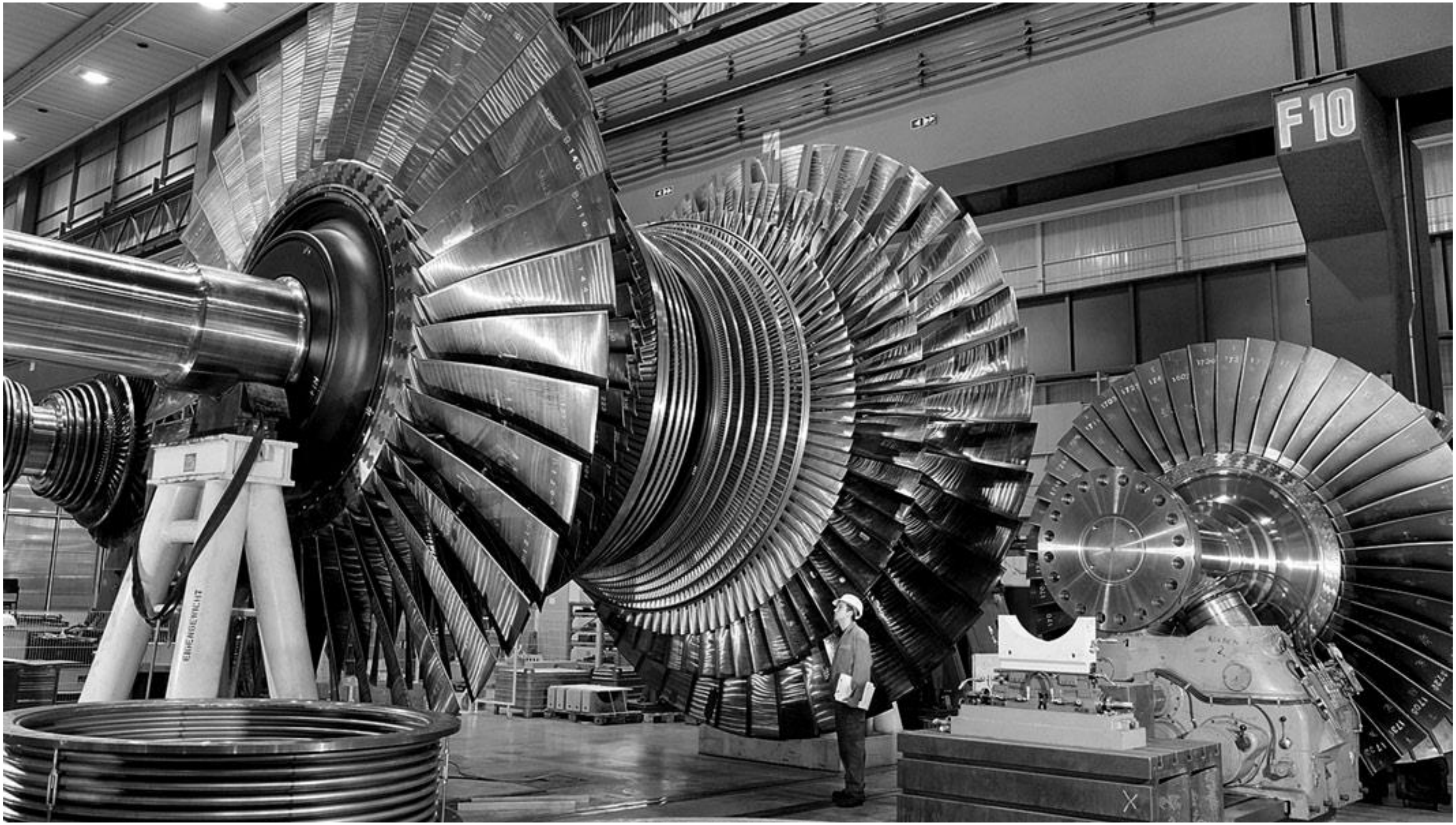


# Piezoelectric SAW (Surface Acoustic Wave) Device with Simulated Poling Condition

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Meggitt A/S, Kvistgaard, Denmark

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COMSOL CONFERENCE 2016 MUNICH

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# Outline



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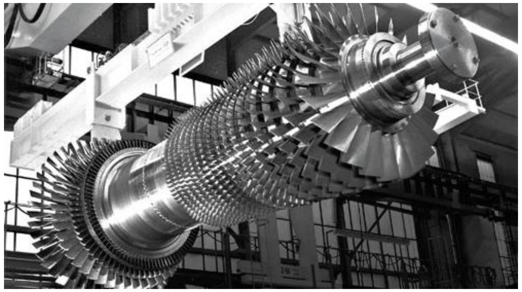
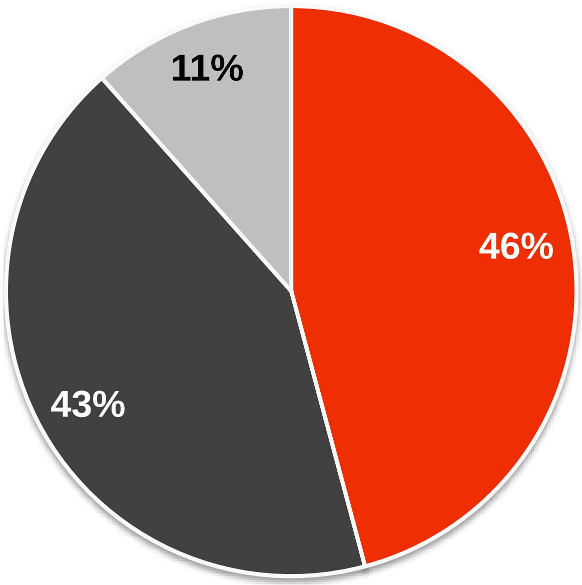
# 1 Company introduction





# Meggitt - overview

- Provides high technology products and systems for the aerospace, defense and other specialist markets, including: medical, industrial, energy, test and automotive
- 60 years experience in extreme environment engineering
- Annual sales (2012), £1,605.8 million, 10% growth in comparison to 2011
- Listed on London Stock Exchange (MGGT)
- FTSE100 company




