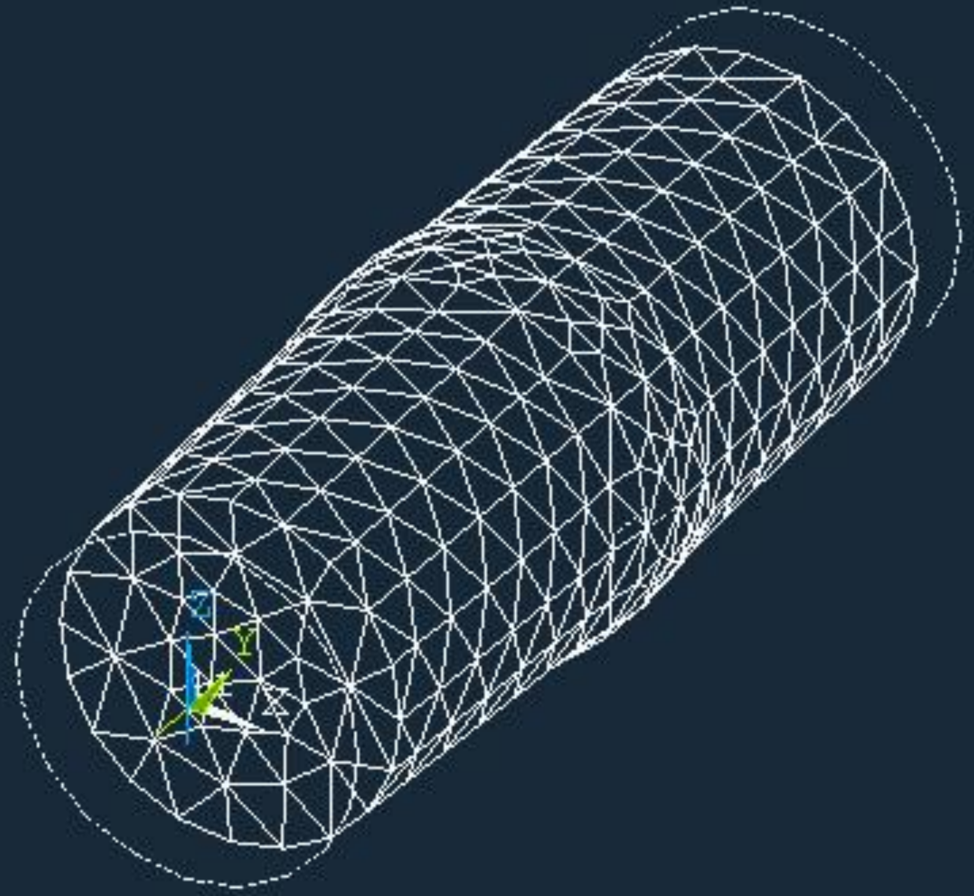
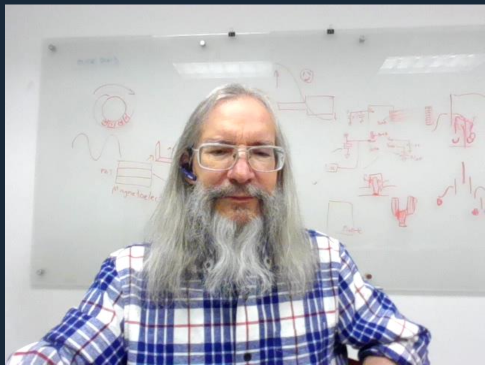
POWER ULTRASONICS

The History. The Mystery. The Science





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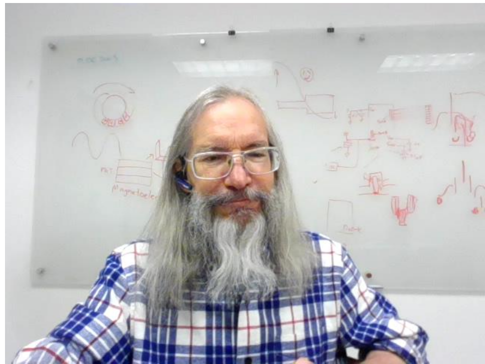
Power Ultrasonics

Piezo driven ultrasonic devices are used for a wide range of applications including;

- Sonar
- Flow metering
- Underwater communications
- Ultrasonic drills
- Ultrasonic cleaners
- Friction welding of both plastics and metals
- Cutting blades
- Dental scalers
- Fluid atomization.

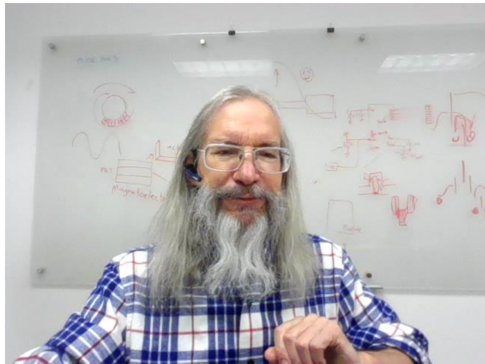


The Langevin Transducer

- Ultrasonics is a subject which is inextricably linked with piezoelectric technology. The Curie brothers Pierre & Jacques are credited with the discovery & 1888 publication disclosing the measurement of the piezoelectric effect in natural crystals.

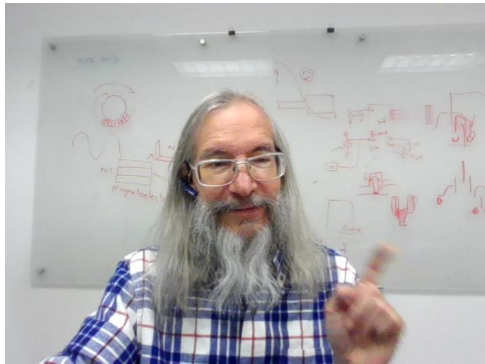
- At that time applications for piezoelectric crystals (mainly quartz) were limited to an electric weighing scale and a pico-ampere current source. Both passive devices. There were no transistors or vacuum tubes, no circuits of any kind to provide the AC drive signals that could have turned the crystals into sources of useful vibration.

But this guy…..



