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Loss mechanisms in XBARs – laterally excited resonators on thin platelet of lithium niobate.

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Background, Motivation and Objective

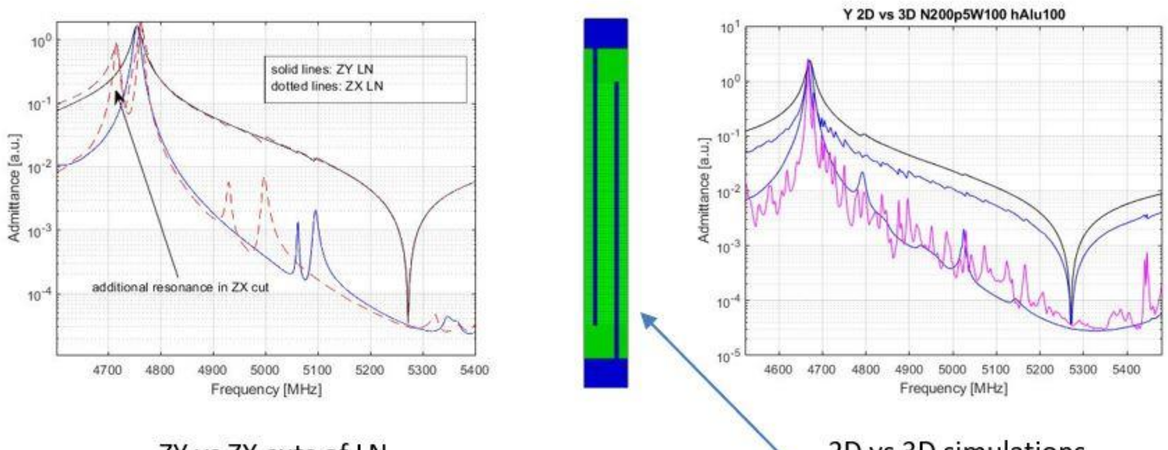
Recently we presented laterally e**X**cited **B**ulk **A**coustic **R**esonators (XBARs,[1]) based on thin (0.4 µm) monocrystalline layers of ZY-cut $LiNbO_3$ (LN). In XBARs, electrodes with low metallization ratio and periodicity on the order of a few microns are used to create an electric field inside a LN platelet, parallel to its plane. Such an applied field generates standing shear wave resonances in the thickness direction, between the electrodes. The structure has excellent piezoelectric coupling, good Q factor and it can be produced with optical lithography at frequencies from 3 GHz to 6 GHz, potentially up to 15 GHz. This opens a gateway to designing filters for 5G mobile phones. Low loss in passband and acceptable power handling are important. Both these parameters depend on loss mechanisms in the XBARs, which we discuss in this paper.

Statement of Contribution/Methods

For simulation of device performances, distribution of acoustic and electric fields in devices, we used our 2D FEM software [2], for both periodic structures and devices with finite number of electrodes. Recently, a 3D version of the software was developed for periodic, finite aperture simulation of devices.

Results/Discussion

The estimated material limit for the Q-factor for LN shear bulk wave resonator is in the order of Q~ 5000 at 5 GHz. Periodic 2D XBAR structure simulations give Q values around 3000, ignoring resistivity of electrodes. The resonance frequency is determined by the thickness of LN platelet but it is also influenced by the periodicity of the structure, as in A1 Lamb mode. We also observe parasitic A1-3 horizontal 3rd harmonic mode which is important for ladder filter design on XBARs. Including the resistivity simulations of XBAR with 100nm-300nm thick Aluminum electrodes, (Nt=200), and aperture W=100 µm results in Q-factors between 300-600 which are close to values observed experimentally. 3D simulations give similar results. The amplitude and frequency position of parasitic modes can be influenced by electrode geometry and Q-factors are influenced by the presence of the propagating parasitic modes. The ZX-cut of LN results in more spurious modes than the ZY-cut (see figure below). First experiments with filter design show that devices with minimal IL close to 1 dB can be obtained at central frequency close to 5 GHz with relative passband comparable to 10%. These experimental results will be presented in a parallel paper at this Symposium.



ZY vs ZX cuts of LN,
a=0.3 µm, hAlu=0.3 µm, Nt=200, W=100 µm

2D vs 3D simulations
One device period

[1] V. Plessky, et al. Electronics Letters 55.2 (2018), pp. 98-100.
[2] J. Koskela, et al. "Hierarchical Cascading Algorithm for 2-D FEM Simulation of Finite SAW Devices." IEEE trans. on UFFC 65.10 (2018), pp. 1933-1942.