OE 52% / Aftermarket 48%

- Civil aerospace
- Military
- Energy and other

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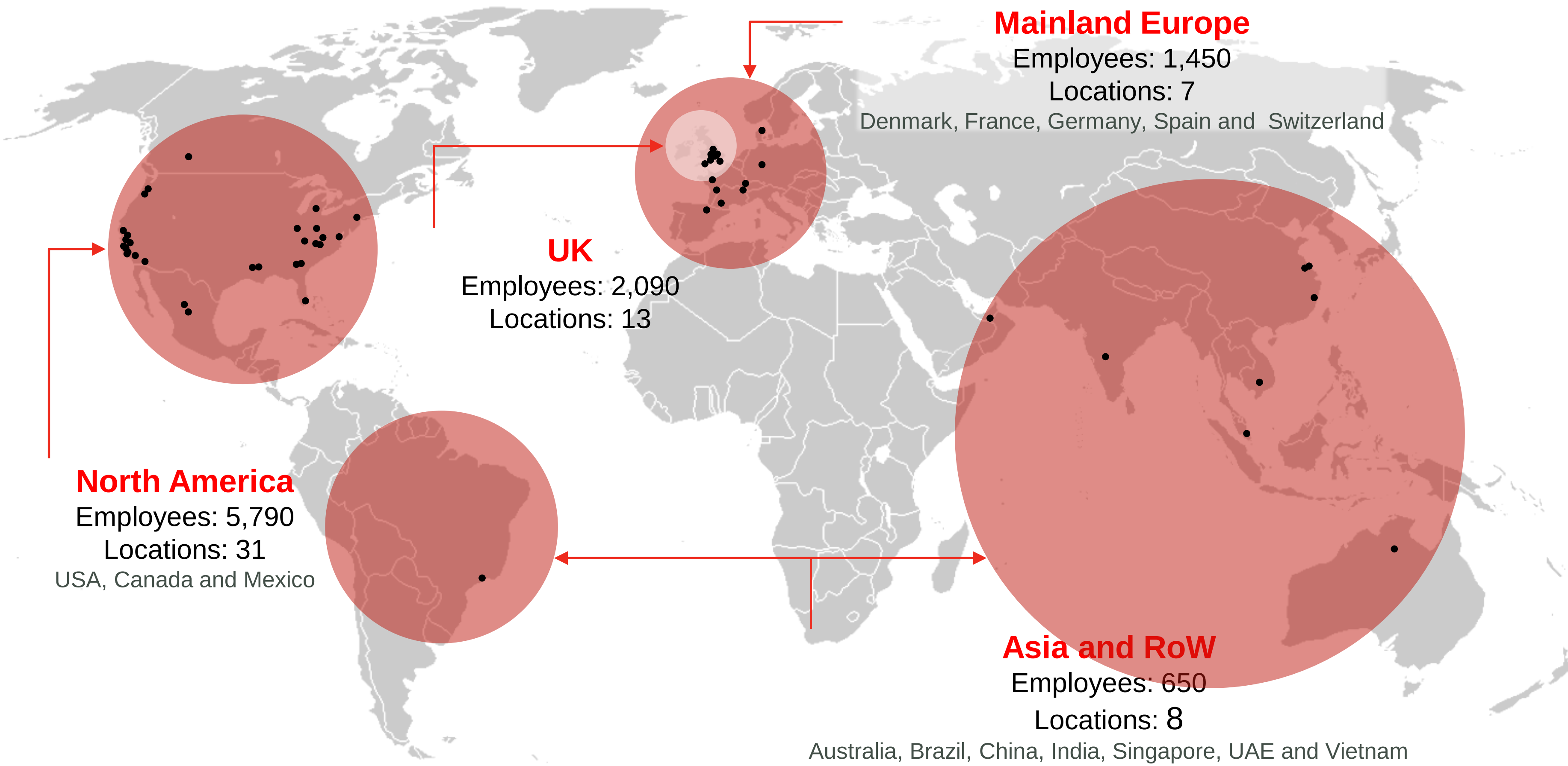
# A global presence

**Over 10,000**
**employees worldwide**



# Meggitt Sensing Systems Denmark

- Meggitt A/S is a manufacturer of piezoelectric materials, components, devices
- 2-3 million units produced annually
- Major markets
  - Medical ultrasound
  - Underwater acoustics
  - Acceleration sensors
  - Flow meters
  - Energy Harvesting

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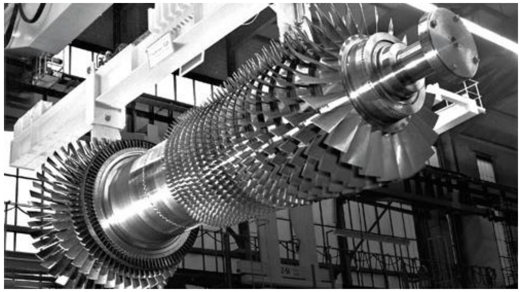
# 2 | Motivation

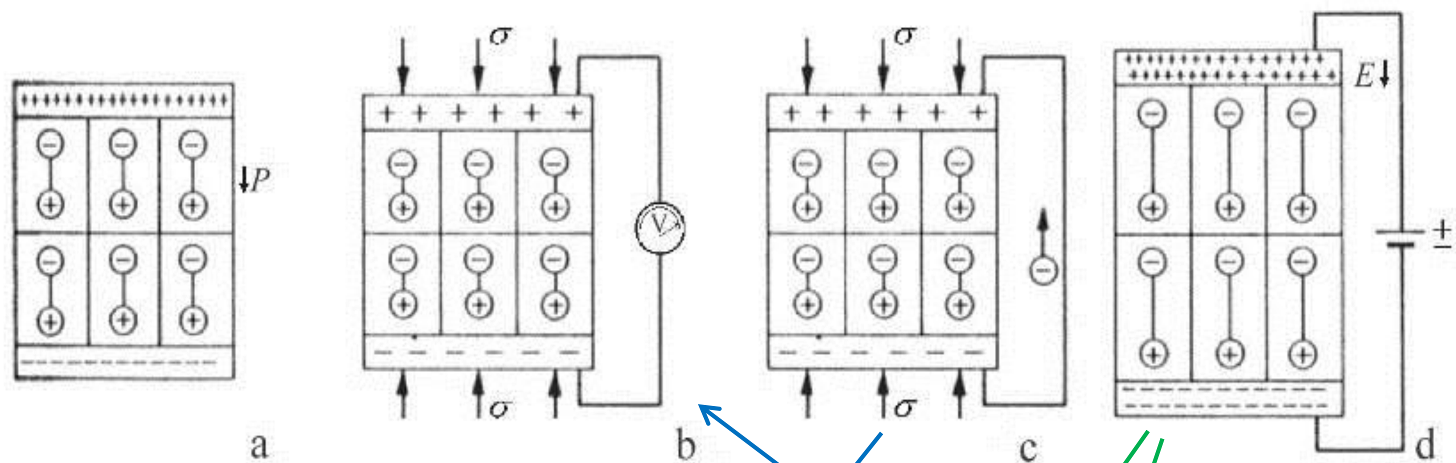




# The piezoelectric effect

*Piezoelectricity*: the formation of electricity due to mechanical stress – or the formation of mechanical stress caused by an electric voltage.

