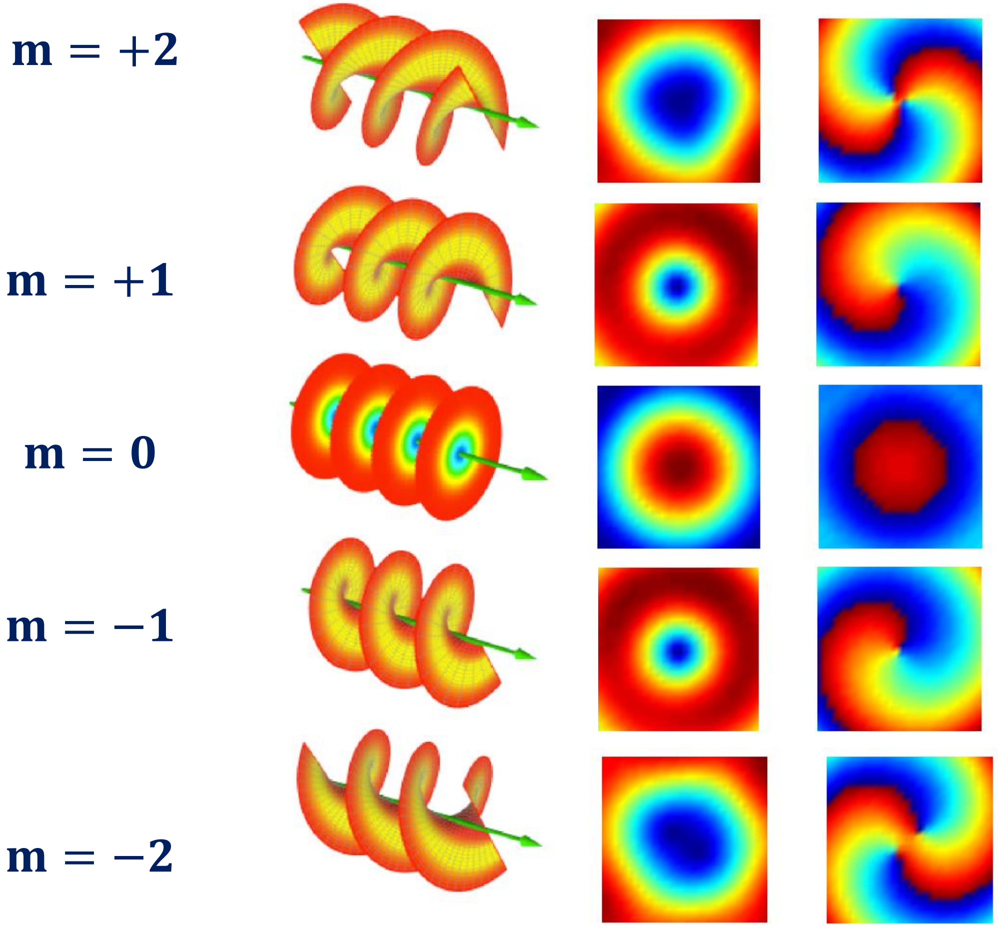
- The constant phase surface of the beam is a helicoid.
- There exist a phase singularity at the center of the beam
- They can be used for particle/object manipulation, alignment, ultrasound communications.
- They exhibit self-reconstruction capacity.
- They transport angular momentum which can be transferred to matter.



Acoustic vortex beams

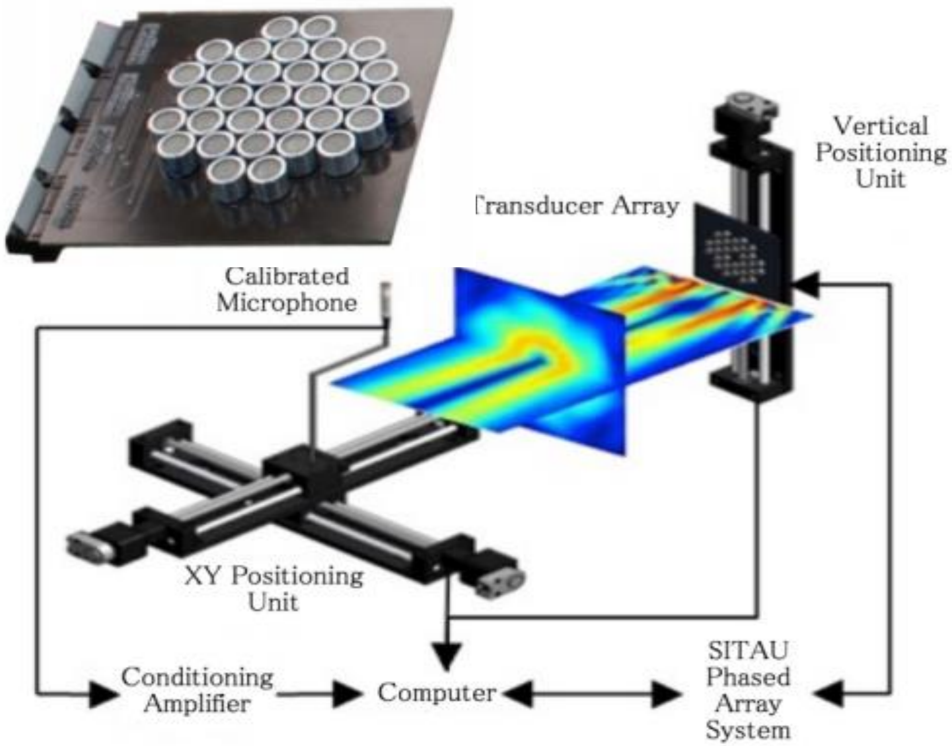
- Vortex beam generation (helical surface, multitransducer, active diffraction gratings)
- Acoustic-Structure Interaction (Particle manipulation & angular momentum transfer)



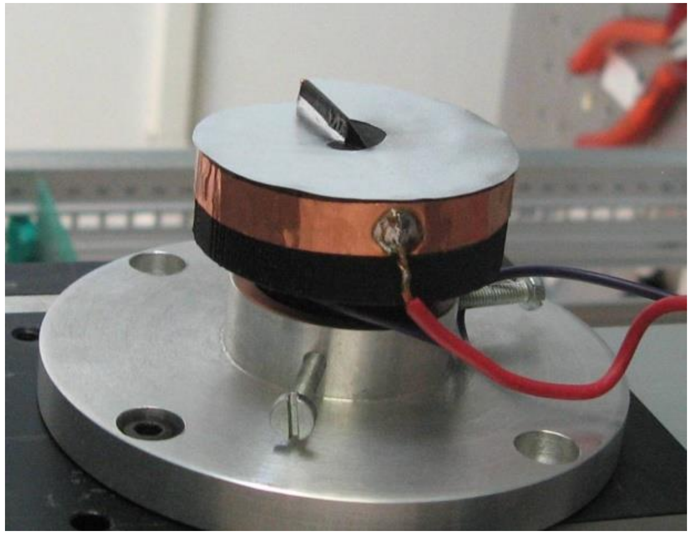


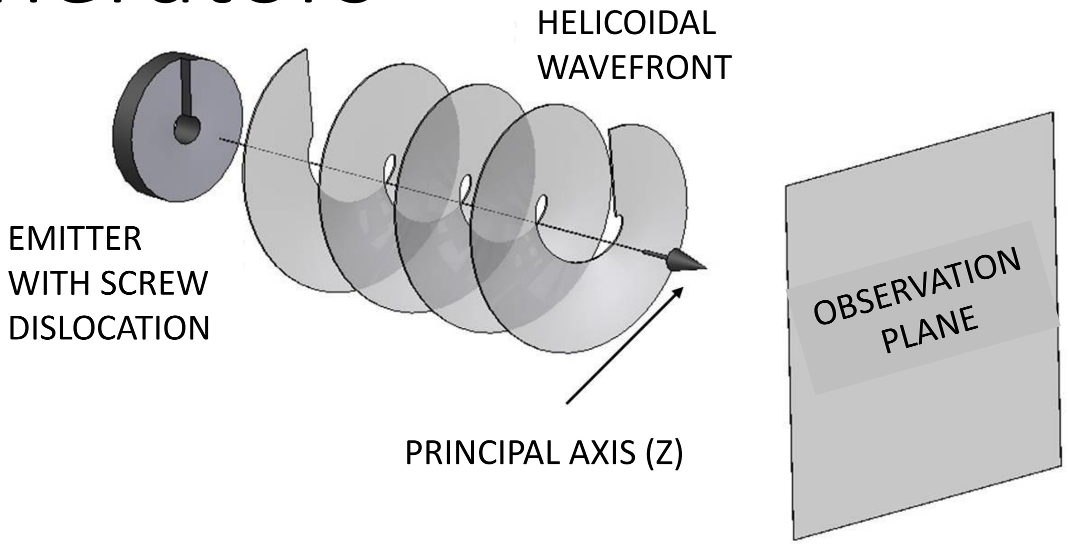
Vortex Beam Generation Technologies

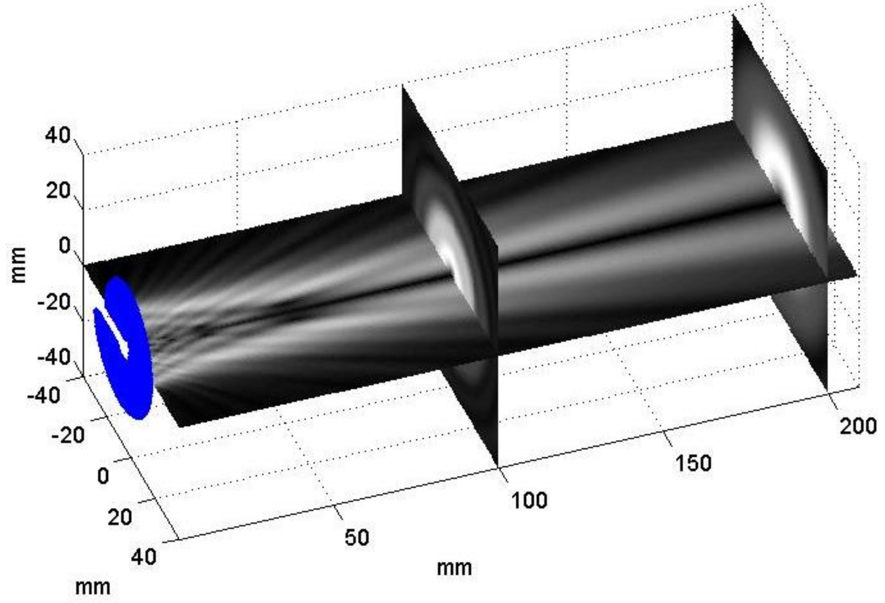
1. Phased Array System + Multitransducer

