Characterization of BAW Modes Harmonically Generated (*f-2f-3f*) in $LiNO_3$ SAW Devices Using COMSOL Multiphysics® Simulation

Xiangnan Pang, Zinan Zhao, Yook-Kong Yong
Department of Civil and Environmental Engineering, Rutgers University, Piscataway, NJ, USA

INTRODUCTION: A surface acoustic wave (SAW) device utilizes the wave propagation along the surface of a substrate, with the vibration that typically penetrate several wavelengths into the depth of material. Recently, the generation of BAW modes in TC-SAW resonator on LiNO3 and its characteristics were observed experimentally in [1]. Based on COMSOL Multiphysics® simulation, we show that the generation of BAW modes were due to nonlinear material properties of LiNO3. Simulation results of characteristics of BAW modes are compared with experimental measurements in [1].

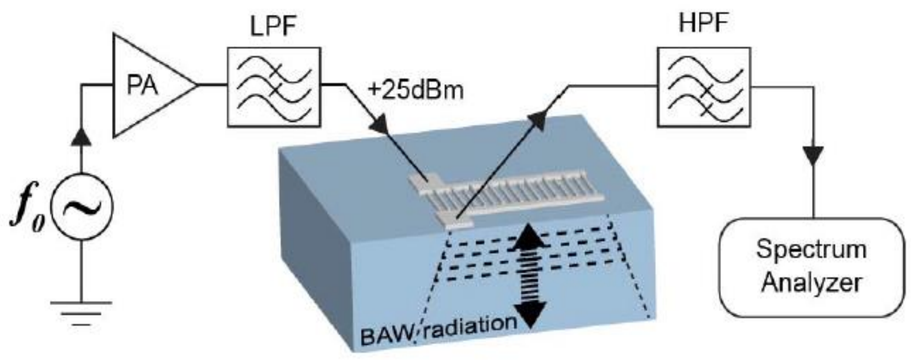


Figure 1. Schematics of measurement setup in [1] and presentation of generation of BAW modes in TC-SAW device.

COMPUTATIONAL METHODS:

