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LITHIUM NIOBATE BASED SAW DEVICE FOR MULTI-PARAMETER SENSING : MODELLING AND SIMULATION USING COMSOL MULTI-PHYSICS.

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SAW : SURFACE ACOUSTIC WAVE

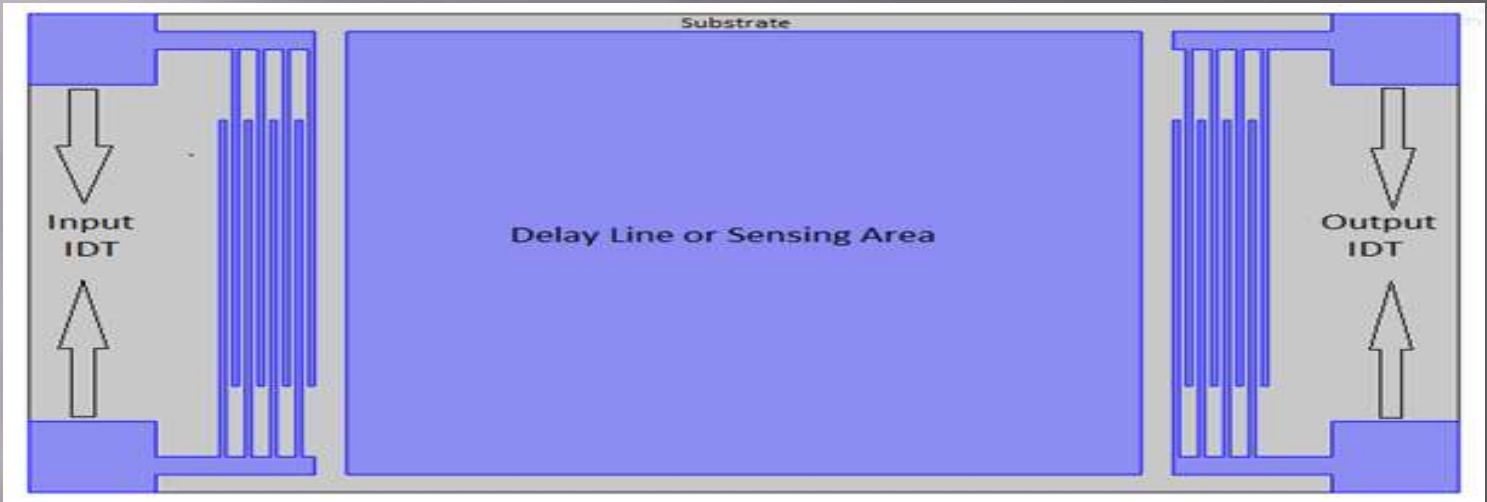
- These are a class of *MEMS* based on the modulation of properties of travelling Surface Acoustic Waves.
- It utilizes *piezoelectric* phenomena : It transduces electrical signal into mechanical wave which gets easily altered while propagation.
- The altered mechanical wave is then converted back to electrical signal at the output terminal.
- Changes in amplitude, phase, frequency or time delay between the input and output signals can be used to measure the presence of desired phenomena.
- The sensor system constitutes :
  i. A piezoelectric substrate.
  ii. Inter-digital transducers- Input and Output.
  iii. Sensing element.
  iv. Delay line.

MERITS OF SAW DEVICES

Dimension of a SAW device relative to it equivalent electrical component for signal processing.

- These can be designed to provide complex signal processing functions with a single package containing, a substrate, a piezoelectric thin film, input and output IDT.
- These are cost competent as they can be mass produced using semi-conductor micro-fabrication technique.
- They posses outstanding reproducibility in performance.
- Its application in mobile and space borne communication is increasing rapidly as they are small, rugged, light and power efficient modules.