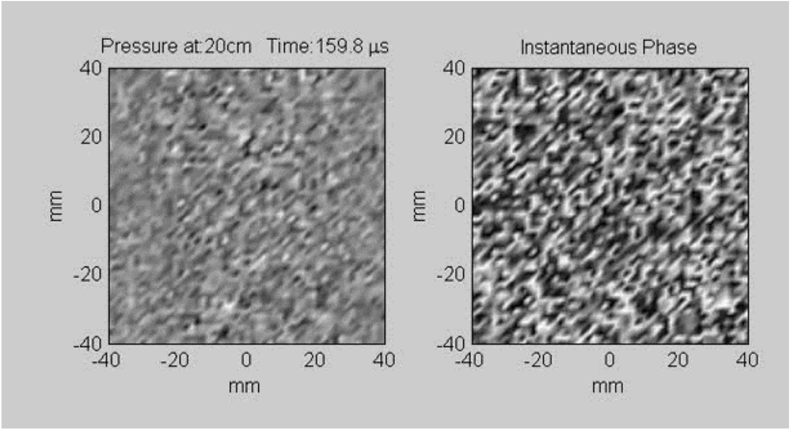


2. Ferroelectret-based developable surface generators

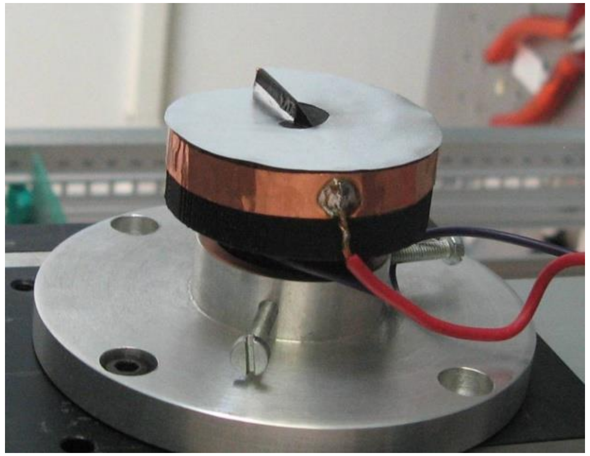


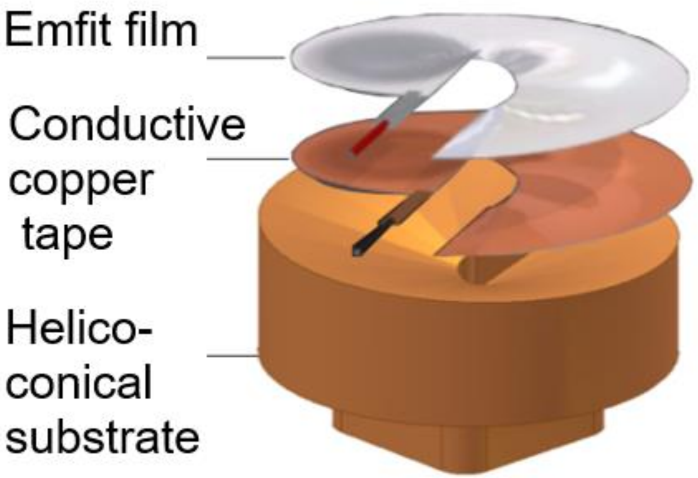


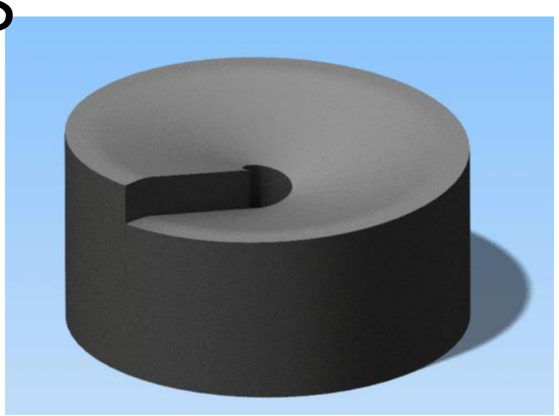




2. Ferroelectret-based developable surface generators

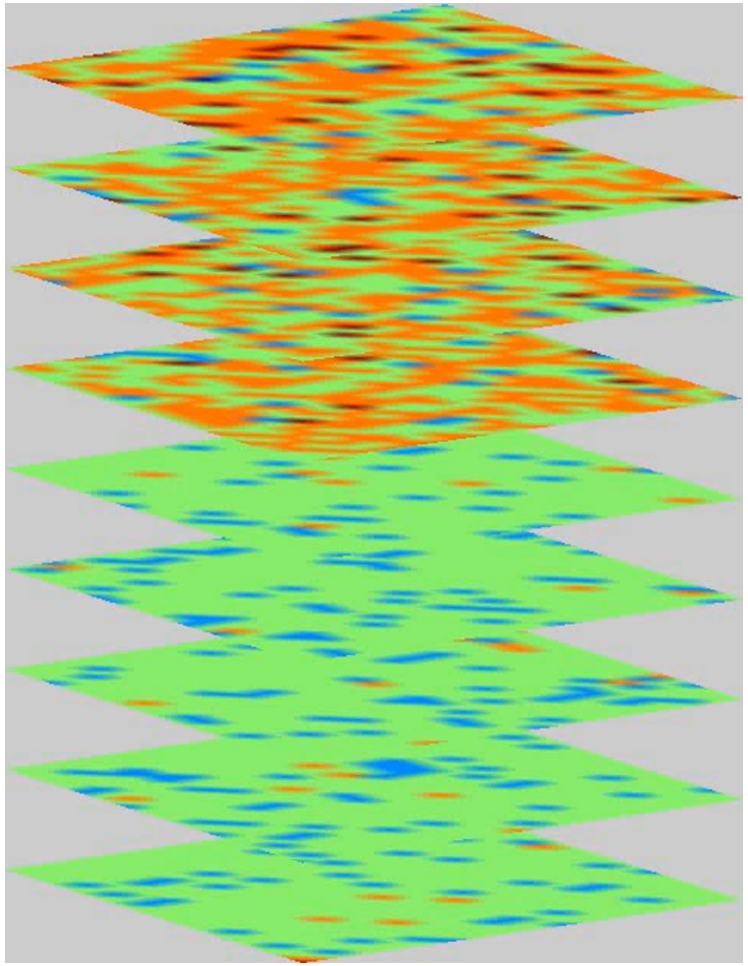


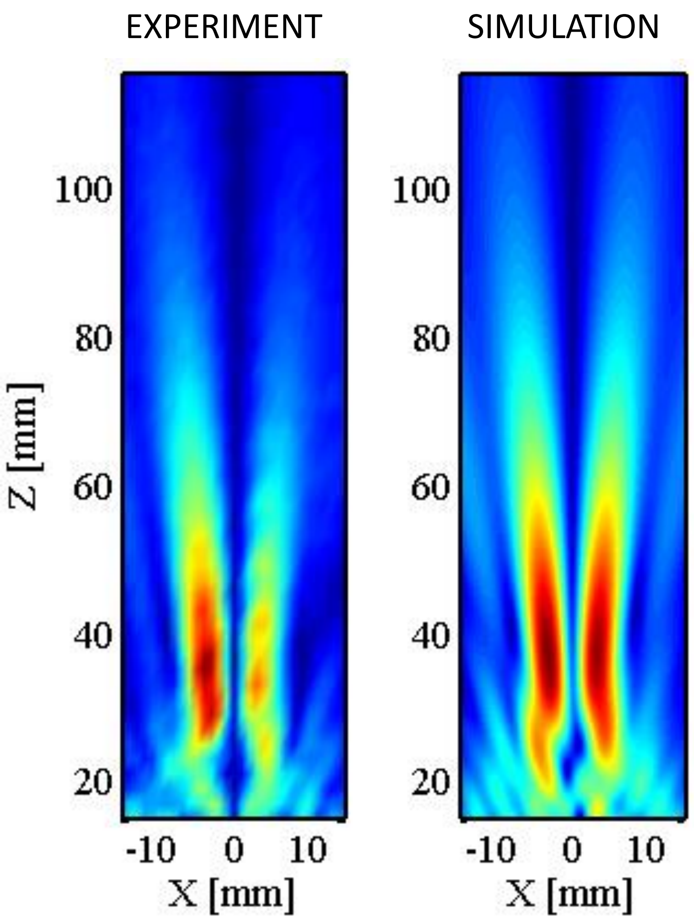




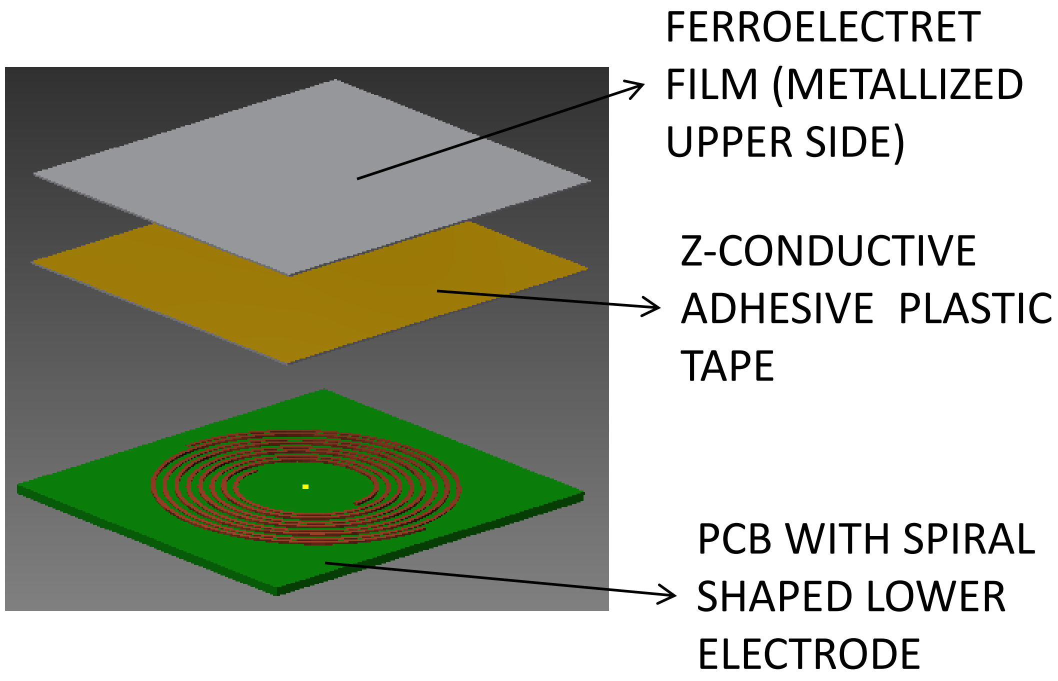
Outer Diameter : 40 mm
Inner Diameter: 5 mm
Cone Angle: 20 degrees
Helicoid Pitch: λ @ 70 kHz