Paul Langevin

- Paul Langevin, really got ultrasonics off the ground.
- His work on submarine detection which began during WWI culminated in a 1920 patent application for a piezoelectric sonar device (not granted until 1941!) He combined new electronic vacuum tube circuits with natural quartz cuts to create a powerful ultrasonic device capable of echo detection of the presence and depth of submarines underwater – which we know as sonar.
- Work on sonar began during WWI when US & European allies had an urgent need for countermeasures against successful German submarine tactics. Several groups worked on differing acoustics approaches, however only Langevin demonstrated a practical working device. Sonar devices were not deployed until after the war however



Langevin’s Sonar Device

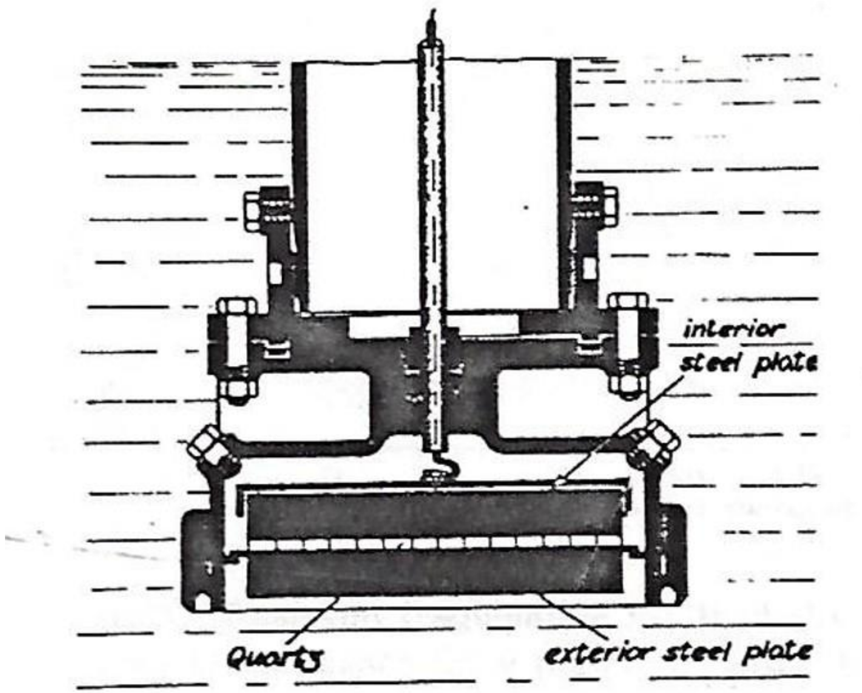
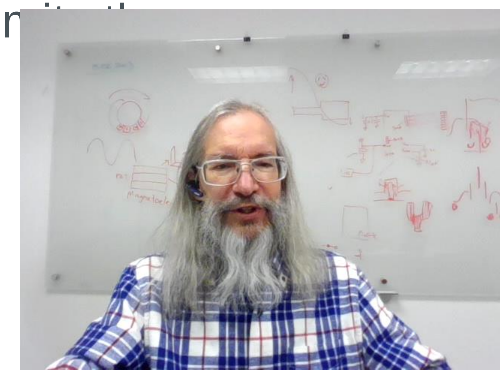


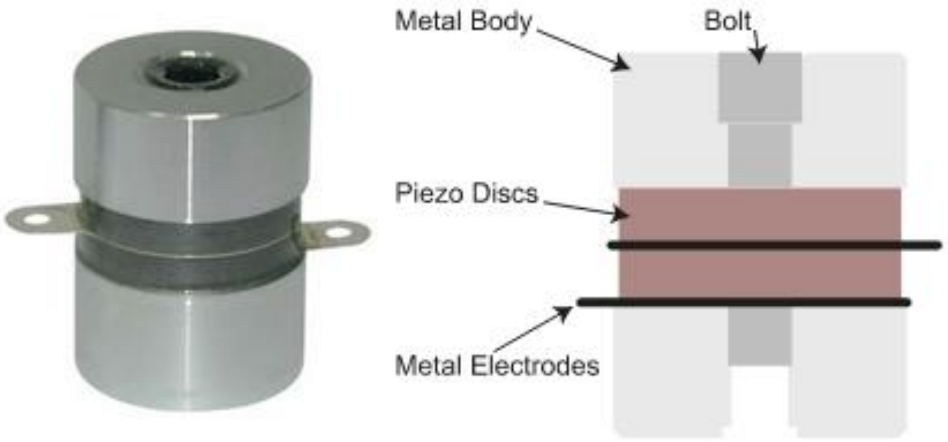
FIG. 1. Langevin’s transducer for depth finding.

- It’s worth looking at how Langevin’s device worked. It embodies the foundational insight that made ultrasonic applications possible:
- A mosaic of quartz crystals (about 10 cm square & 1.5 cm thick) were sandwiched between two large diameter thick steel plates – held together by a hard glue.
- A high voltage AC is applied between the two steel plates exactly at the resonant frequency. This induces an electric field in the quartz crystals which expand & contract vertically, pushing/pulling the steel plates.
- The plate in contact with water transm
pressure wave.



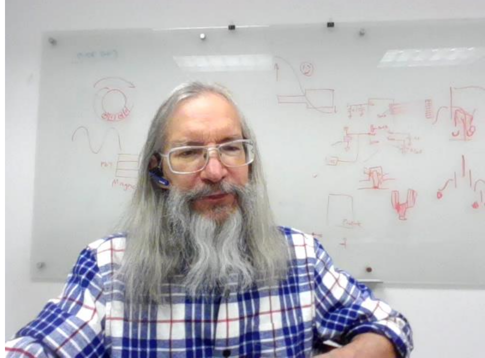
The Langevin Transducer

The term “Langevin Transducer” is now used to describe any piezo-driven longitudinal resonator constructed by sandwiching piezo elements between two plates, commonly using a center bolt.