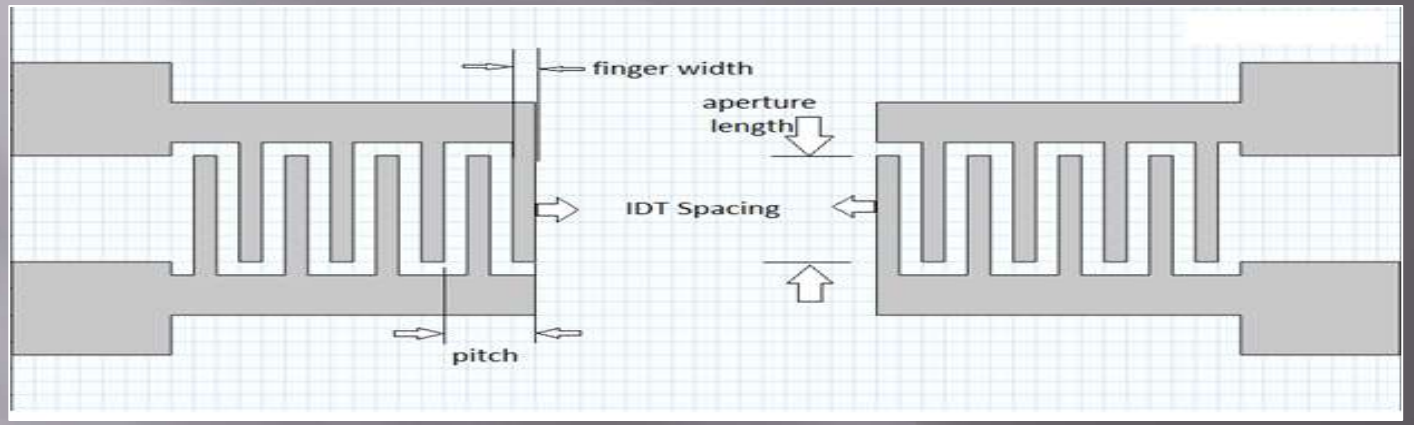
DEVICE STRUCTURE



Basic structure of a SAW device which constitutes an input inter-digitated transducer, an output inter-digitated transducer, piezoelectric substrate and the sensing area.

- RF excitation is provided to the input IDT which results in the generation of surface waves.
- These surface waves when reach the output IDT, are converted back into equivalent electrical quantity using piezoelectric effect.

DEVICE STRUCTURE



Structure of the IDT along with all the parameters

Centre frequency, $f_0 = {}^{V_0}/_{\lambda}$

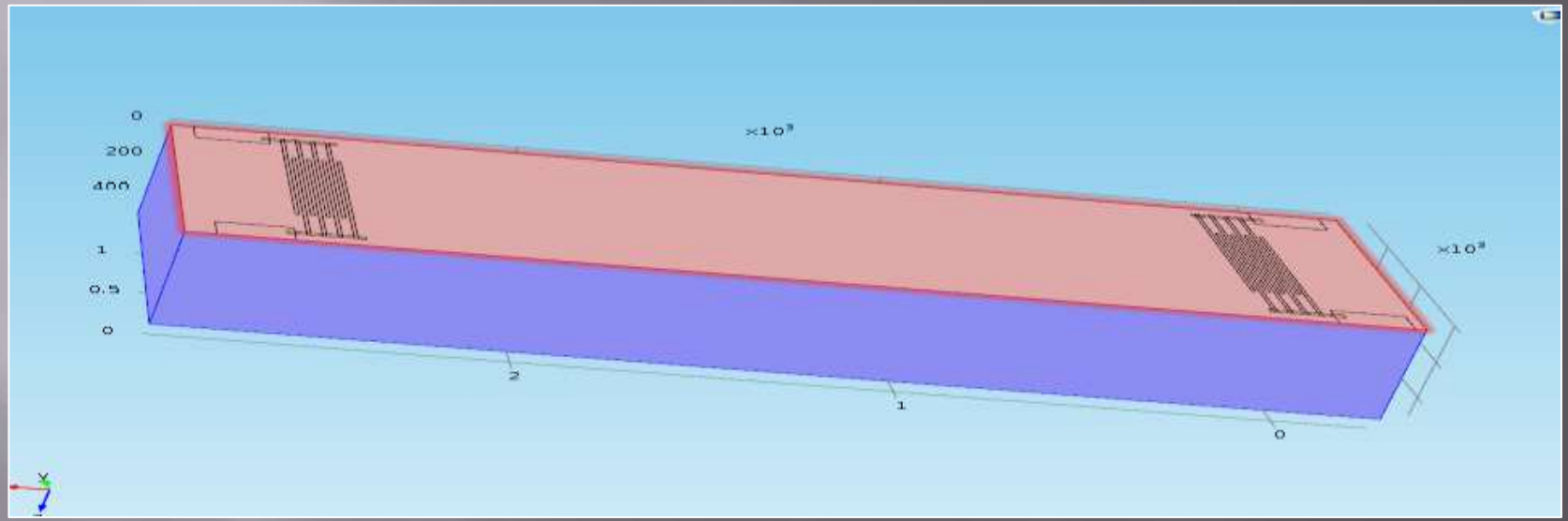
Spectral Bandwidth, $B \propto {}^{2}/_{N_p}$