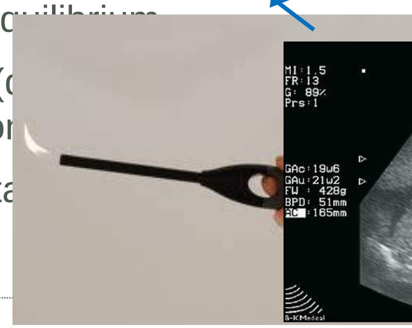
Discovered by Pierre & Jacques Curie in 1880.

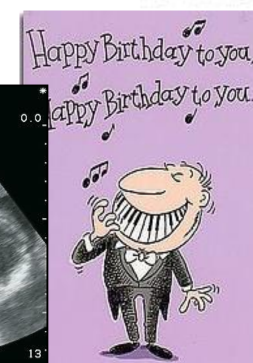



(a) Eq

(b-c) Mechanical excitation (c
conditio

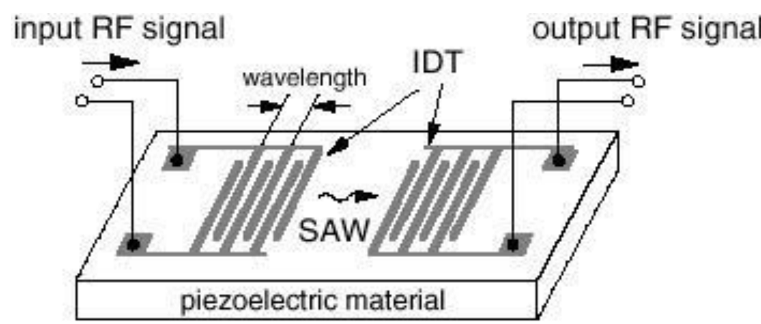
(d) Electrical excita





# Surface acoustic wave (SAW) devices

- Surface acoustic wave devices
  - Composed of a piezoelectric substrate where two interdigital transducers (IDT) are deposited
- Application fields
  - Surface sensitive sensors
    - Physical sensors
    - Chemical/biological sensors
- Common materials seen in literature
  - Piezoelectric crystals (Natural polarization)
- Meggitt as a piezoceramic manufacturer
  - Replace crystals with piezoceramics
  - Higher piezoelectric coefficients ($d_{33}$)
  - Cheap manufacturing
  - More advanced polarization



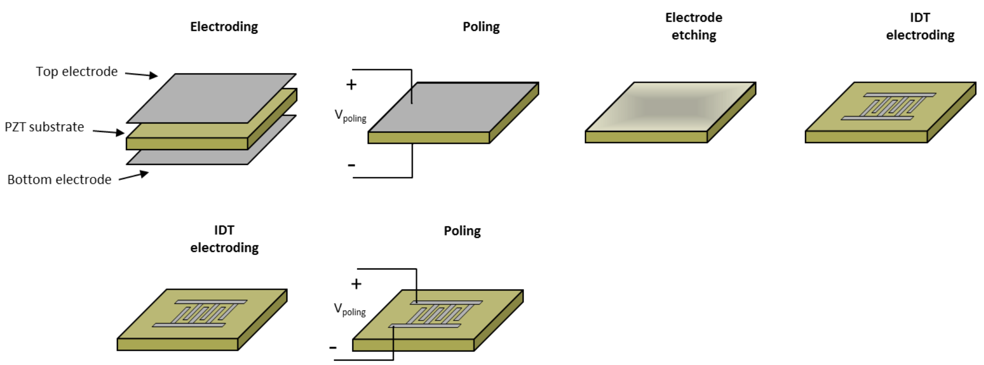

**Diamond-based surface acoustic wave devices**
H Nakahata et.al. 7 February 2003

*http://en.wikipedia.org/wiki/File:Tourmaline.xtal.750pix.jpg*

# Our challenges on SAW devices

» Produce the same product as SAW devices, i.e. a SAW device based on a uniform orientation polarization.
  - Electroding – normally a high temperature process (> $T_c$)
  - Poling steps need to be done after electroding
  - Remove the electrode for poling and redeposit SAW electrodes, without de-poling the original polarization

» We propose a different solution
  - Interdigital poling
  - Easier manufacturing
  - But will it work?