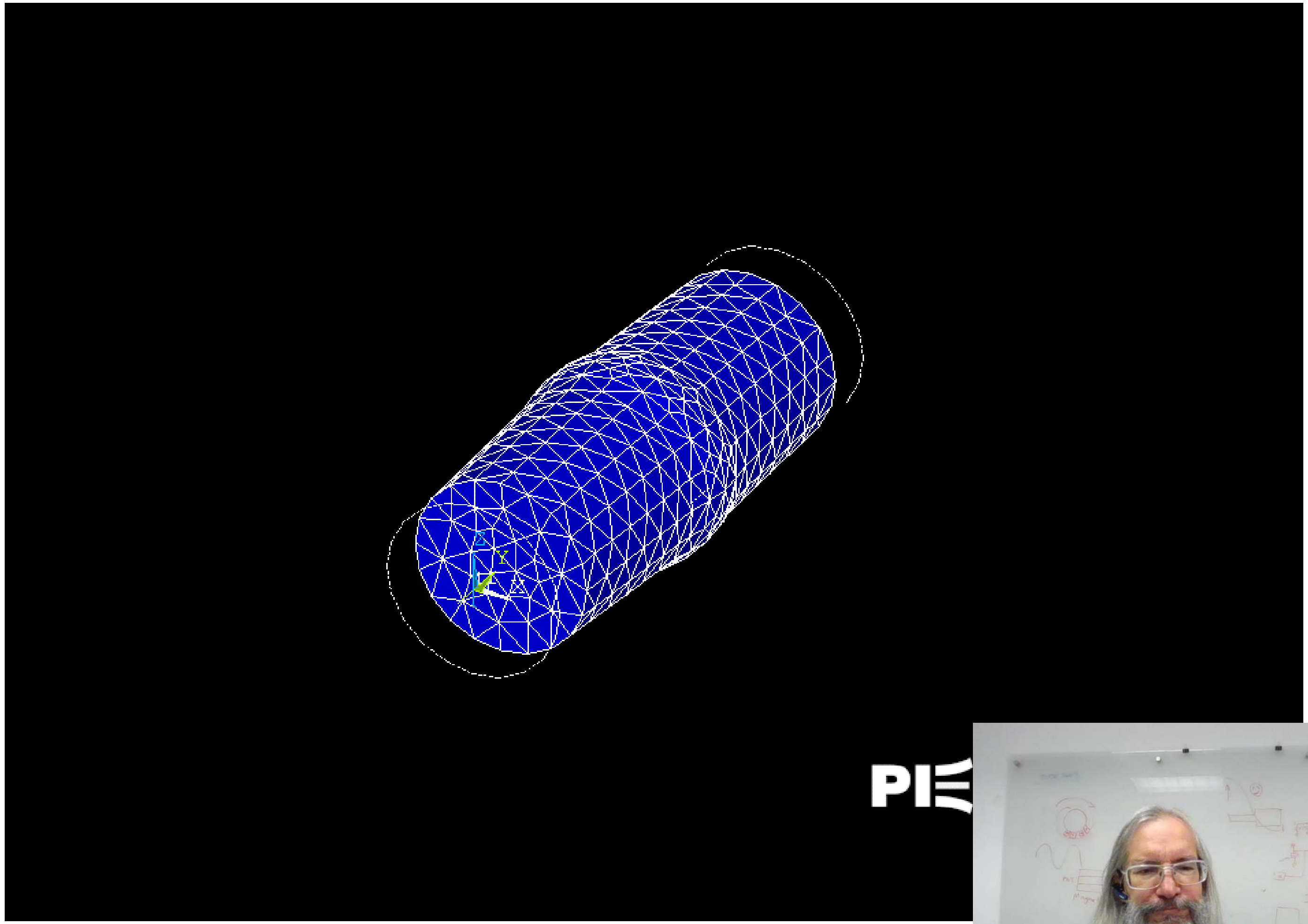
Bolt-clamped Langevin transducer with two piezoelectric layers (www.mmech.com)

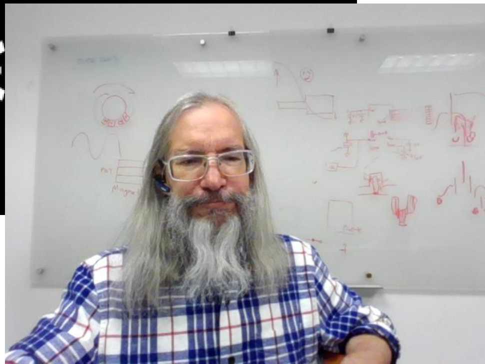
- Why are there two piezo disks?
- Why the bolt?
- What is this transducer good for?
- What exactly do the end plates do?