Pitch, $\lambda = 4 * finger\ width$

V_0 = Velocity of Surface Wave

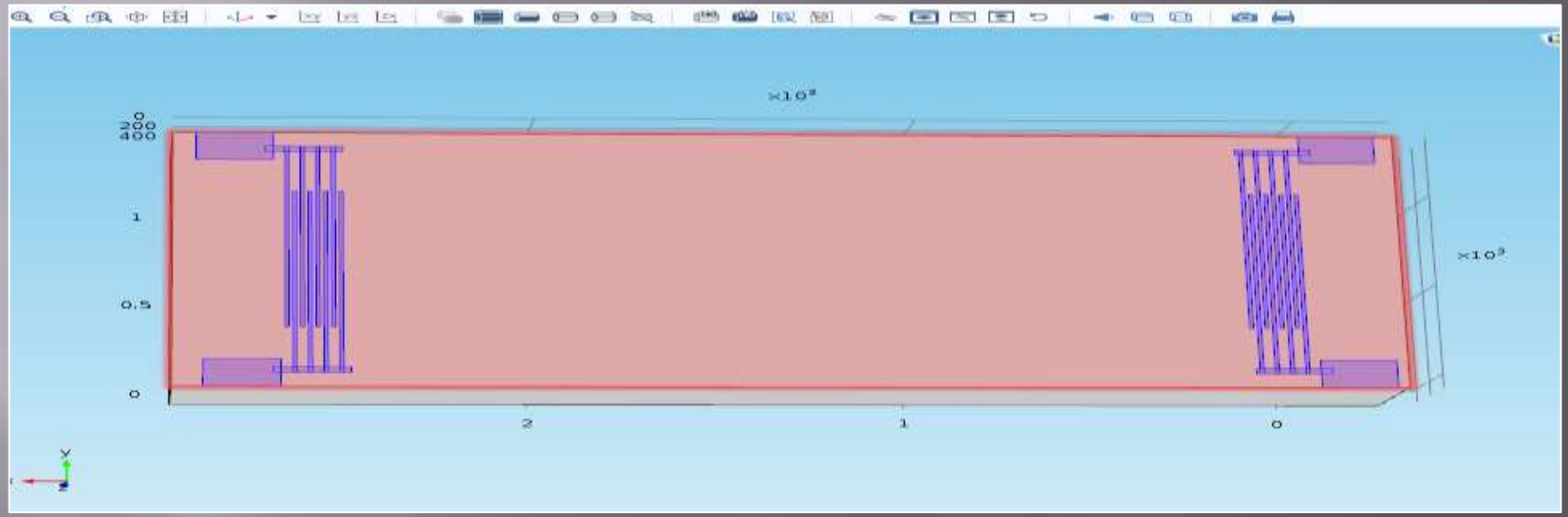
N_P = Number of finger pairs

MATERIAL ASPECTS OF THE MODEL



Inter-digital electrodes = Aluminium (10nm-50nm)
Intermediate layer = Lithium Niobate (400nm-500nm)
Substrate = Silicon wafer (100)