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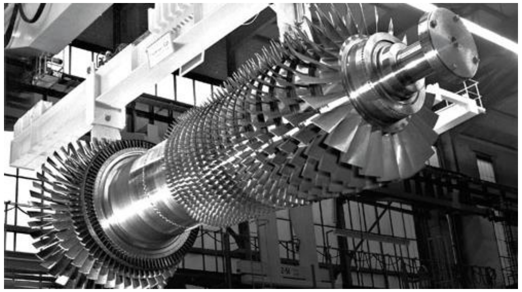
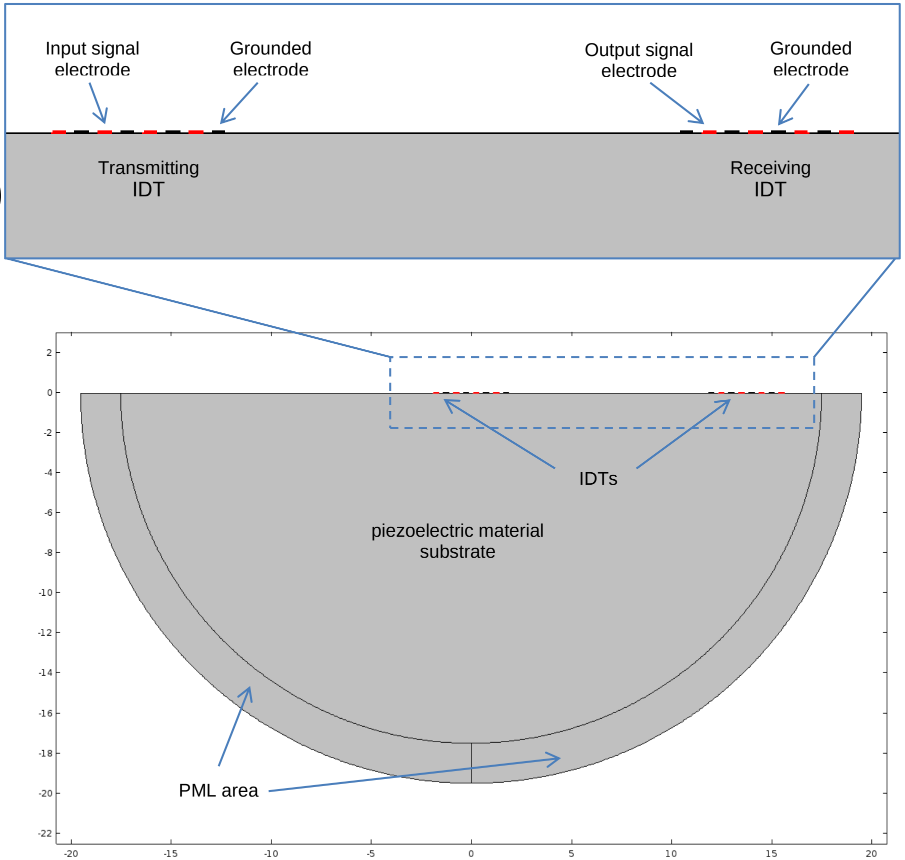
# 3 Uniform orientation polarization SAW





# Single orientation polarization SAW
# The COMSOL model

- Physics – Piezo device (solid mechanics  and electrostatics)
- Frequency domain (1MHz – 3 MHz)
- 2D – IDT as boundary lines
- Material – Pz27 (soft PZT material)
- <u>Z direction polarization</u>
- PML
- Mechanical damping (0.2 %)
- Electrical boundary conditions
  - Ground
  - Terminal (1 V) on input electrods
- Mesh - At least 8 mesh points per wavelength







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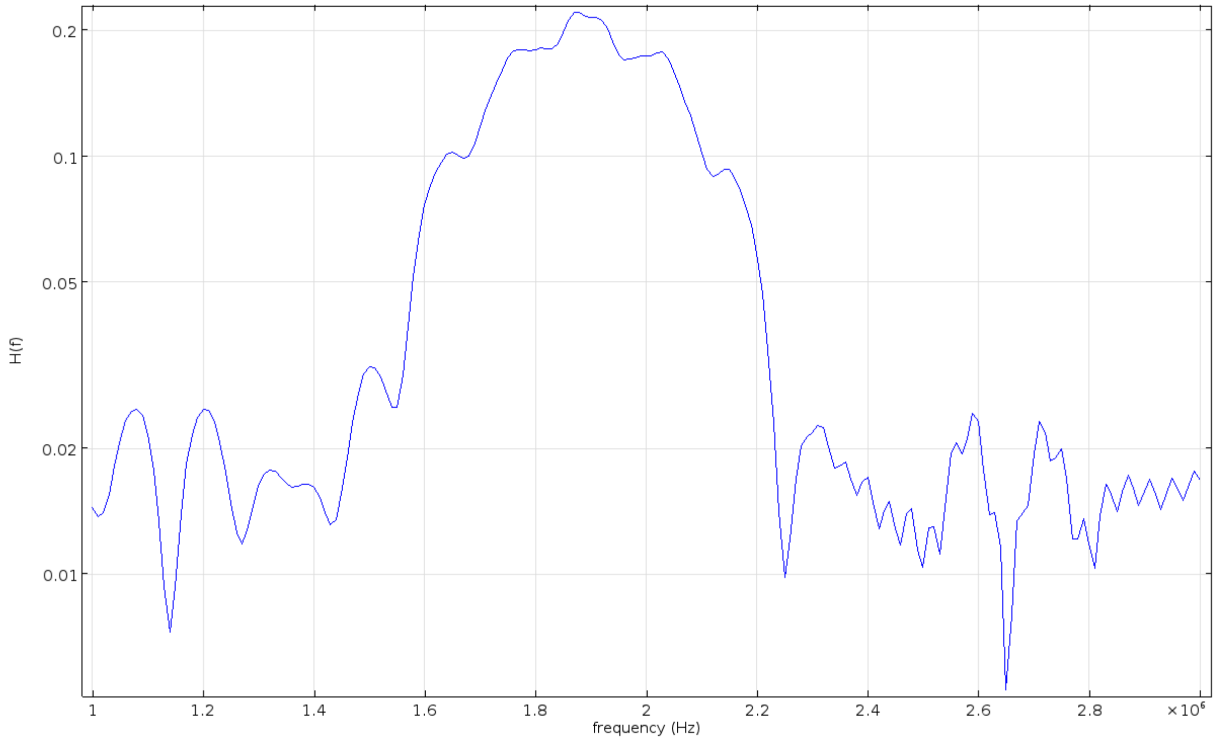
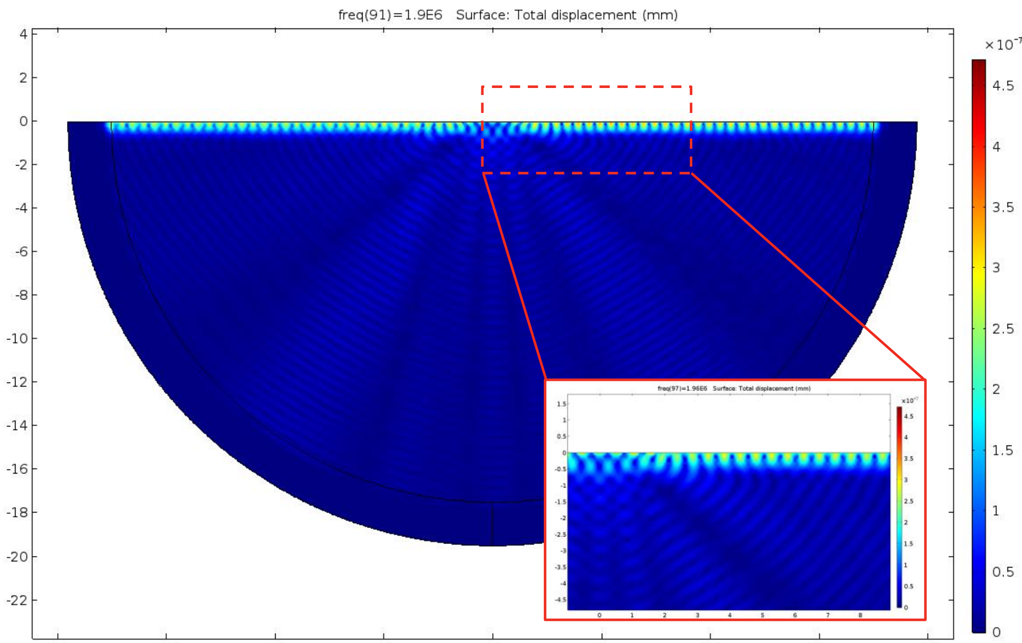
# Results