The Ultrasonic Engine

- By itself, a simple Langevin transducer undergoes motion like this

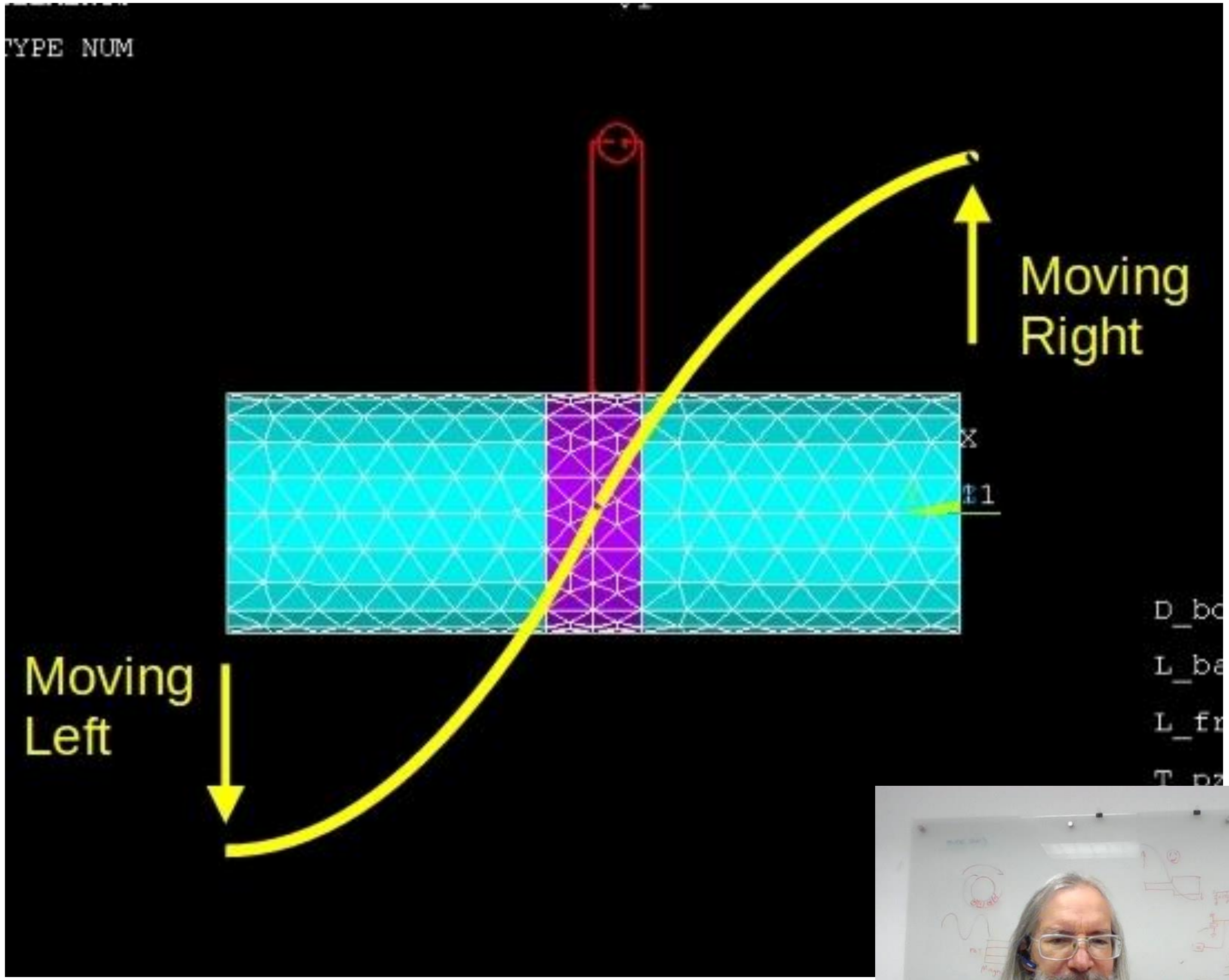


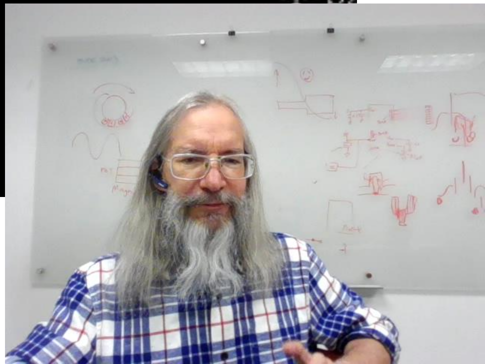


The Ultrasonic Engine

- The Langevin transducer is often depicted as a half-wavelength resonator with standing wave motion. The center of mass is the 'standstill point' or vibrational node with the two ends moving with equal amplitude in opposite directions.

- As a 'standalone' this transducer has limited uses, however it can serve as a very effective 'engine' that drives attached vibratory power trains (transmissions if you will) for many many applications





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The Ultrasonic Engine – Two Variants

Ultrasonic Horn Transducer

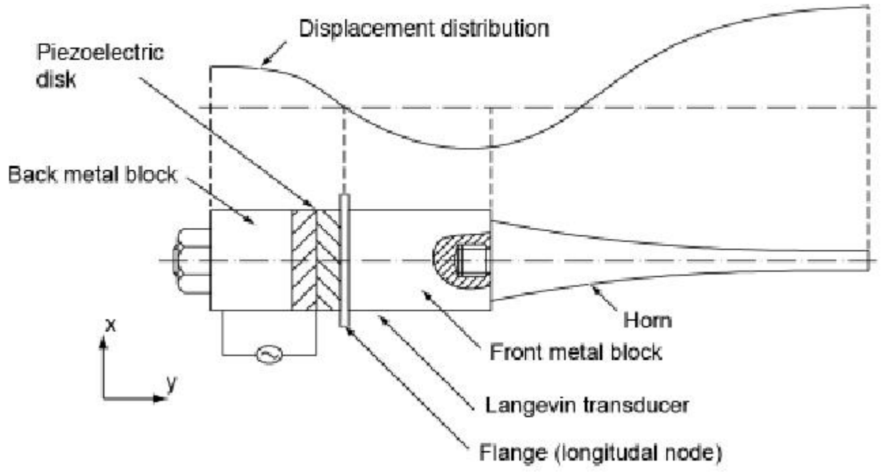
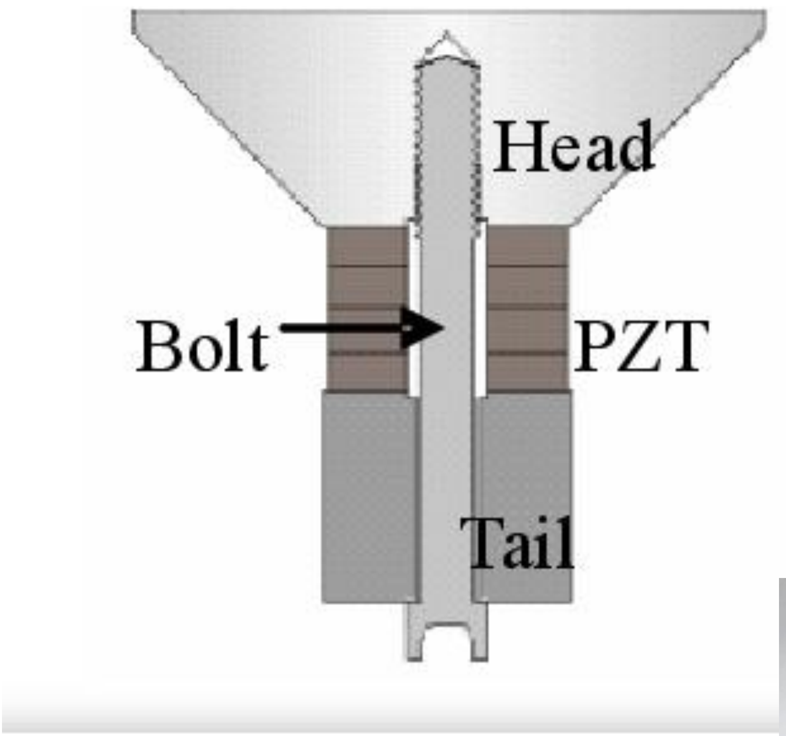
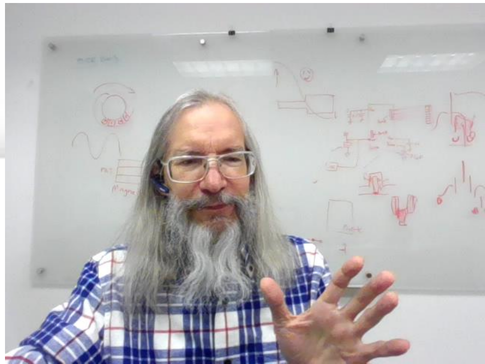


Fig. 1. Schematic of a horn and a Langevin transducer.