MODEL OF THE DEVICE ON COMSOL



Model of Surface Acoustic Wave device

Finger width = 10μm
Finger spacing = 10μm
Pitch = 40μm
Number of finger pairs/IDT = 4
Aperture length = 750μm

→ Frequency, f0 = 83MHz

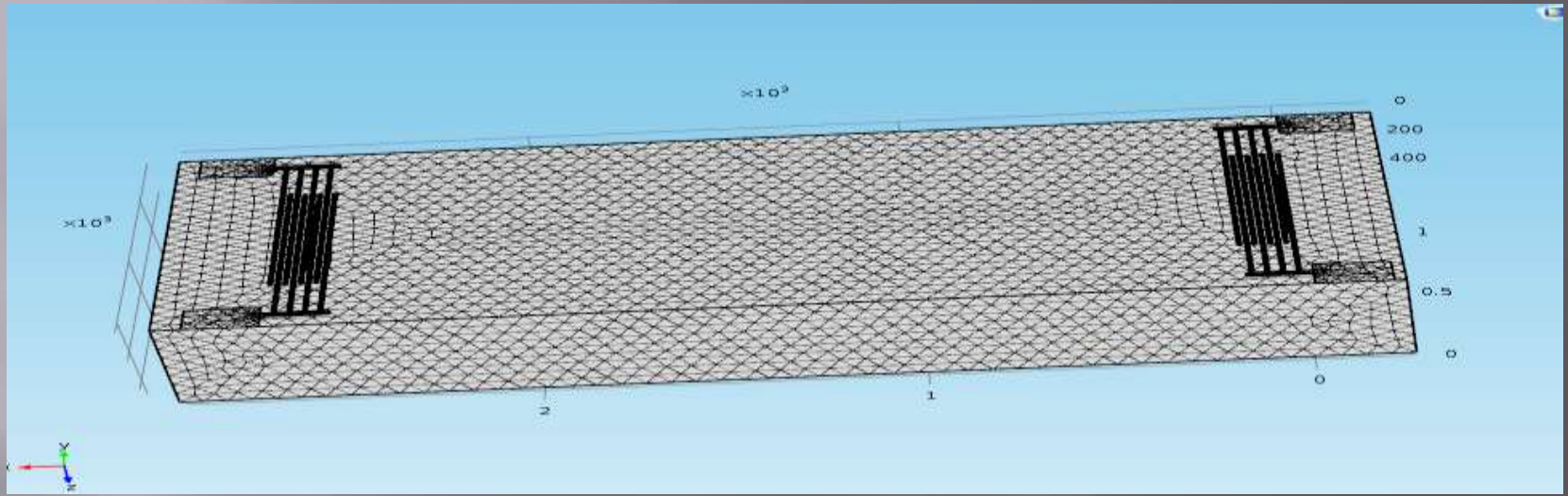
COMSOL : MODULE AND PHYSICS

- A number of analytical and numerical studies such as delta function model, equivalent network model, Green's function model, P-matrix model, coupling of mode method (COM) and Computer Simulation Technology Studio Suite (CST) have been developed to analyze SAW based device. However, these models are more towards to SAW filter and resonator design
- 3D model of SAW device is developed as a function of synchronous frequency and Rayleigh wavelength.

- Physics used in the design are
  I. Electrostatics.
  II. Solid mechanics.
  III. Piezoelectricity.

- Modules used in the design are
  I. AC/DC Module.
  II. Structural Mechanics.