» Frequency response module $|H(j\omega)| = |\frac{V_{out}(j\omega)}{V_{in}(j\omega)}|$

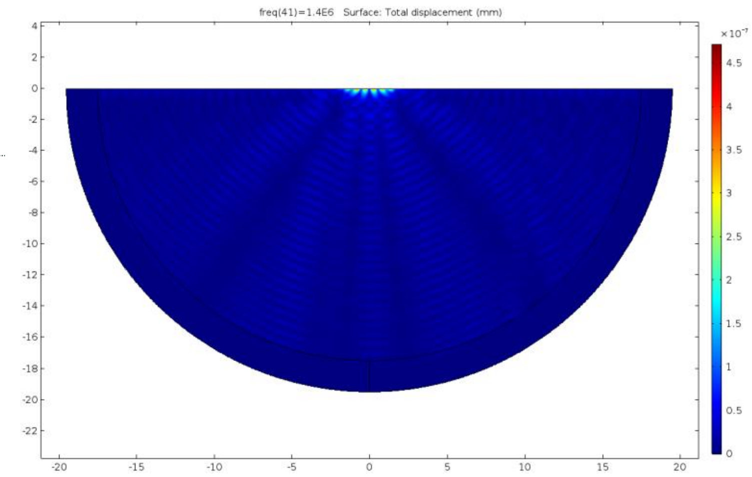


# Results

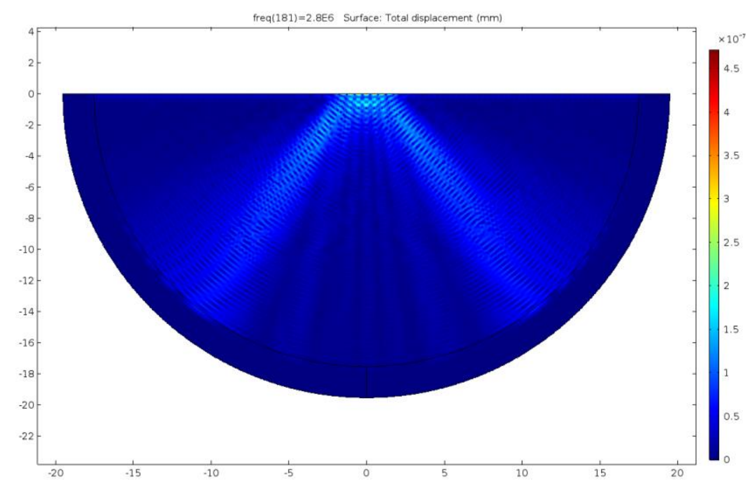
» SAW wave at different frequencies




1.9 MHz




1.4 MHz




2.8 MHz

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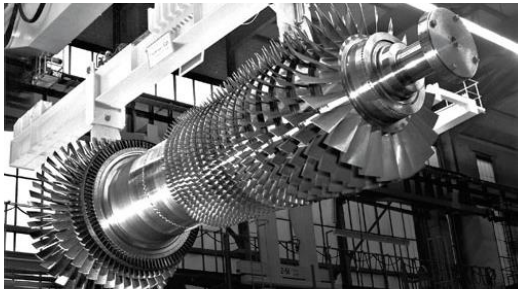
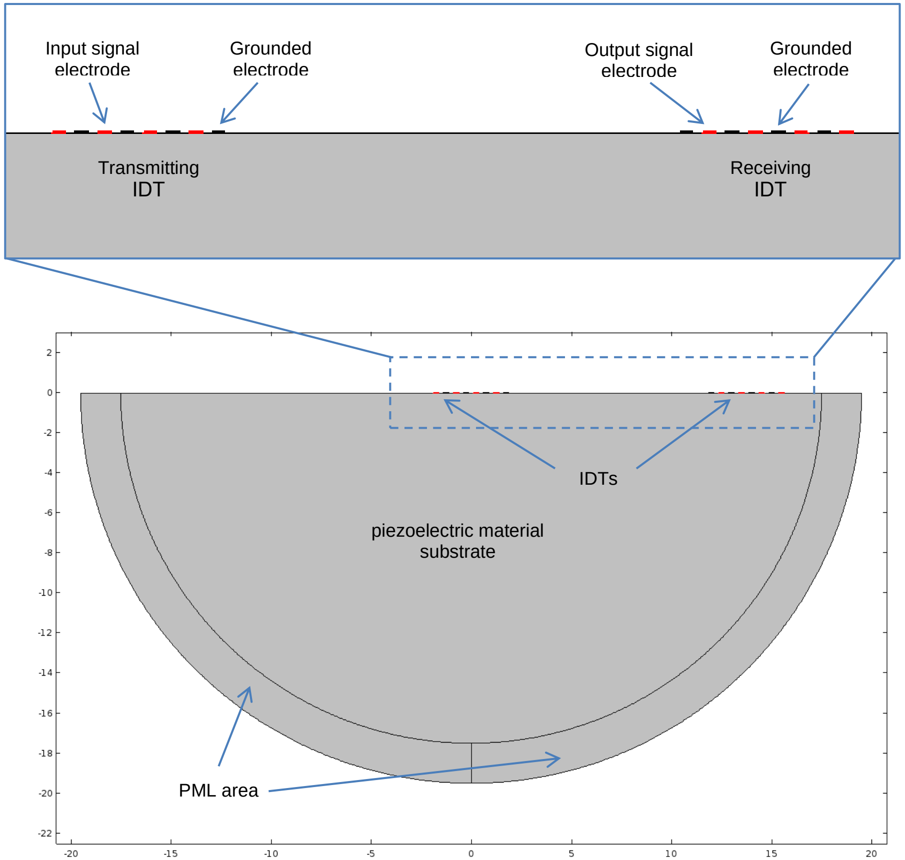
# 4 | Interdigital polarization SAW