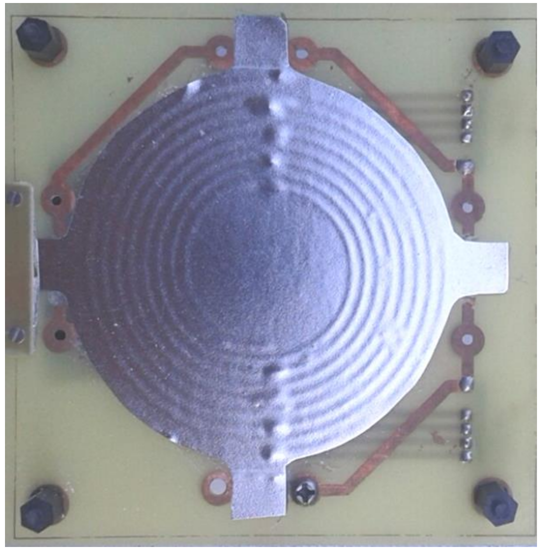
4. Experimental Resultts: 20° - 70 kHz

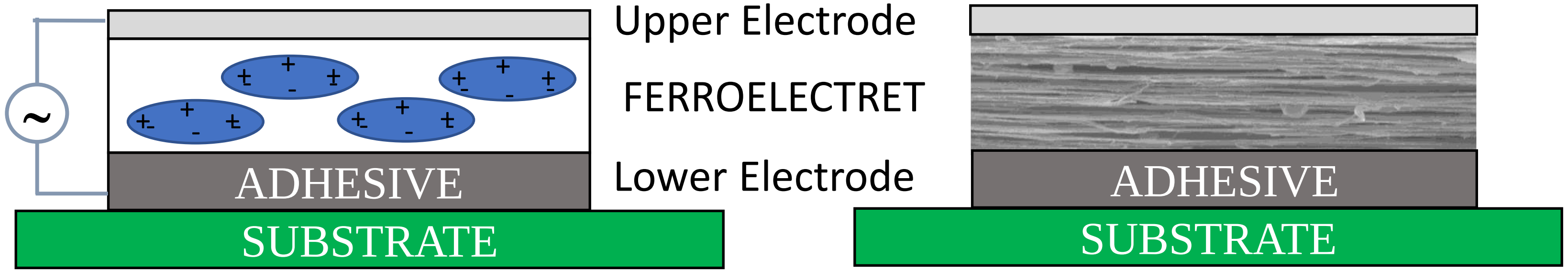




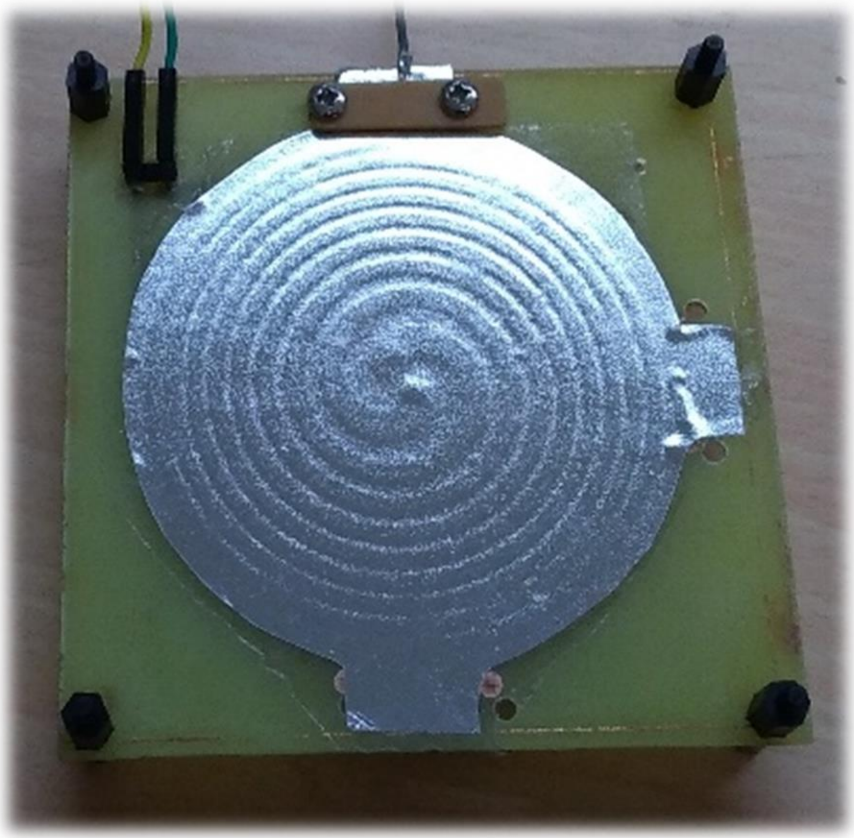
3. ELECTROACTIVE DIFRACTING GRATINGS



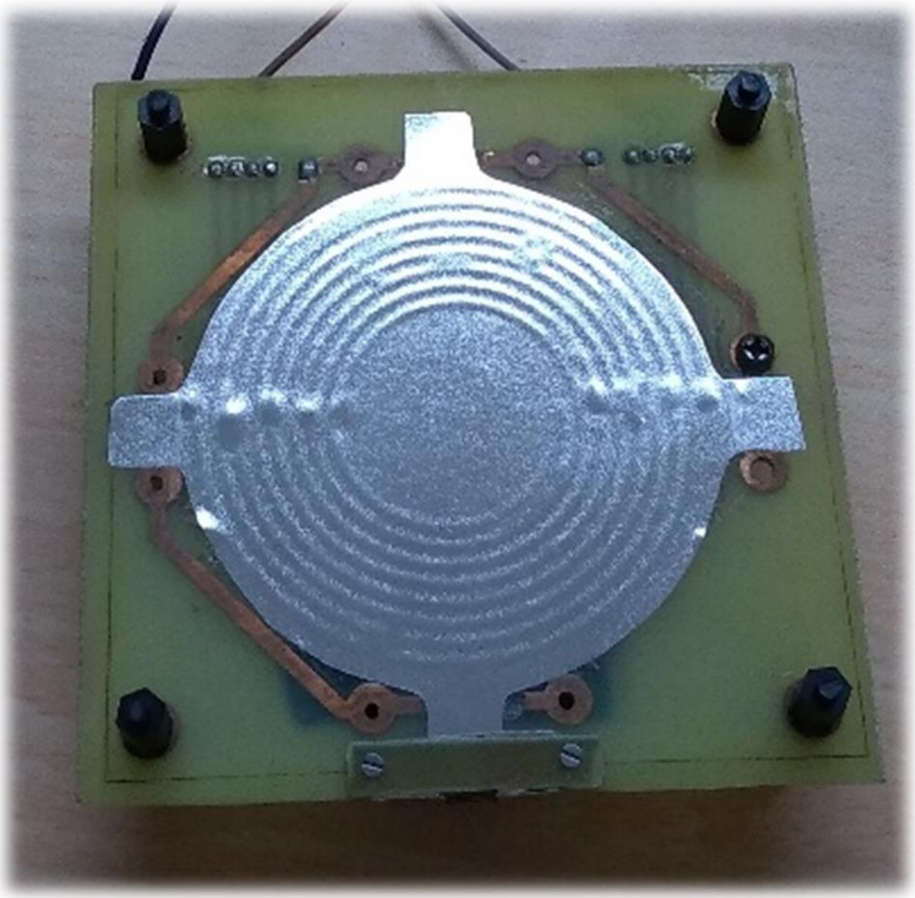




ELECTROACTIVE DIFRACTING GRATING



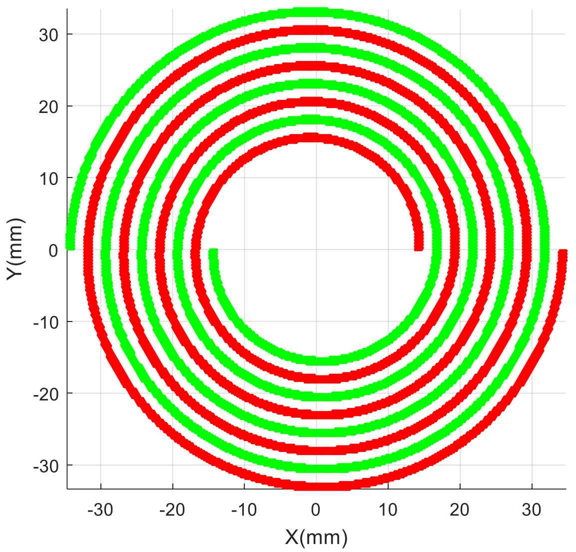
Focused Active
Grating Transducer

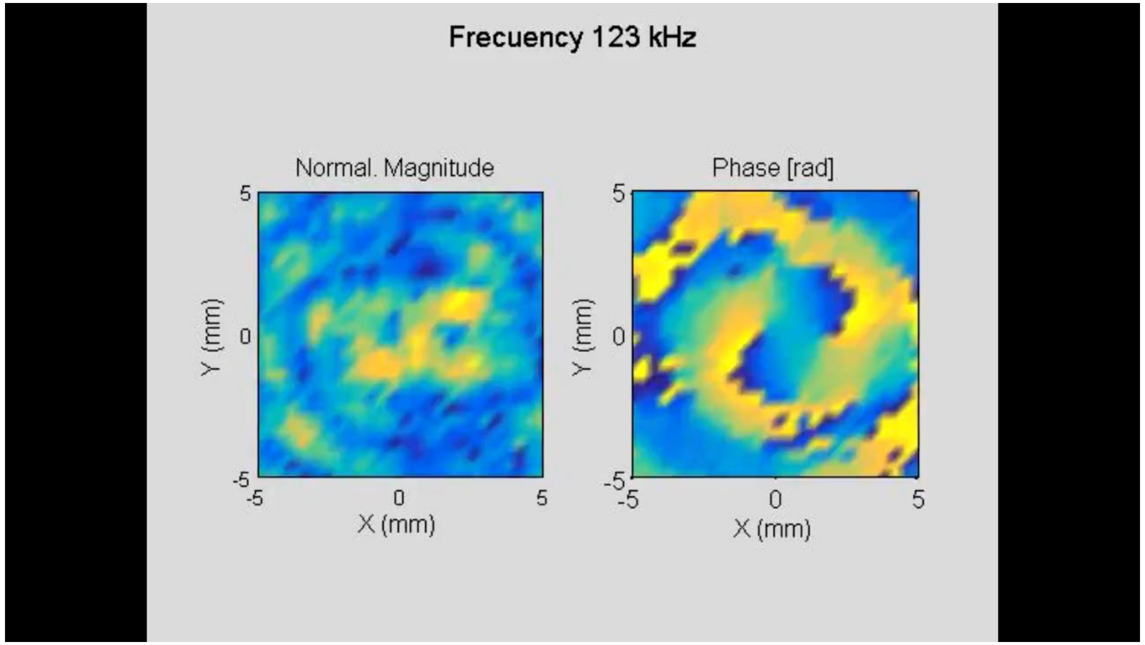


Arquimedean Spiral
Transducer

Arquimedean Spiral – Two Arms

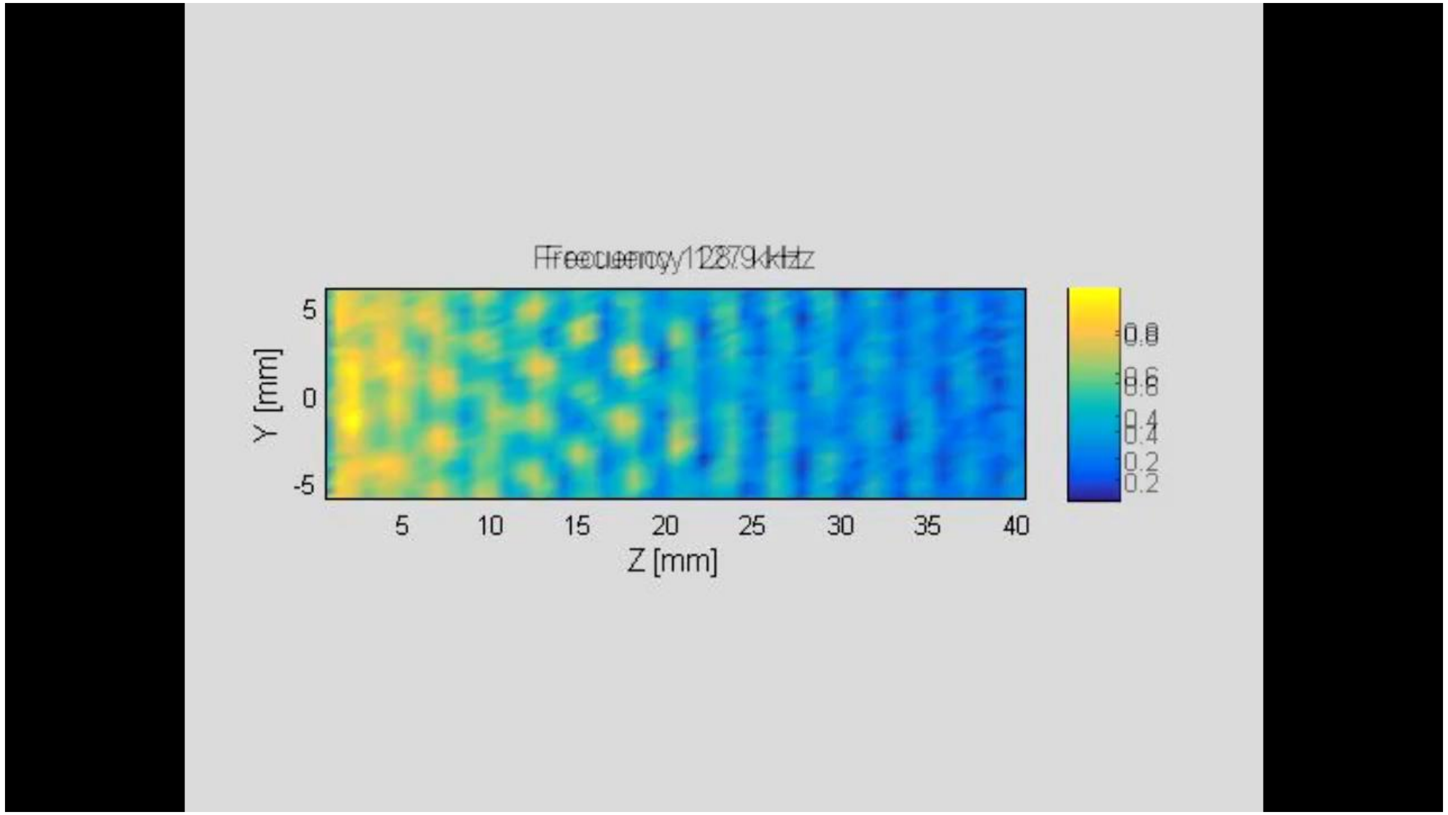
Acoustic field as a function of frequency





Transverse plane measured at 20 mm
from the ADG.

The focal point is shifted as frequency increases!!