MESHING



- Meshing : With this operation we can mesh individual faces and domains.
- The model uses triangular mesh at the top of the surface and then by using the swept feature of COMSOL we swept the mesh from the source boundary to destination boundary.
- Swept Meshing : This meshing is utilized in thin geometries with sharp bends.

SIMULATION STUDY : EIGEN-FREQUENCY

- An Eigen frequency gives a list of all the natural frequency of the system.
- It gives a look at the deformed mode shape to see what displacement is qualitative.
- Once we have performed Eigen-frequency step to find all potential modes, then frequency domain study is performed where we need to apply a load or a displacement over a range of frequencies and measure the displacement.
- When vibrating at a certain frequency, a structure deforms into a corresponding shape, the *eigenmode.*

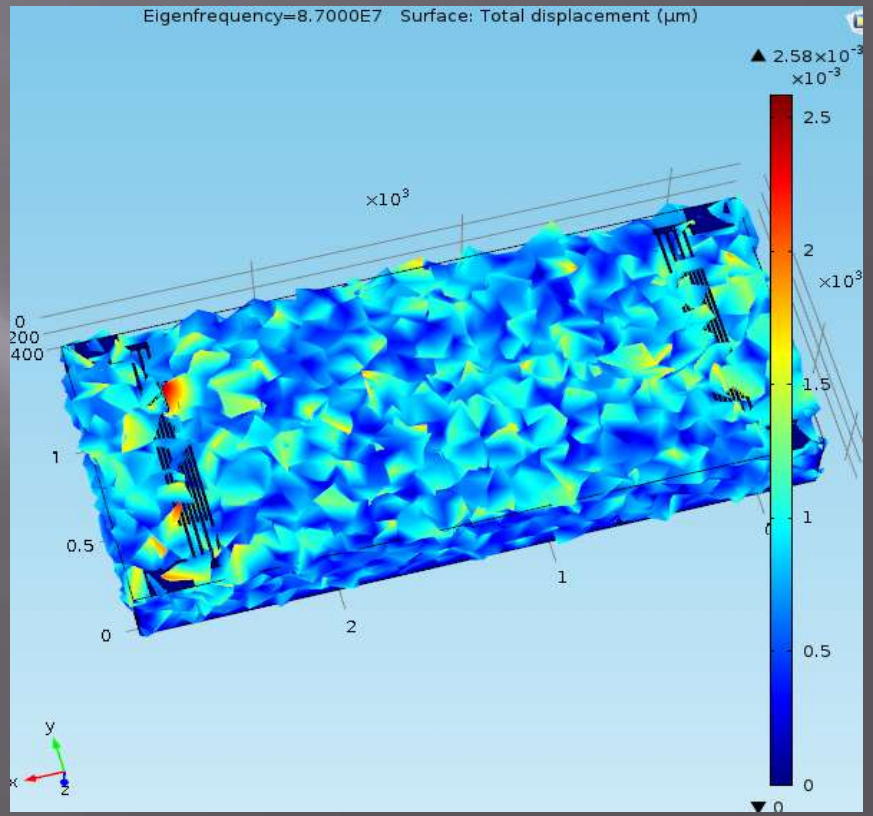
WHY EIGEN FREQUENCY STUDY IS IMPORTANT?

- It helps to investigate suitable choices of time steps or frequencies for a subsequent dynamic response analysis.
- It provides eigenmodes for further analysis based on modes superposition.
- It also provides insights into how design changes can a certain Eigen frequency by studying its mode shape.

SIMULATION STUDY : EIGEN-FREQUENCY

- COMSOL Multi-physics manages to show dimension plot surface total displacement simulation and the signal output at varying frequency response.
- The biggest constraints faced is large amount of computational physical memory is needed for high resolution data to achieve higher accuracy.

COMSOL Simulation 3D plot surface to displacement Of a two port SAW sensor at varying frequency Response.



THANK YOU