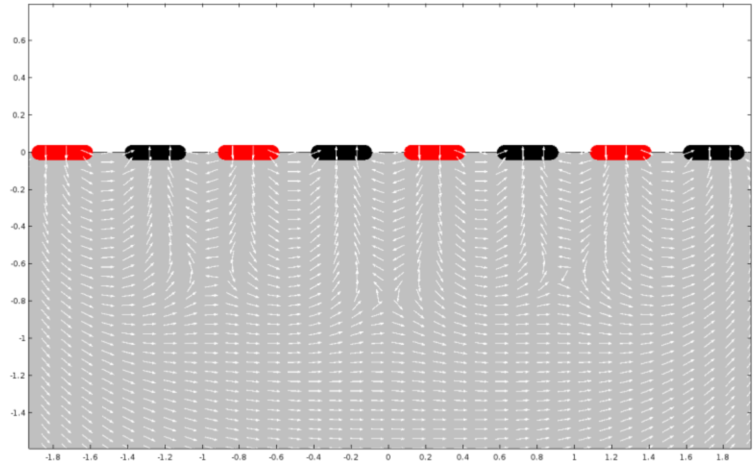
# Interdigital polarization SAW
# The COMSOL model

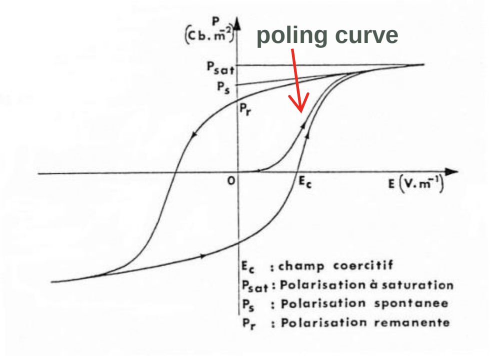
- Physics – Piezo device (solid mechanics  and electrostatics)
- Frequency domain (2.5MHz – 4.5 MHz)
- 2D – IDT as boundary lines
- Material – Pz27 (soft PZT material)
- <u>Interdigital polarization</u>
- PML
- Mechanical damping (0.2 %)
- Electrical boundary conditions
  - Ground
  - Terminal (1 V) input electrode



# Simulating the poling process to produce IDT polarization

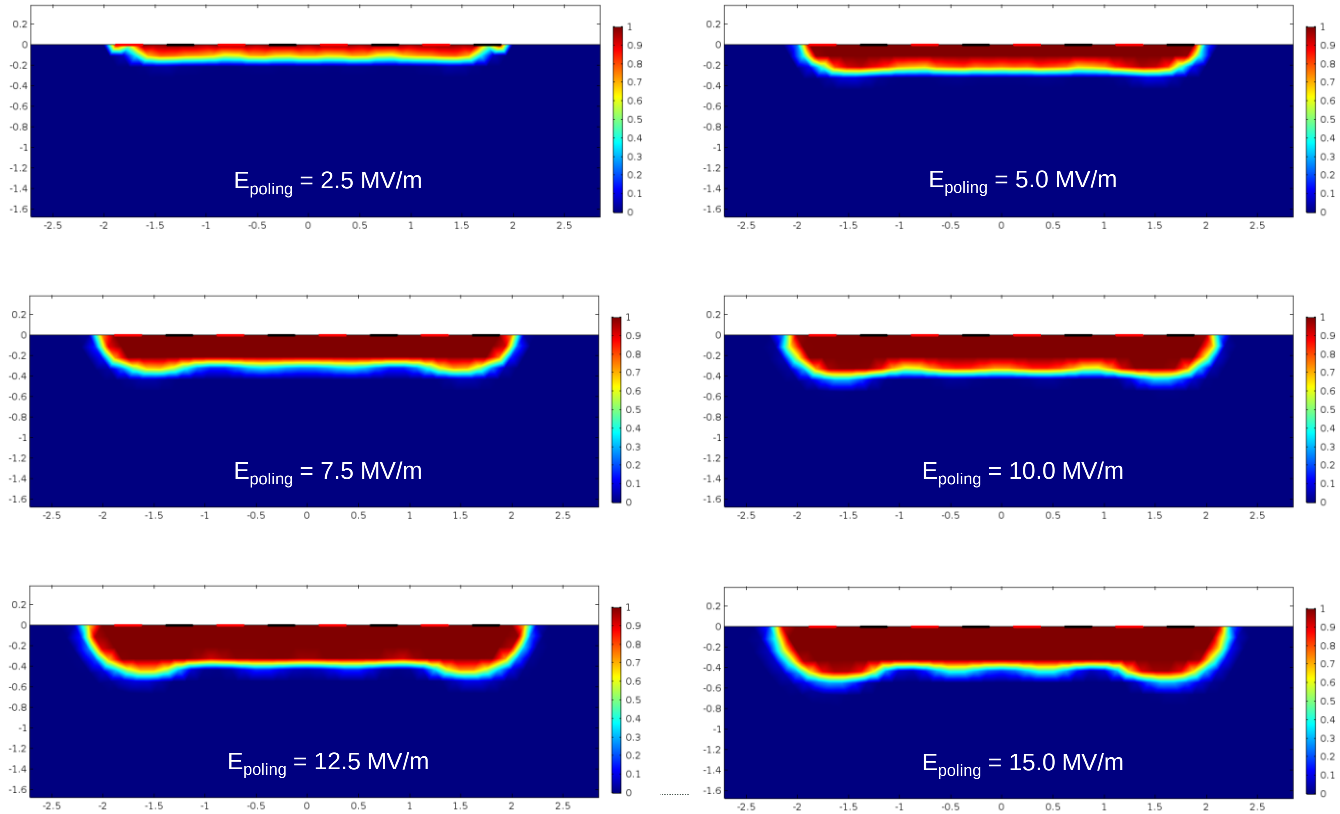
- IDT polarization
  - Introduction of a stationary study to simulate the poling before the frequency domain study
  - High poling voltage on the terminals (red) and ground on the other (black)
  - Determine the electrical field caused by the applied poling voltage
  - The field magnitude determines piezoelectric coefficient with respect to the virgin curve of the material