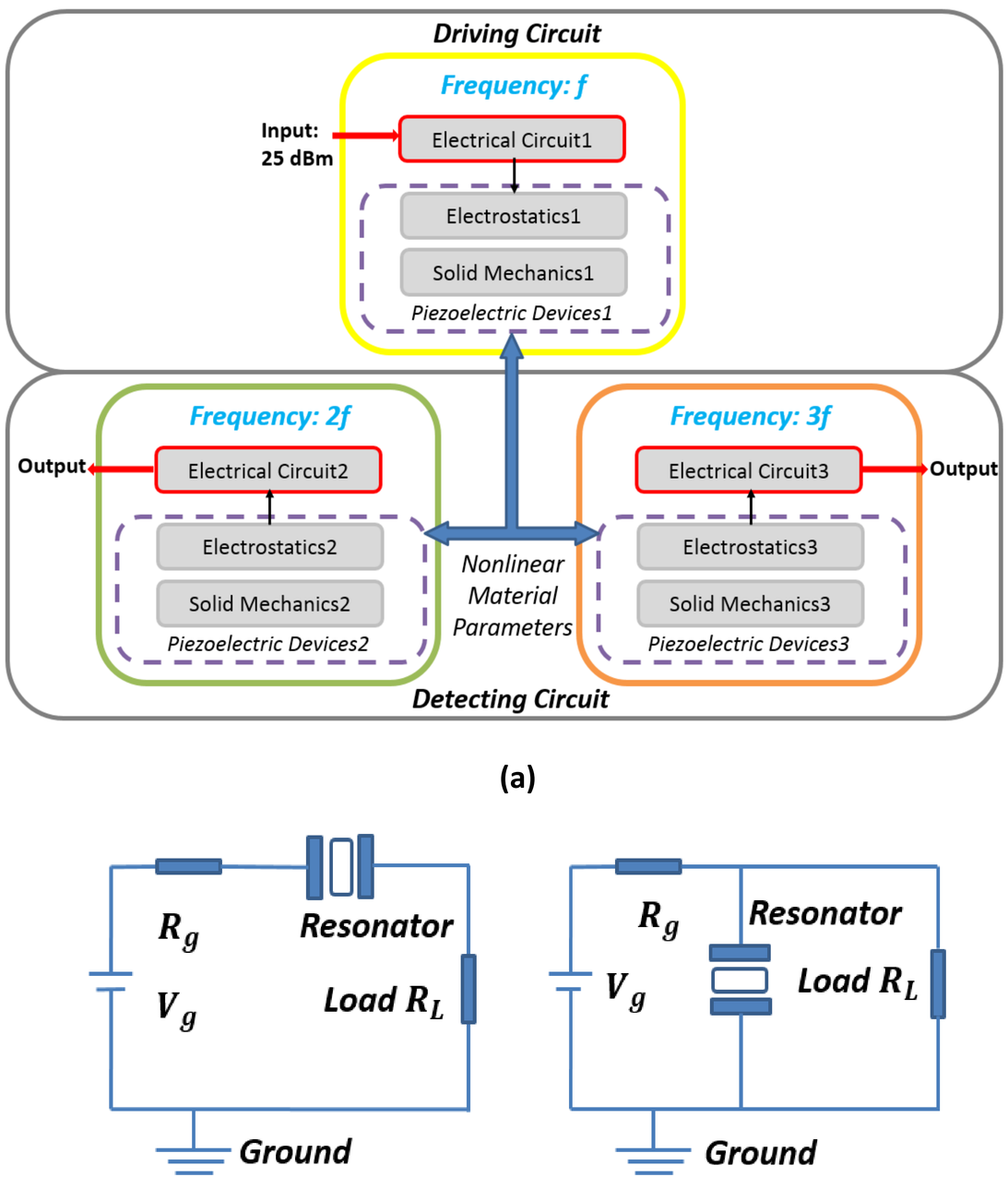


Figure 2. (a) Simulation Flowchart and Interfaces in COMSOL Multiphysics; (b) Electrical connection of piezoelectric resonator in driving or detecting circuits: series (left) and parallel (right).

RESULTS: The TC-SAW resonators in [1] were made on 128° YX LiNO3 substrate, with 100 electrodes pair in length direction and 20 wavelengths in aperture direction. The period was 2.3 um and two substrate depth were considered: 150 um and 500 um. In simulation, 25 dBm power at fundamental frequency *f* was input to the resonators. The BAW modes harmonically generated by the nonlinear material constants were identified. The output power available at 1st, 2nd, 3rd harmonic with *f, 2f, 3f* were calculated and compared with experimental measurements.

