Mapping acoustic field distributions of VHF to SHF SAW transducers using a Scanning Electron Microscope

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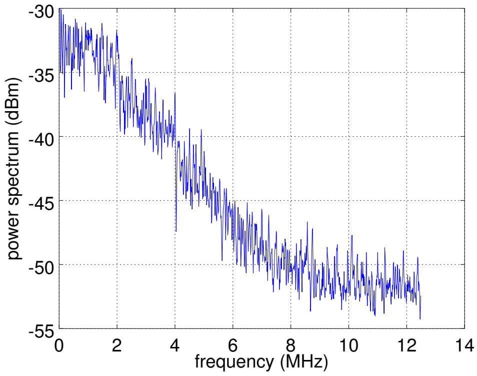
Scanning Electron Microscopy mapping of VHF Surface Acoustic Wave devices

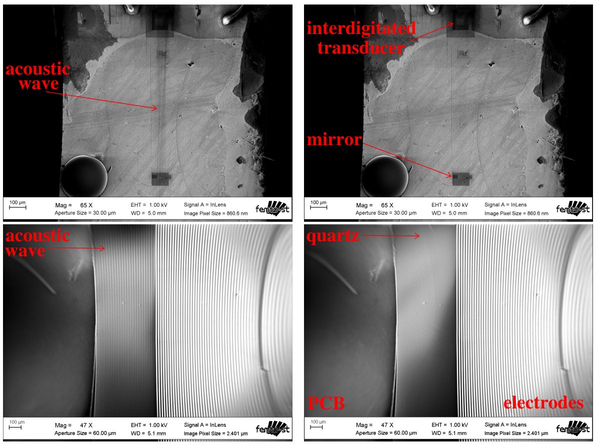
- Scanning Electron Microscopy (SEM): recording backscattered & secondary electrons of the target illuminated by electrons (charged particle path bent by electric field associated with acoustic wave propagating on piezoelectric substrate)
- Low incoming electron energy ($\leq$1 keV) to reduce charging on insulating piezoelectric substrates
- **In-line** secondary electron detector most sensitive to the deflection induced by the acoustic field associated electric field
- SEM detector **bandwidth (2 MHz) insufficient** for time resolved SAW device acoustic field mapping (100-3000 MHz) [1] →
- ⇒ standing wave pattern (resonator) or interference between electromagnetic and acoustic related fields [2]
- Compatible with **shear wave** and **sub-micrometer** resolution acoustic field mapping
- **Fast** measurement ($\ll$1 s) but **qualitative** mapping (not quantitative as optical interferometric methods)



SE2 photodetector bandwidth measurement

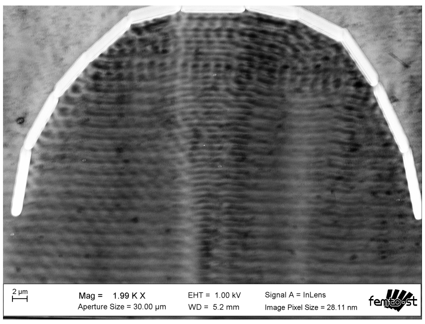
Rayleigh wave (LNO) and STW wave (quartz) acoustic field mapping

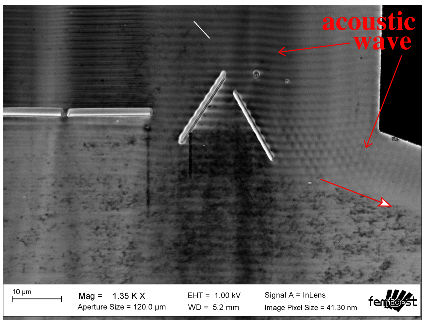
- Demonstration on SHF Rayleigh wave delay line (lithium niobate) and VHF STW wave (quartz).
- **Optical interferometric analysis** of STW device shows <10 pm out-of-plane displacement over IDTs ⇒ **SEM sees shear waves** →
- Rayleigh wave on LNO at 2.4 GHz : 1.5 μm wavelength, hardly accessible with optics
- Well resolved collimated beam despite propagating wave ⟶
- Failure to observe electric field associated with Love mode propagation due to the 1.5 μm thick insulating (SiO_2) guiding layer.
- Advantages over optical measurements: fast (<1 s acquisition), compatible with shear wave, high spatial resolution
- Drawbacks over optical measurements: qualitative mapping, **not** quantitative
- BUT ability to interact with the sample through Focused Ion Beam (FIB) milling of the piezoelectric substrate ↓

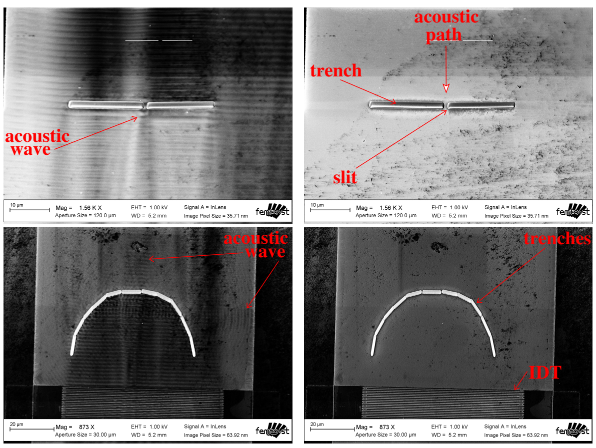


Top: 2.45 GHz Rayleigh wave. Bot.: 126 MHz STW wave

Interfering with wave propagation: FIB milled obstacles



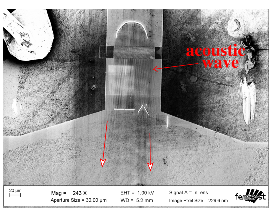




- Acoustic wave penetration of the order of the wavelength.
- High frequency operation to be compatible with FIB-milled structures,
- reflected Rayleigh wave propagation **in directions in which no coupling might be expected**
- Point source from slit between trenches.
- Etch rate in ST-cut quartz: 0.14±0.03 $\mu m^3/nC$ (consistent with LNO)

Left: with acoustic field. Right: no acoustic field.
Top: point source from slit experiment. Bottom: half coral.

Conclusion & perspectives: stroboscopy



- Possibility to implement **stroboscopic** [3] measurement if incoming electron beam is focused away from sample unless a reproducible wave pattern is met.
- Interaction mechanism of electrons with surface electric fields remains to be understood for **quantitative analysis**.

Bibliography:
[1] G. Eberharter & *al.*, Applied Physics Letters, **37**, p. 698, 1980.
[2] D. V. Roshchupkin, & *al.*, Applied Physics Letters, **60**, p. 2330, 1992.
[3] H. P. Feuerbaum, & *al.*, J. Phys. E: Sci. Instrum., **11**, p. 529, 1978.