# Simulating the poling process to produce IDT polarization

» Different poling voltages (standardized fields)



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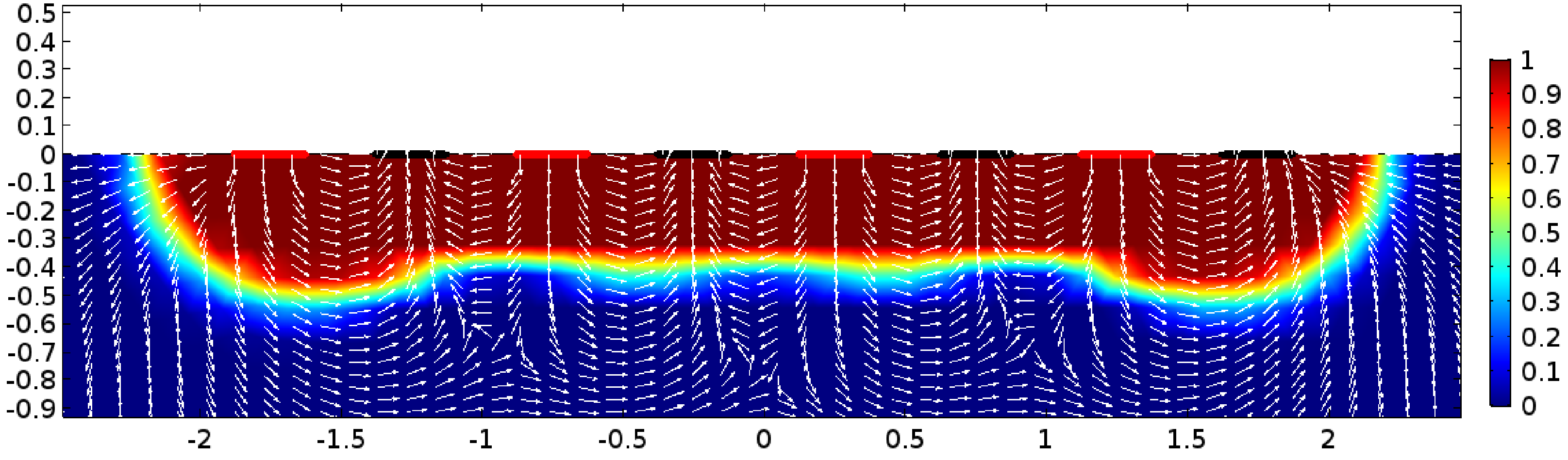
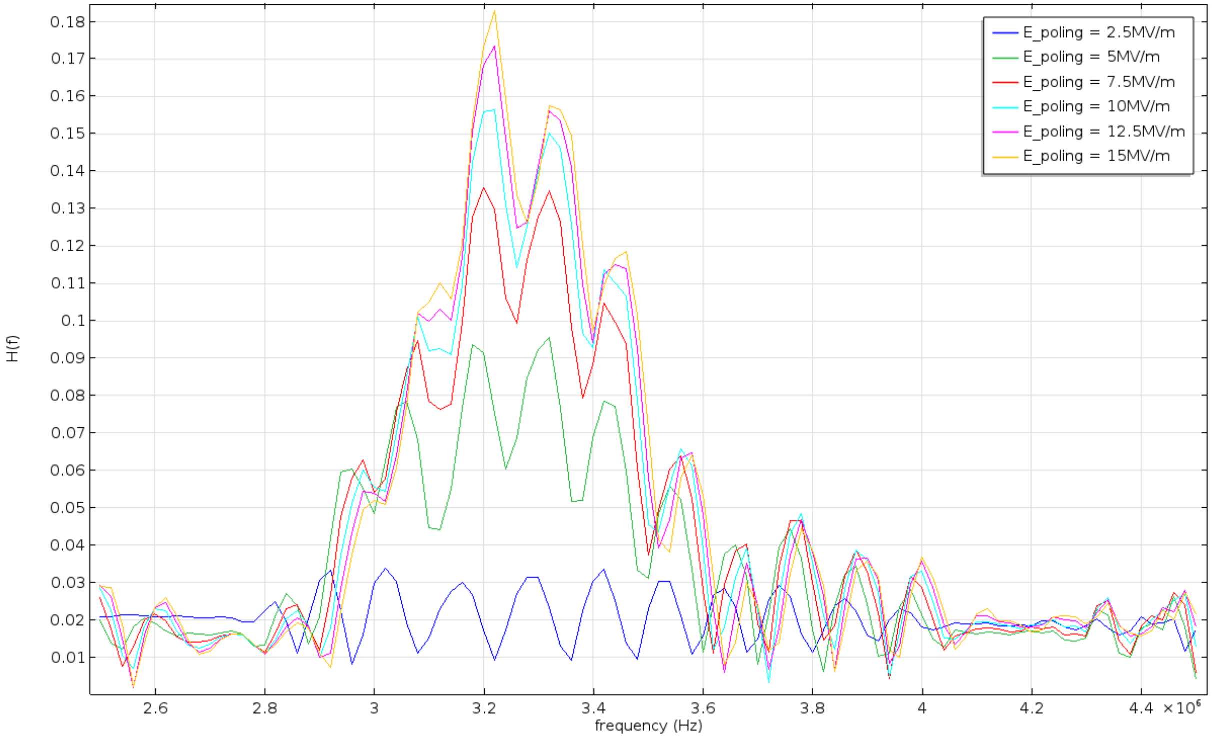
# Simulating the poling process to produce IDT polarization