(credit: "DESIGN OF AN ULTRASONIC STEEL HORN WITH A BÉZIER PROFILE")

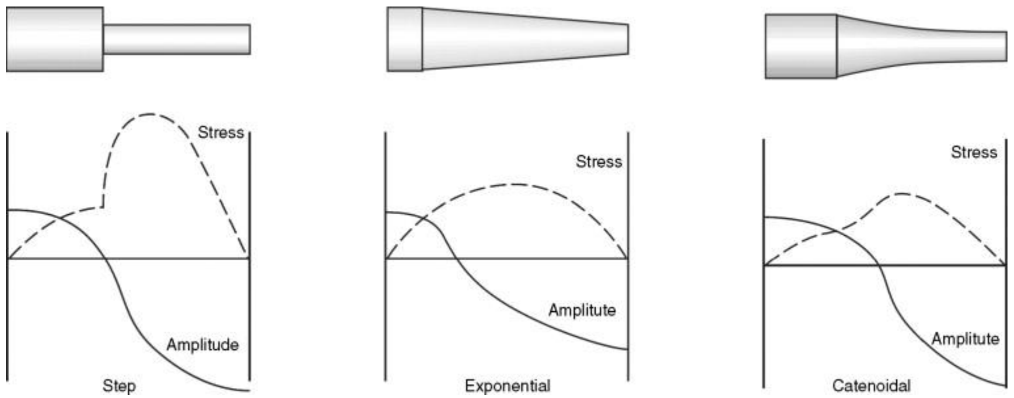
Tonpilz Transducer



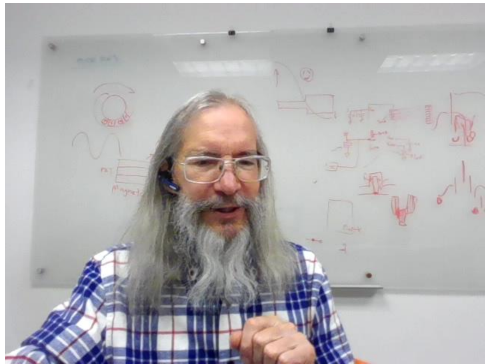


The Ultrasonic Horn 'Transmission'

- A tapered horn is bolted to one end of the engine. It is a mechanical transformer – exactly analogous to an electronic transformer. It transfers the low-velocity-high-force of the Langevin 'engine' to high velocity-low-force at the tip.

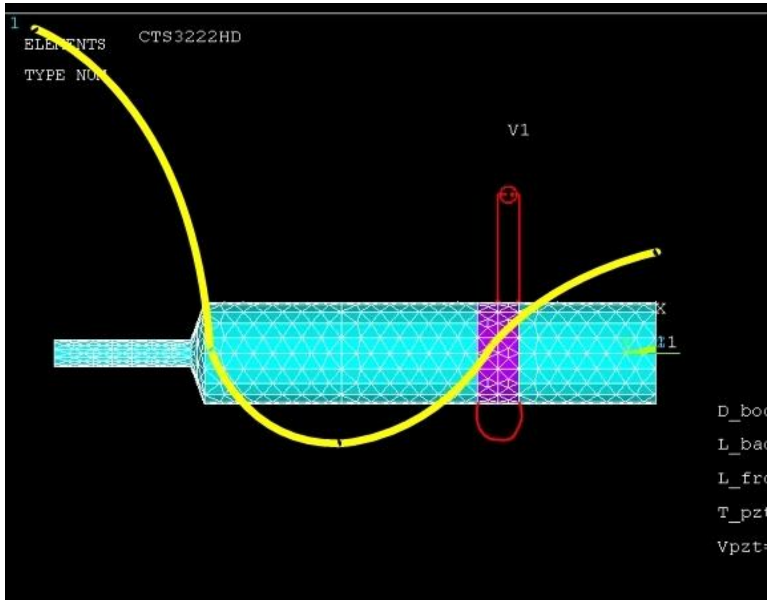


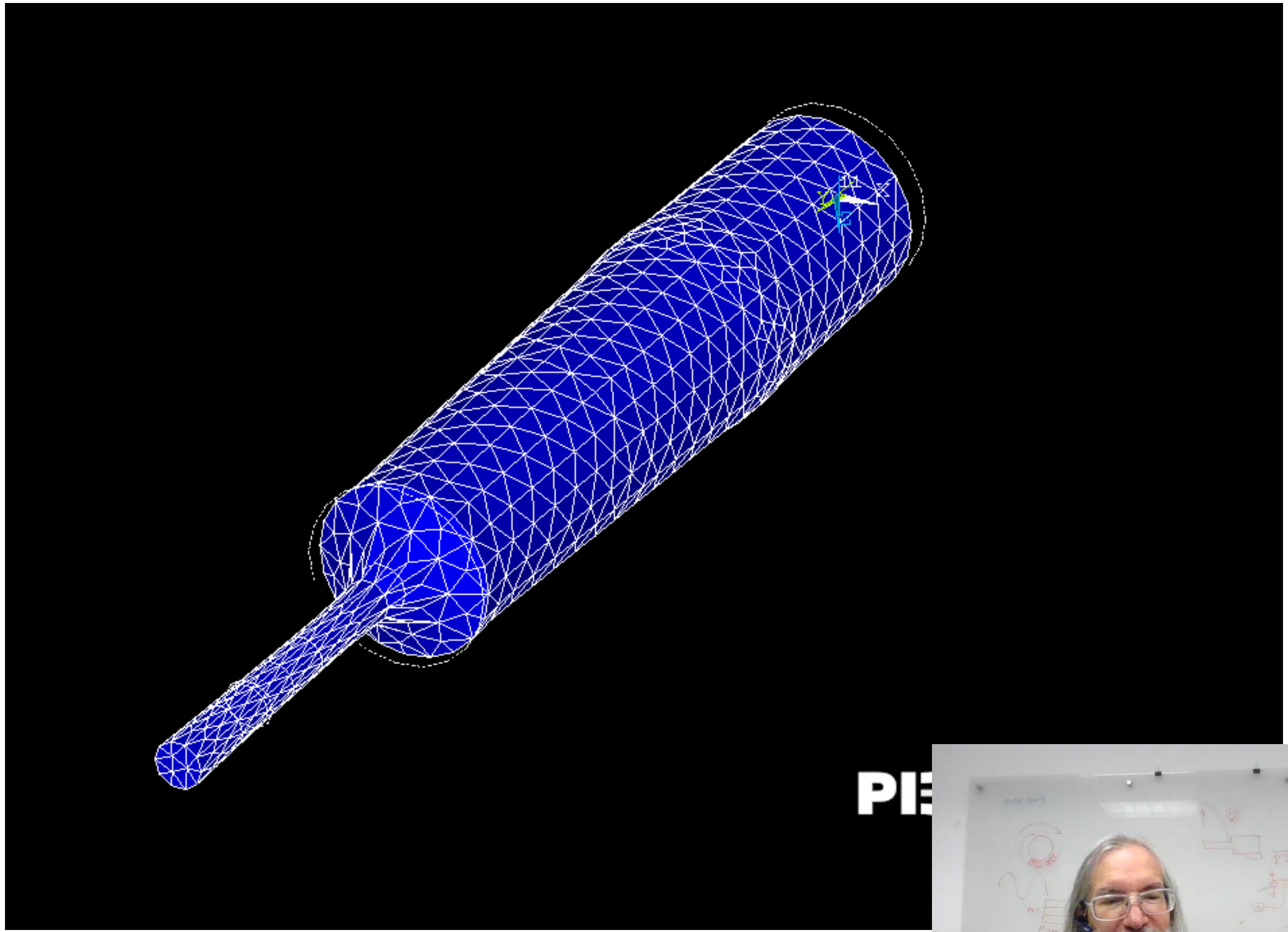
- The geometry of the horn determines the degree of motion amplification, with the step horn achieving the highest velocity amplification. It can be approximated as a half-wave resonator having the same resonant frequency as the Langevin