Experimental simulation results

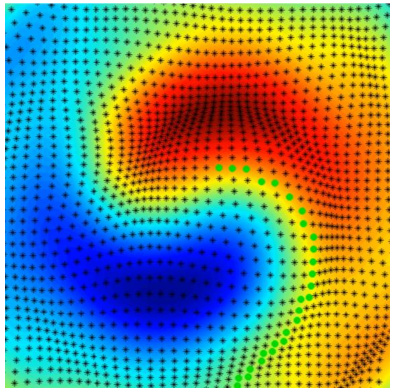
For frequencies between 130 kHz and 170 kHz, the focal points shifts from 20 mm to 32 mm, aproximately

4. High-power vortex beams

Acoustic Vortices (AV) + ***Ultrasonic Vibrations*** = ***Sonotrode-based prototype to produce AV in air***

Acoustic Vortices (AV)

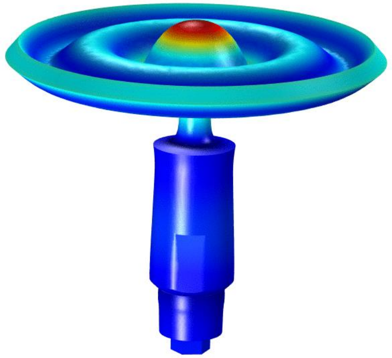
- *The constant phase surface of the beam is a helicoid.*
- *There exist a phase singularity at the center of the beam*
- *They can be used for particle manipulation and alignment.*
- *They exhibit self-reconstruction capacity.*
- *They transport angular momentum which can be transferred to matter.*