- At 15 MV/m
- Align z-direction of the material (the poling direction) with the field direction



# Results

» Frequency response module $|H(j\omega)| = |\frac{V_{out}(j\omega)}{V_{in}(j\omega)}|$







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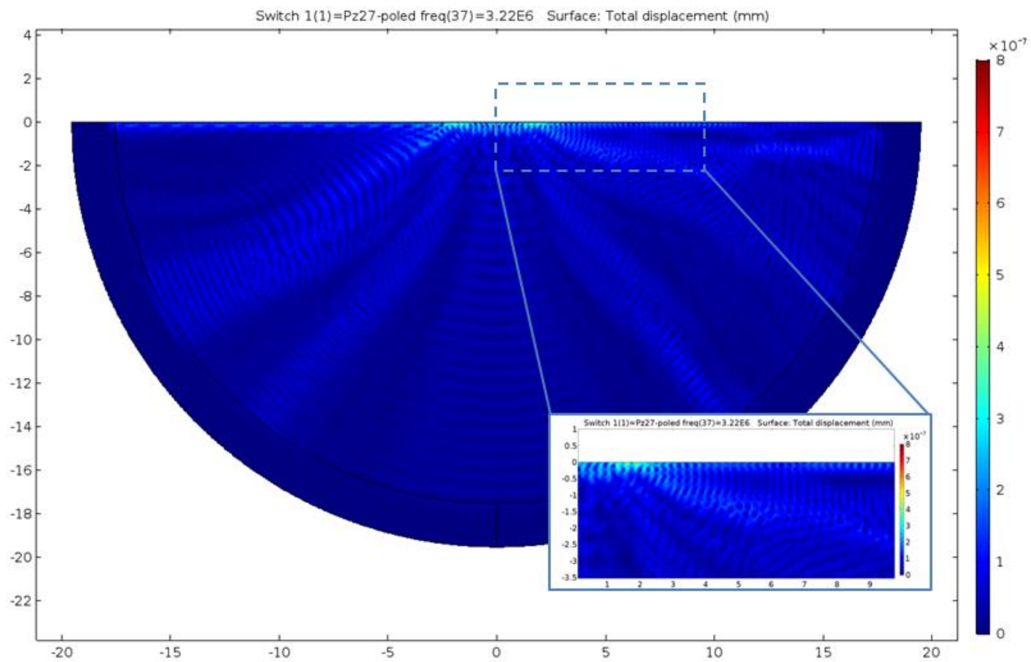
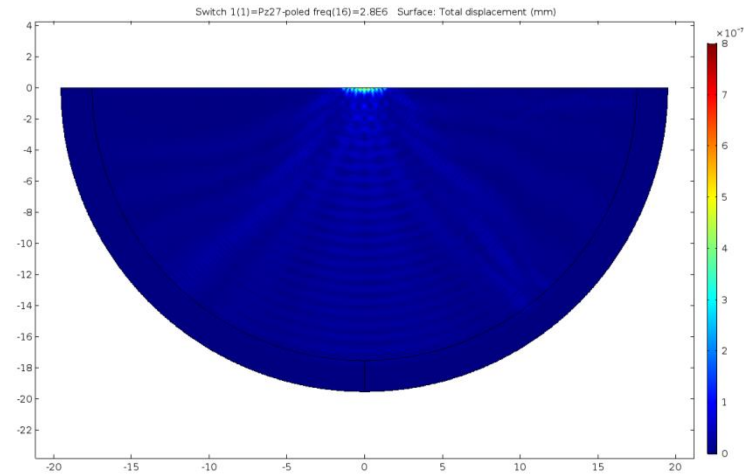
# Results

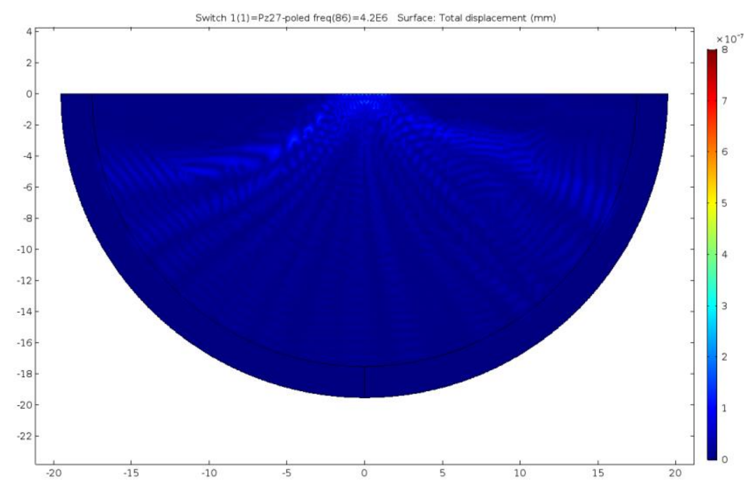
» SAW wave at different frequencies with a poling field of 15 MV/m




3.2 MHz




2.8 MHz




4.2 MHz

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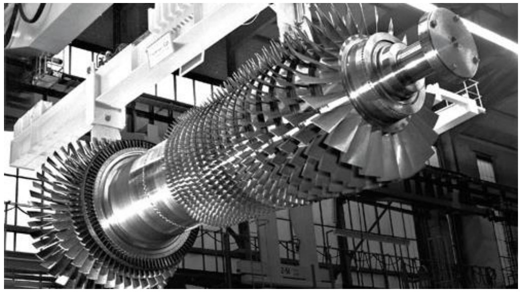
# 5 | Conclusions



# Conclusions

- » Better understanding of SAW devices through COMSOL
- » A interdigital poled SAW device does not perform as well as a z-direction poled device
- » A fully interdigital poled SAW will works, but the surface wave generation is not pronounced
- » The interdigital poled SAW device has a higher center frequency
- » Capability to do poling simulations for modeling complex structures

» Special thanks
  - Michele Guizzetti (Meggitt A/S)
  - Erling Ringgaard (Meggitt A/S)
  - Konstantin Astafiev (Meggitt A/S)
  - Tomasz Zawada (Meggitt A/S)
  - Morten Siwertsen (COMSOL Denmark)
  - COMSOL Support

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Thank you

# Industrial manufacture of piezoceramics