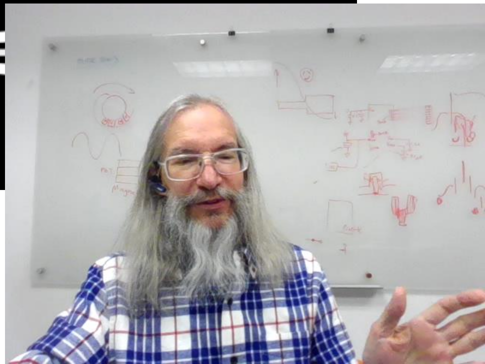


Ultrasonic Horn in Action

- Huge gain in tip motion is due to conservation of momentum!



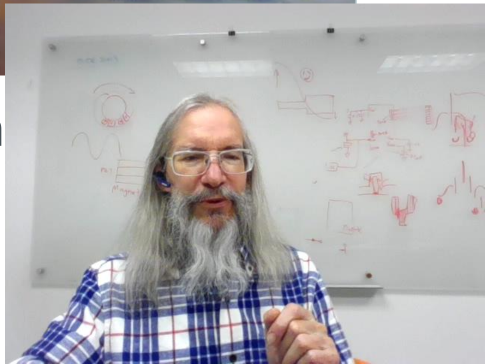




Ultrasonic Horn Shapes

- There is and infinite variety of possible horn shapes with special purposes, i.e. geometries that are ‘application specific’. The key to each design is that it converts the steady-state vibration at the face of the ‘engine’ to a steady-state vibration on the face of the horn’s end to a motion and cross-sectional shape that accomplishes the task.

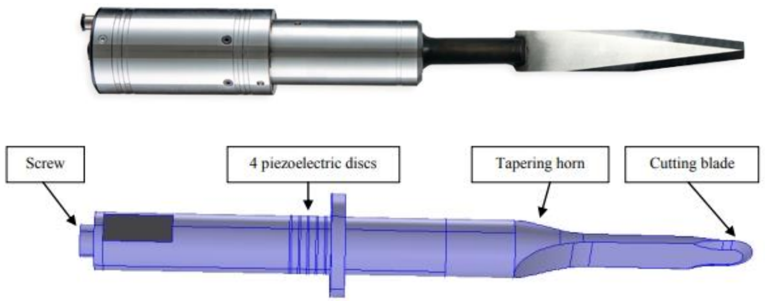
(credit: sharpertek.com/ulho.htm



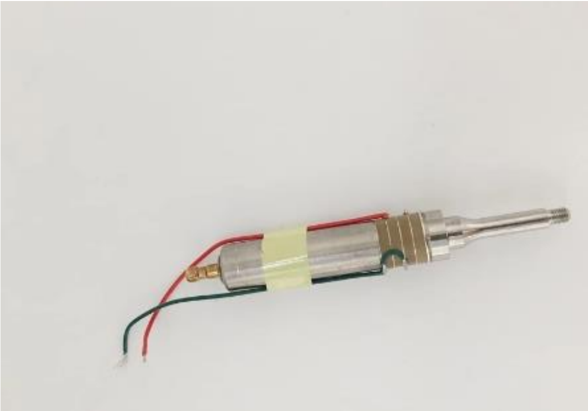
The Langevin Transducer Applications

Mechanical Power Concentration

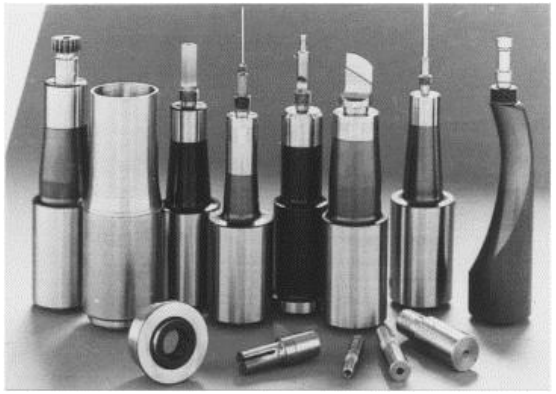
Ultrasonic Plastic Welder
Ultrasonic Cell Disruptor/Homogenizer



Ultrasonic Knife
(credit: sonotec.com/en/product/cutter/)