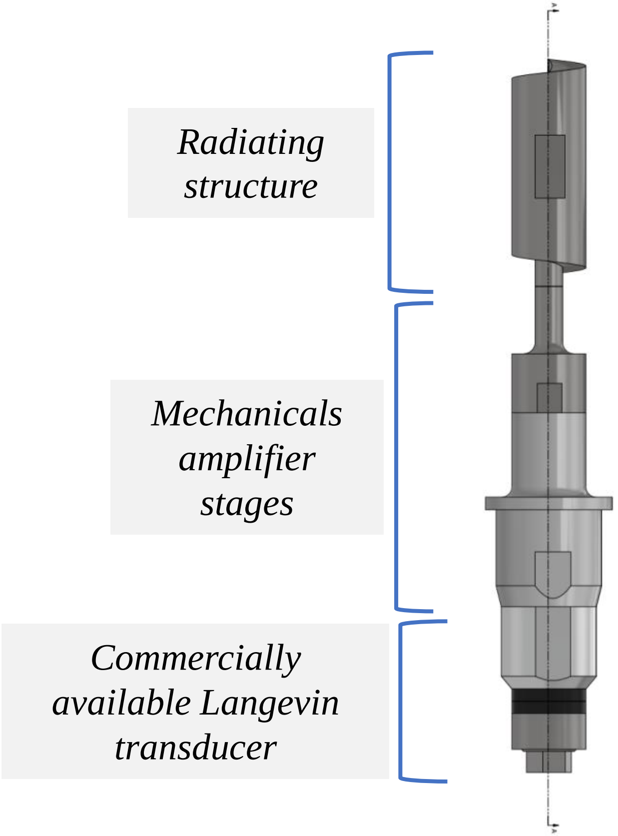
Ultrasonic Vibrations

- *The sonotrode structure operates at longitudinal vibration and flexural modes between 20 kHz and 100 kHz.*
- *Produce high power ultrasonic waves in air .*
- *Have multiple industrial applications, e.g: ultrasonic cleaning, ultrasonic welding, ultrasonic defoaming.*

Vibration mode of the Sonotrode



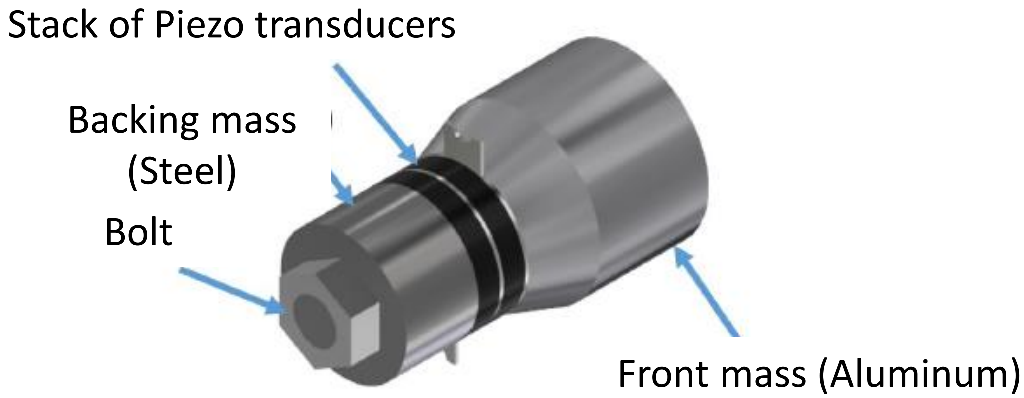
Sonotrode-based prototype to produce AV in air



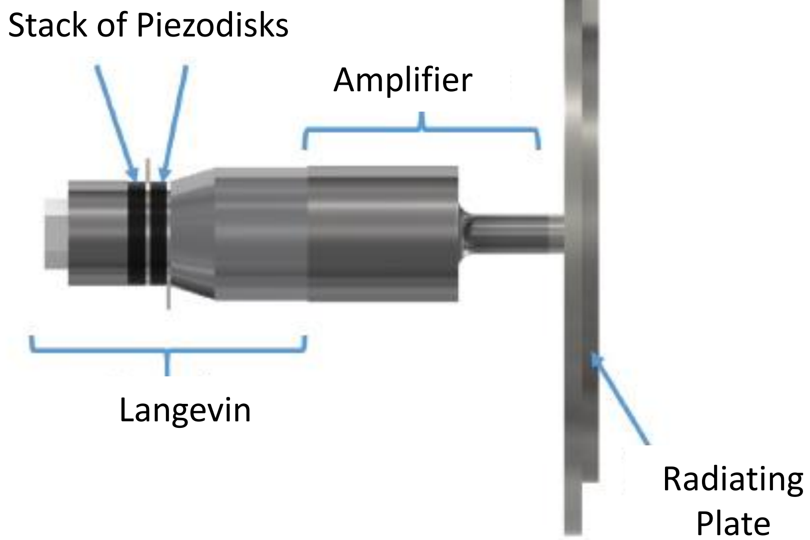
- Perhaps simpler than using a multielement array. But more complex than a monoelement transducer.