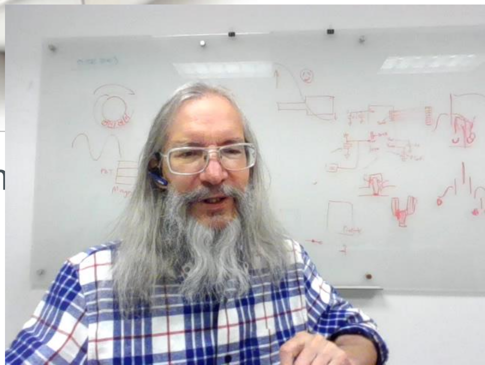


Dental Plaque Scaler



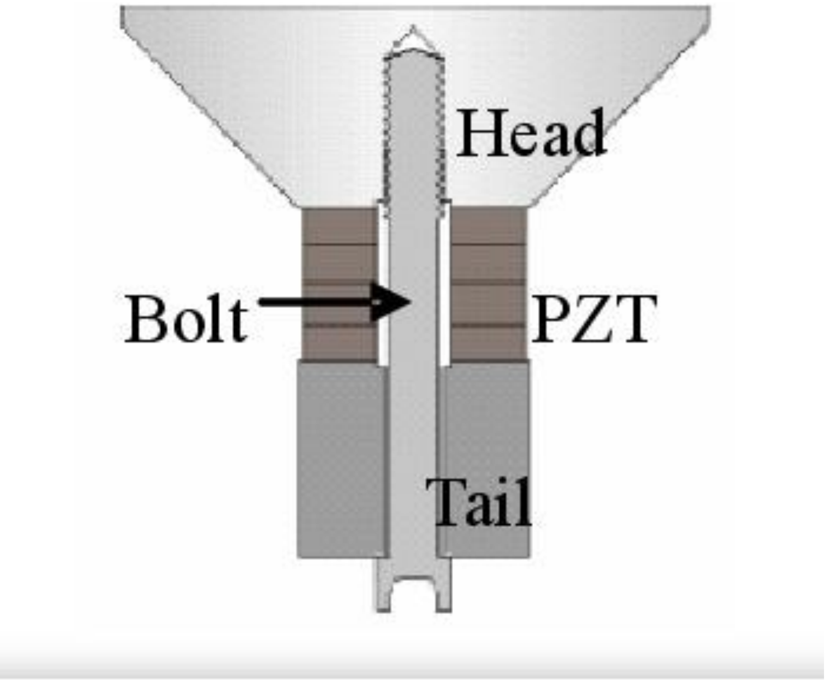
(credit: “Review on ultrasonic machining” T.B. Thoe et al, 1998)

Flow Through

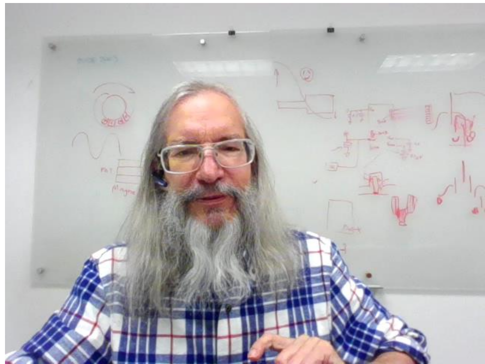


The Tonpilz ‘Transmission’ – aka Acoustic Mushroom

- Low density, large area Head (Alumium or Titanium)
- High density, heavy Tail (Steel)
- Symmetry is of Langevin engine is abandoned
- Area of Head is large
- Higher efficiency
- This adaptation is for broadcasting powerful acoustic waves into liquid media.
- Matches PZT mechanical impedance to liquids better than simple symmetric Langevin.

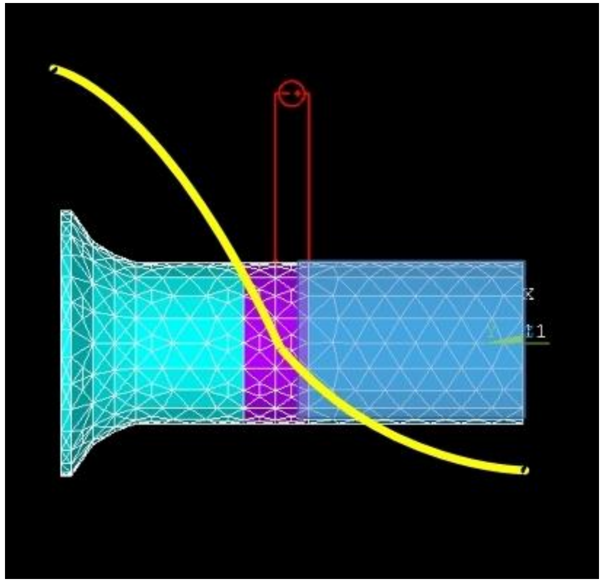


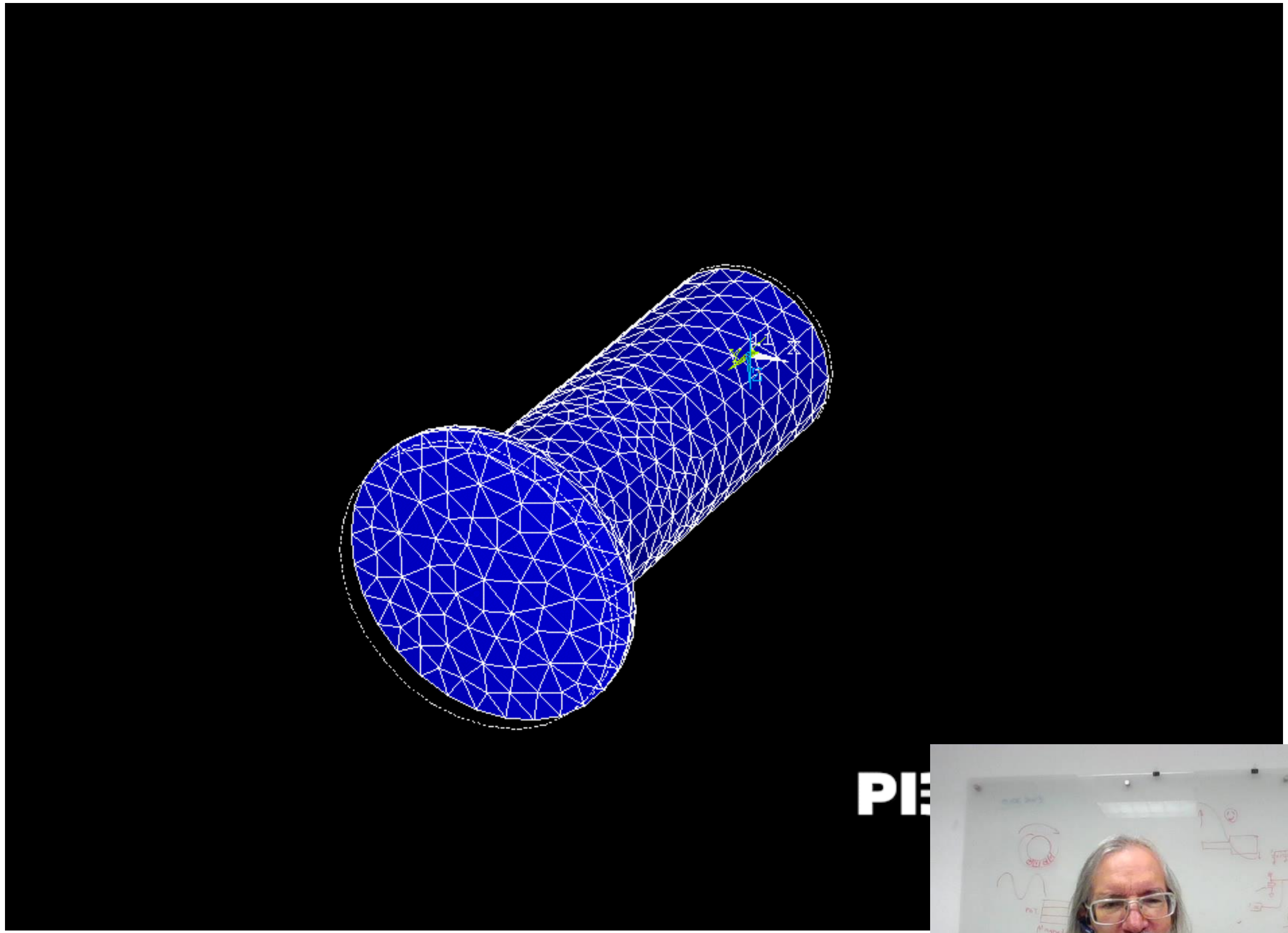
NOTE: There was a Monsieur Langevin, but there was no Herr Tonpilz

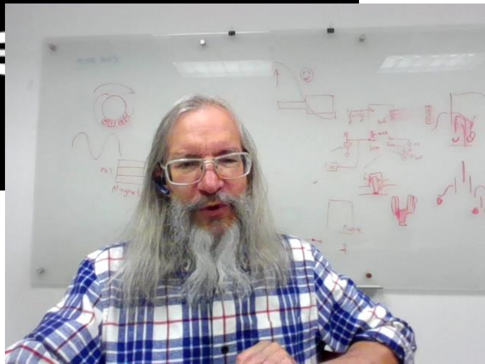


Tonpilz in Action

- Lion’s share of motion happens at the front end because the heavy back end acts as an inertial anchor.
- Conservation of momentum again!

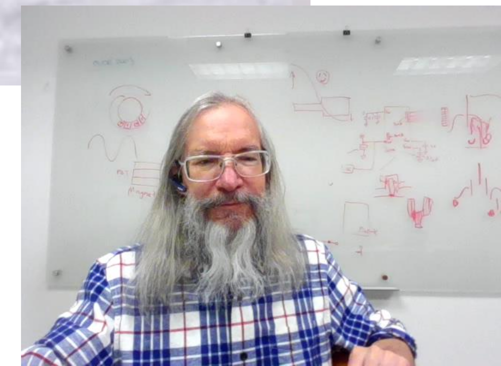






Tonpilz Horn Applications

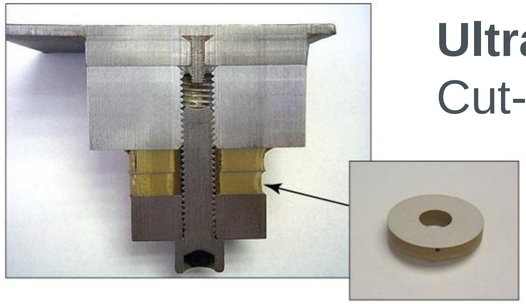
Credit: ultrasonic-resonators.org



Tonpilz Transducer Applications

Acoustic Transmit/Receive in Fluids

Tonpilz Type
Ultrasonic Cleaner Module



Ultrasonic Cleaner Module,
Cut-away view of Bolt-On

Tonpilz Sonar Transducer

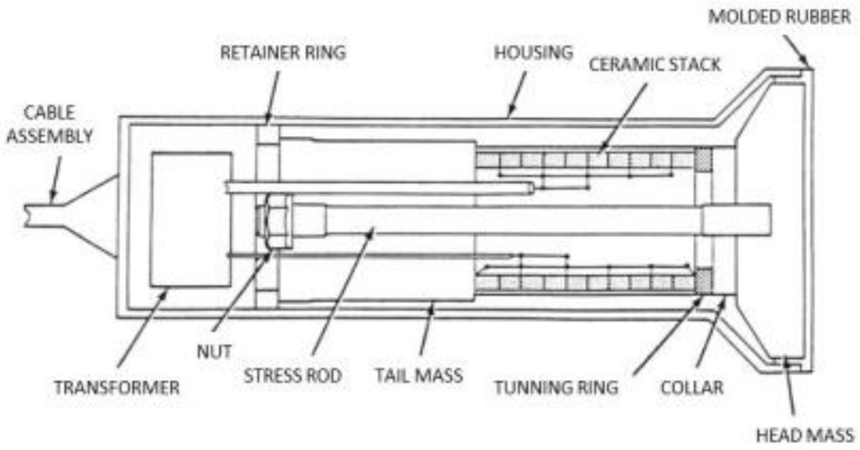
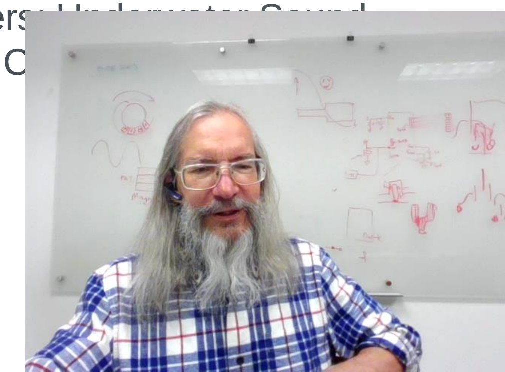


Figure 7. Tonpilz Transducer[21]

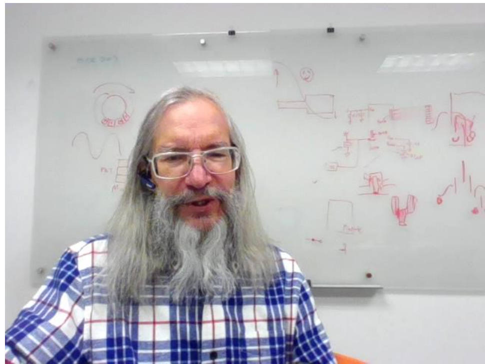
(credit: Properties of Transducers
Sources & Receivers, Stephen C



Favorite Tonpilz Transducer

- The ‘shared tail mass’ Tonpilz transducer
- Omni-directional planar broadcast pattern

(credit: texasacoustics.org, University of Texas, Austin



Resources/References

Ultrasonics.org

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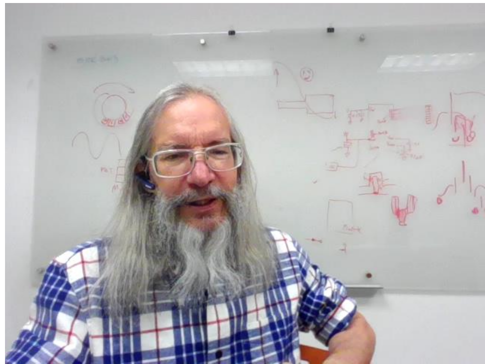

Thank You!

- Thank you for taking the time to learn a little about a corner of the power ultrasonics universe!
- **If you have any questions, please feel free to reach out to us at piezo.com**