High Power Ultrasound

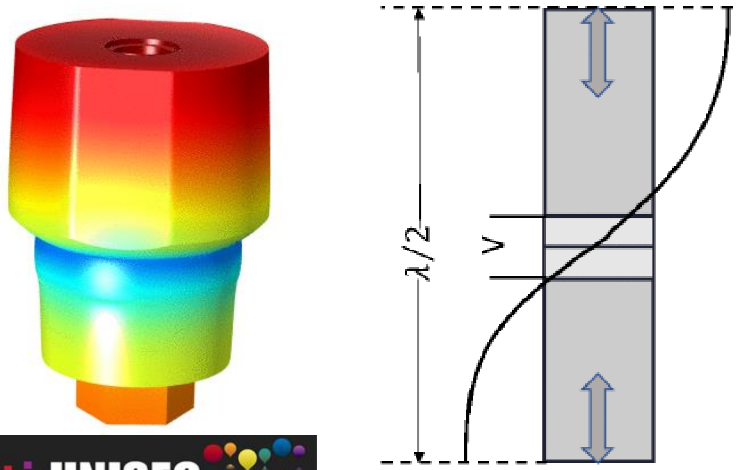
Langevin Transducer



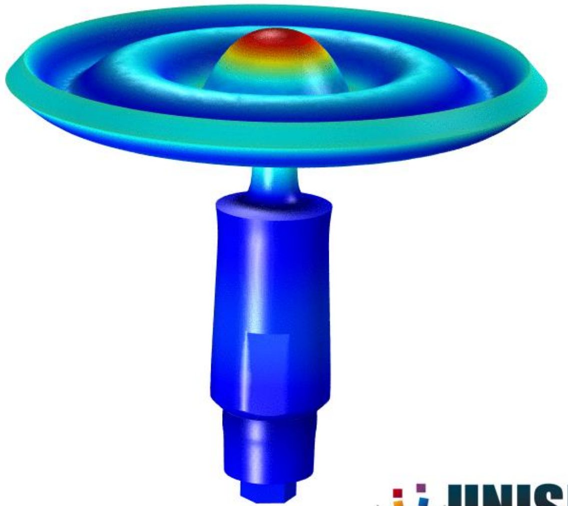
Radiating Plate Sonotrode



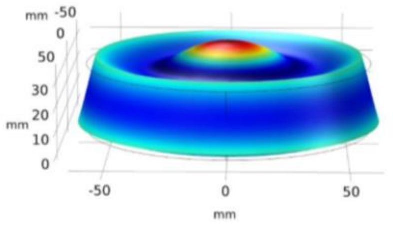
Extensional vibration of the Langevin

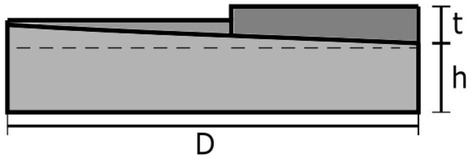


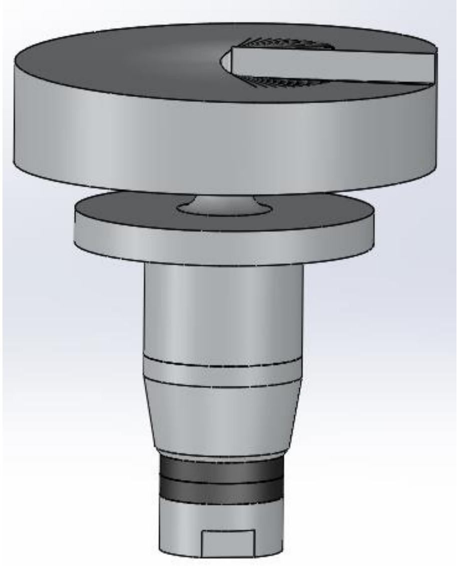
General vibratory behavior

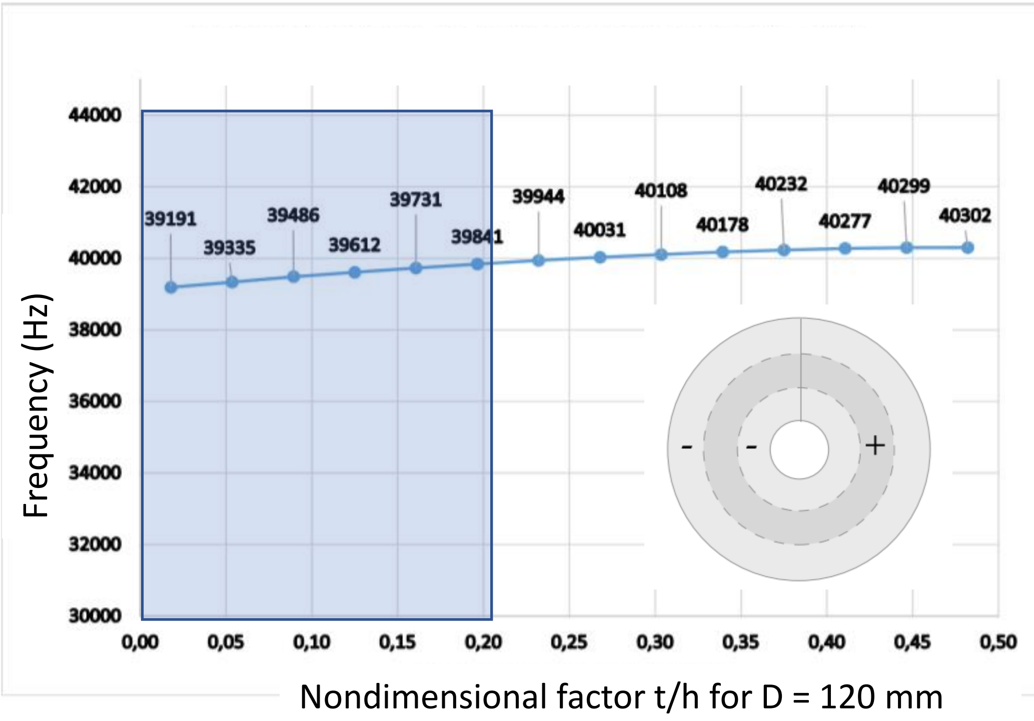


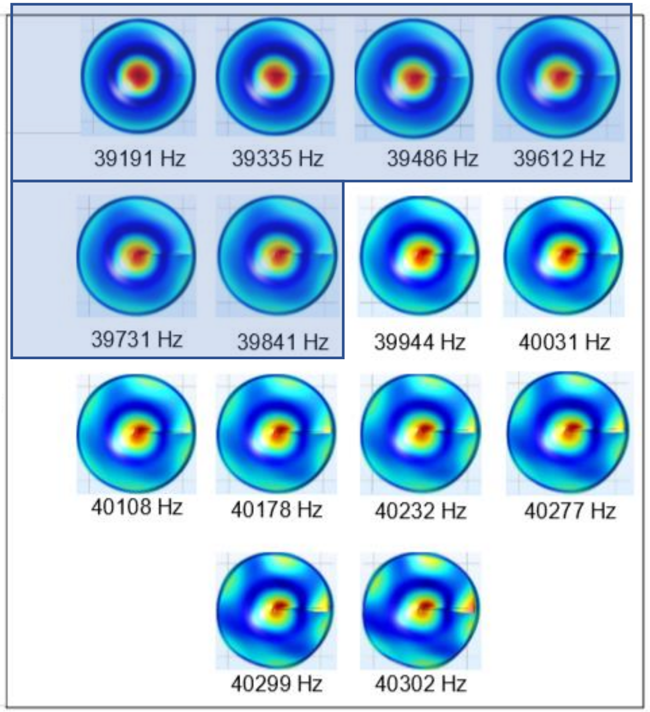
2. Prototype Design 2: Flexural Radiating Surface









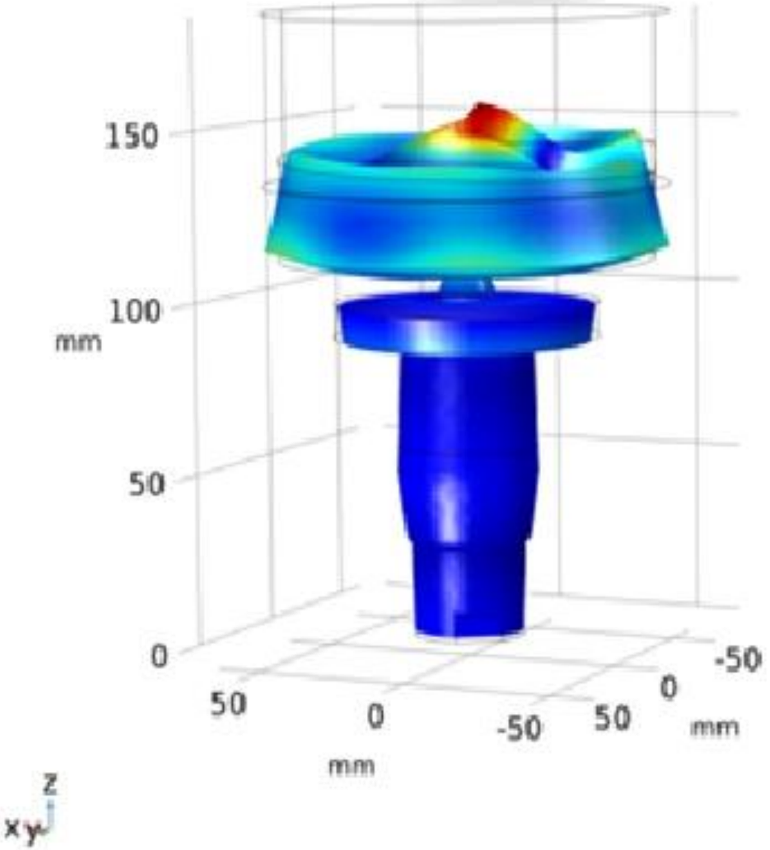


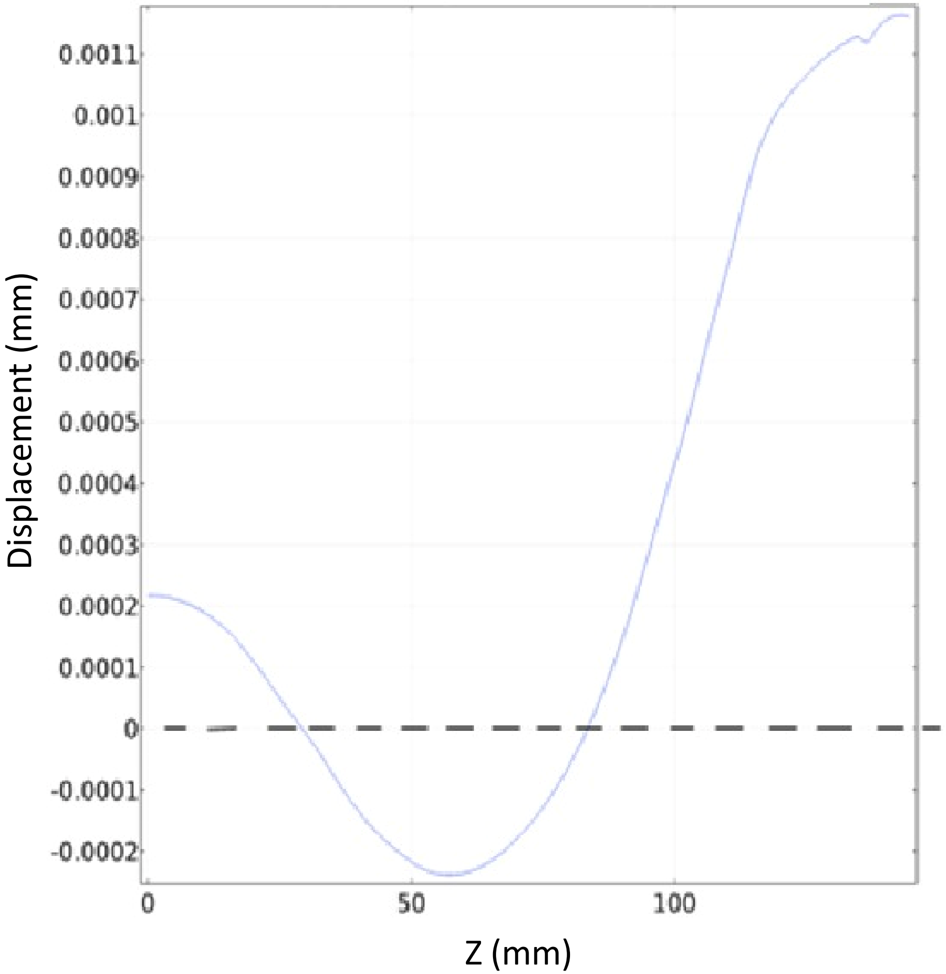
Change in the vibration mode for different t/h factors and D = 120 mm.

1. Find the desired mode at the operation frequency of the Langevin for a plate of thickness ***h*** and diameter ***D***.
2. Add the helical section of pitch ***t*** avoiding a high distortion of the selected mode
3. Use ***t/h*** < 0.2 as a rule of thumb.

Idealy, we are generating concentric vortices, emulating a Bessel beam.

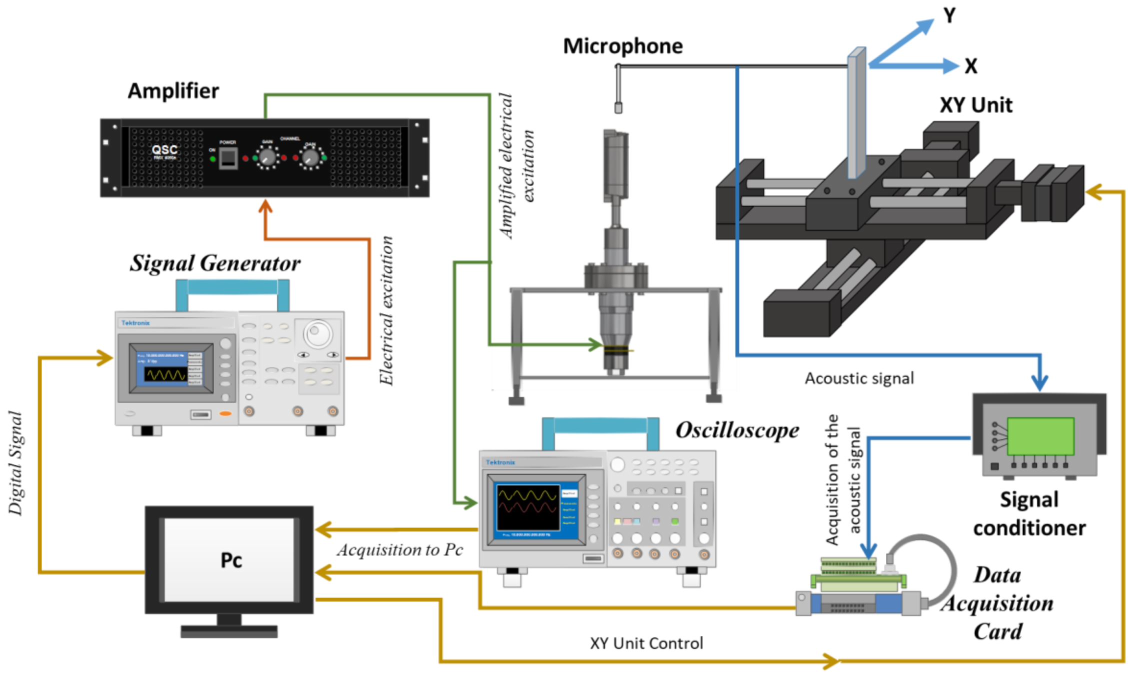
2. Prototype Design 2

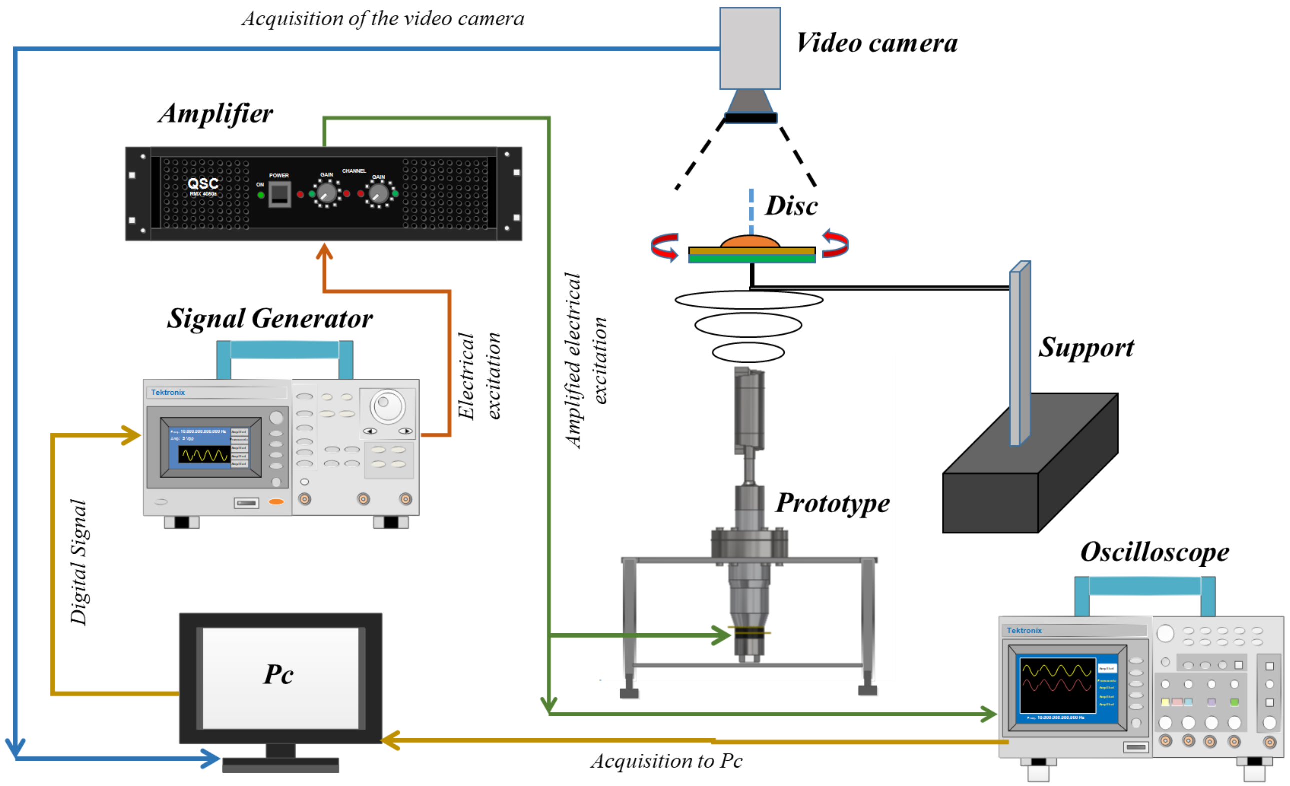




Frequency: 40087 Hz

3. Experimental Characterization





- Vibratory pattern characterization (LDV)
- Acoustic field measurement
- Transferred angular momentum
- Acoustic Torque Estimation on flat cork disks.

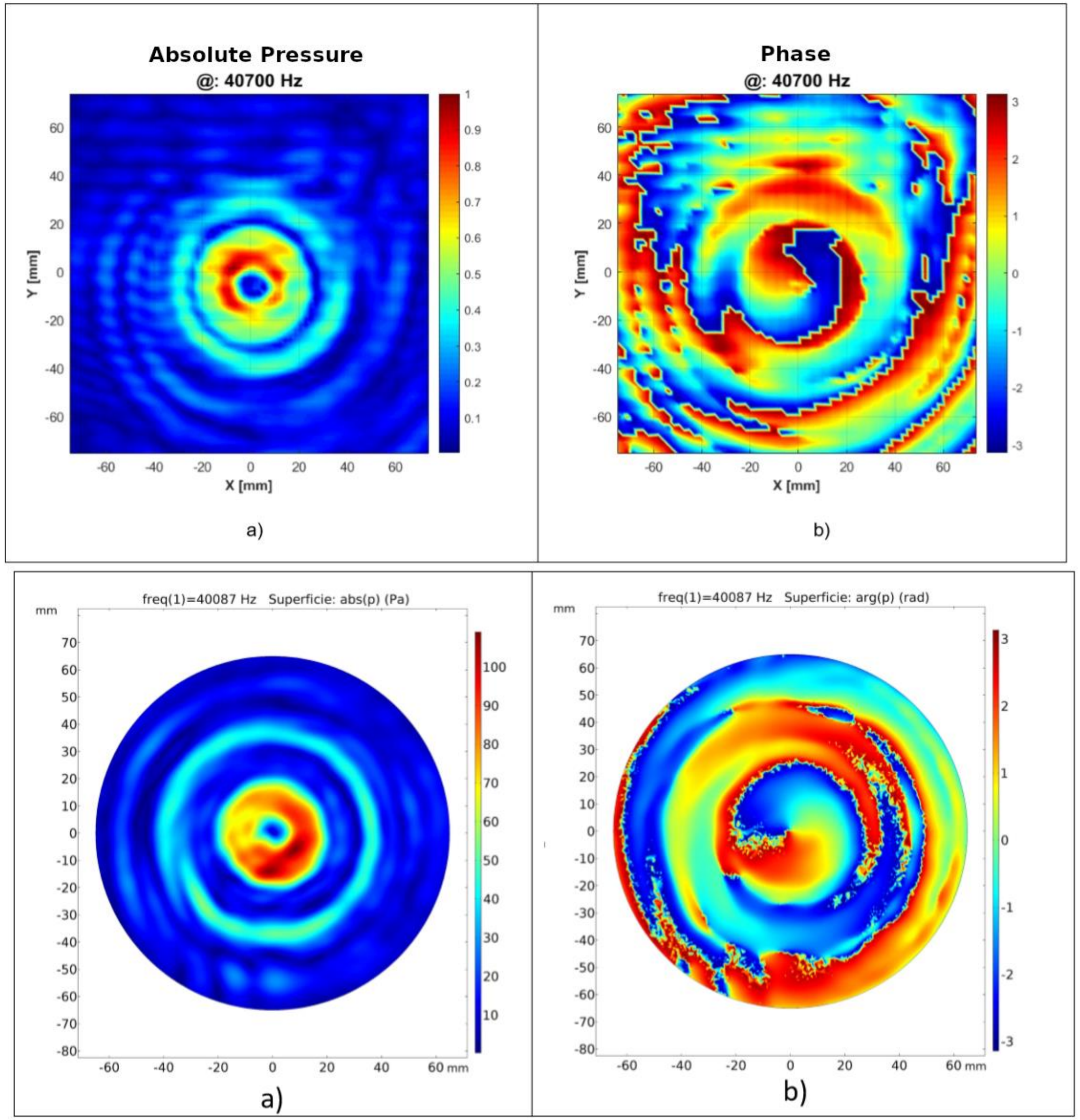
$$T_a \approx \frac{I_{disk}\omega_{ss}}{\tau}$$

I_{disk} : Moment of inertia of the disk sample
ω_{ss}: Angular velocity of the disk in steady state.
τ : Time constant of the first order response of the disk velocity.

Acoustic Results.

Fabricated Prototype

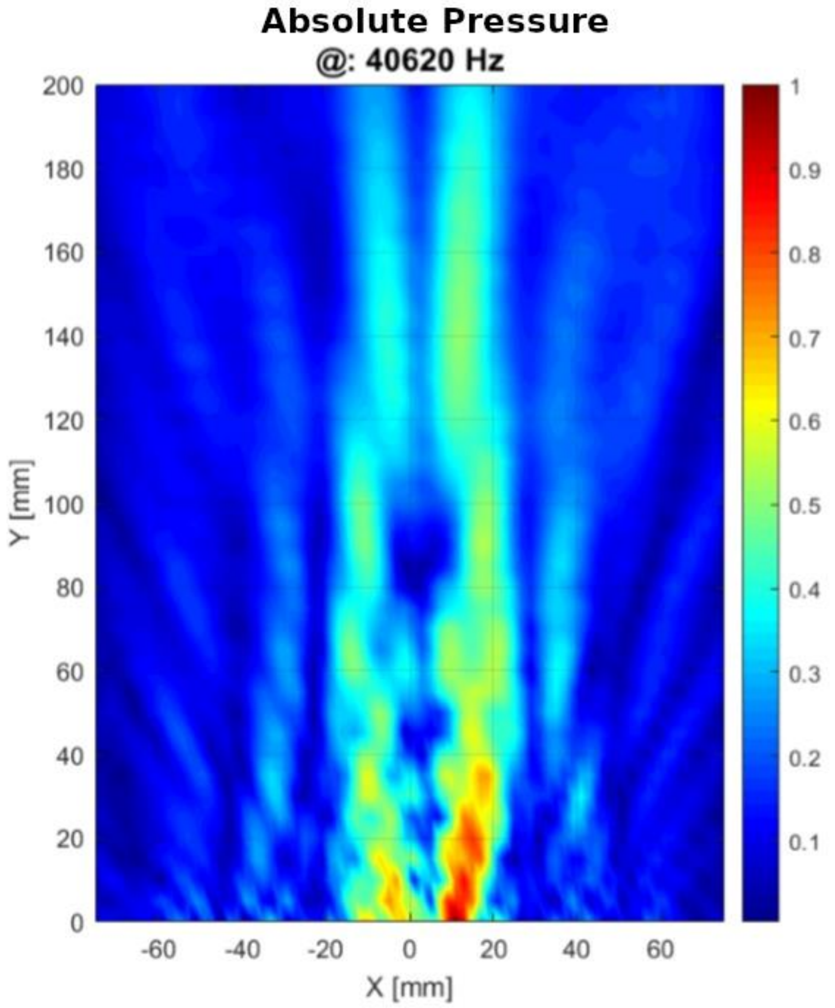
Measured field at 40 mm from the source



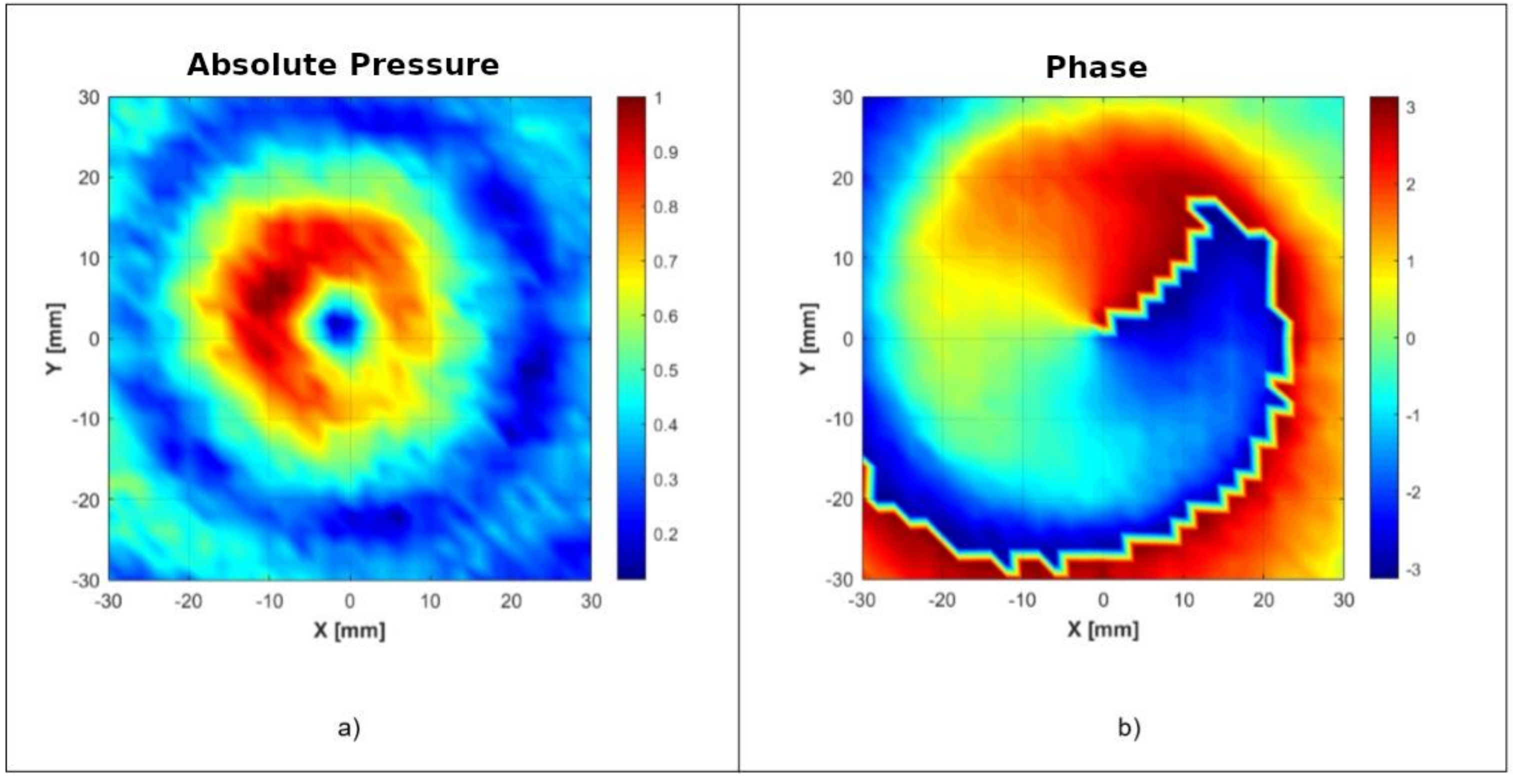
Experiments

Simulation

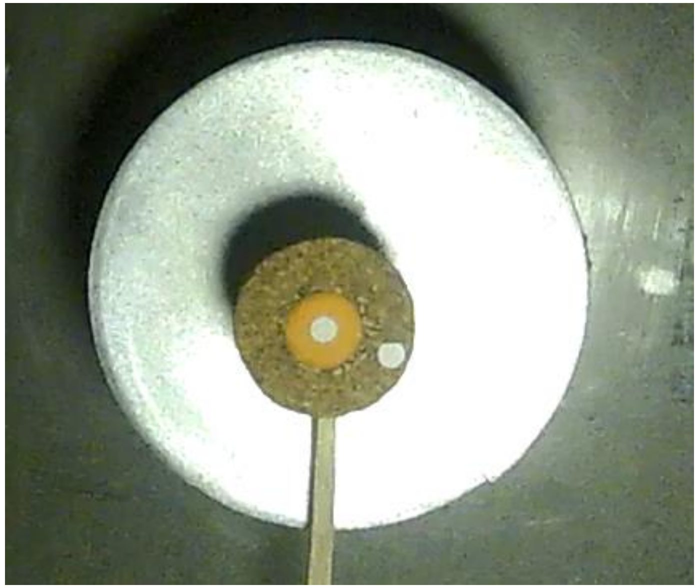
Acoustic Results.

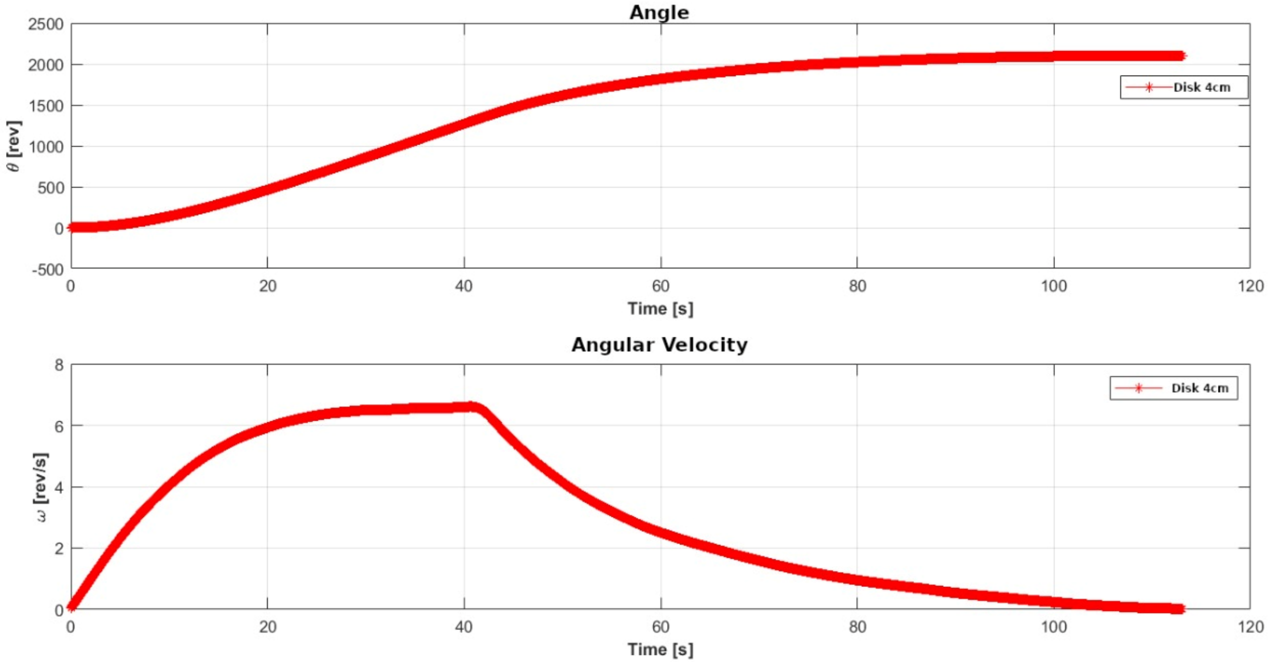


Measured field at 150 mm from the source



2. Results: Prototype 2.





- *Disk diameter: 40 mm*
- *Moment of inertia : 4.25 gr-cm^2*
- *Maximum Transferred Angular Momentum: 173.6 gr-cm^2/s.*
- *Applied Voltage: 100 Vp.*
- *Disk location: 40 mm from the source*
- *Estimated Acoustic Torque: Ta = 17.3 dyn-cm.*

4. Conclusions and Future Work

- *Several alternatives for vortex beam generation are available. They can be used in air and water.*
- *As long as the helical geometry vibrates in phase, without significant variations in its radiating surface, a good quality vortex is obtained.*
- *Sound pressure levels of up to 148 dB has been obtained at 4 cm from the source, at 180 Vp.*

4. Conclusions and Applications

- *Higher topological charges are posible by easily modifying the geometry of the radiating surface.*
- *Particle trapping and alignment are possible.*
- *Acoustical potential applications: ultrasonic propulsion, attitude control, modal analysis, mechanical sample characterization, among others.*

Thank You

joao.ealo@correounivalle.edu.co