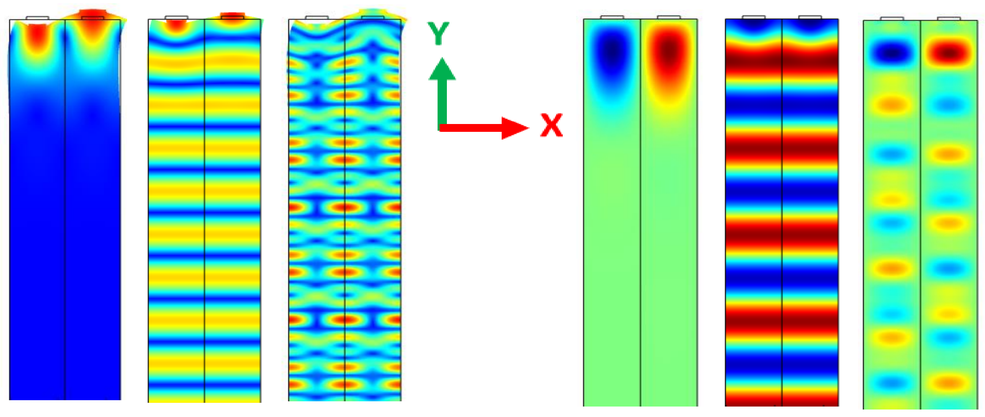
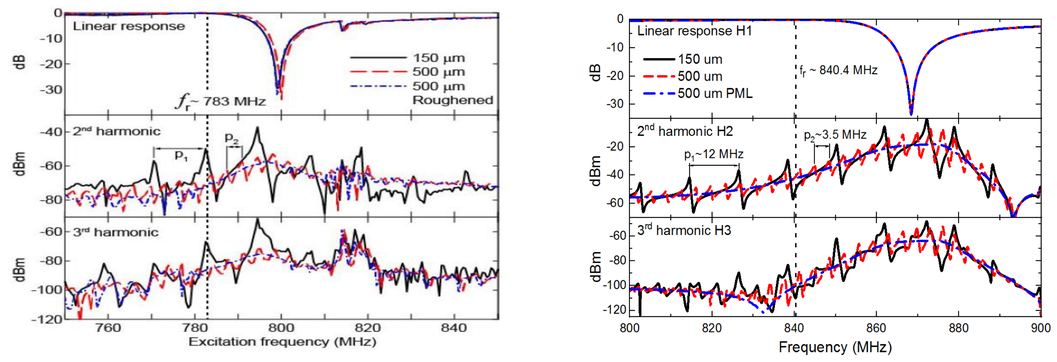
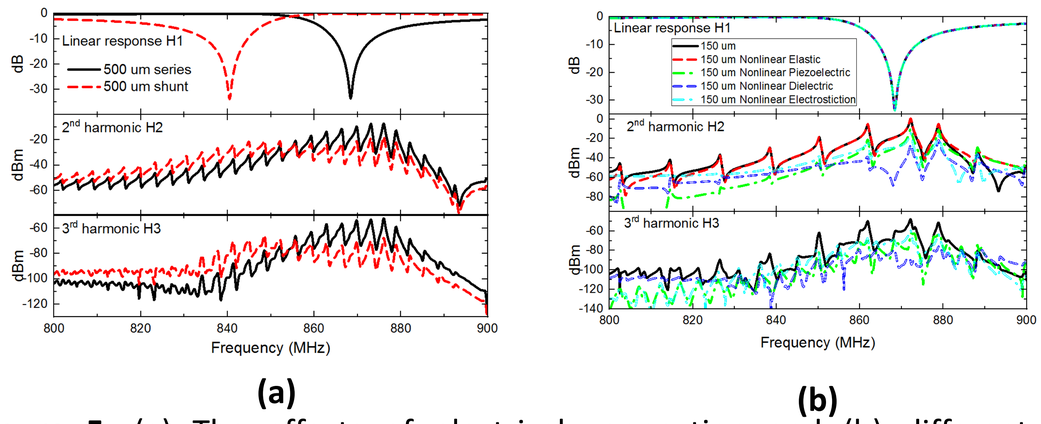


Figure 3. FEM model *f*-SAW, *2f*-BAW and *3f*-BAW displacement mode shapes (left), and their respective electric potential mode shapes (right) of an 840.4 MHz 128° YX LiNO3 SAW resonator. H1 propagated in the X-direction whereas H2 and H3 travel in the Y-direction.



(a) (b)

Figure 4. (a) Experimental measurement and (b) simulation results of harmonic power in 128° YX LiNO3 SAW resonators.



(a) (b)

Figure 5. (a) The effects of electrical connection and (b) different nonlinear material constants on the harmonic signal in 128° YX LiNO3 SAW resonators.

CONCLUSIONS:

- BAW modes harmonically generated in SAW resonator were simulated using COMSOL Multiphysics® and compared with experimental results;
- The possible dominant generation mechanism were identified in the harmonic power levels.

REFERENCES:

1. Solal, M., Kokkonen, K., Inoue, S., Briot, J. B., Abbott, B. P., & Gamble, K. J., Observation of nonlinear harmonic generation of bulk modes in SAW devices, IEEE transactions on ultrasonics, ferroelectrics, and frequency control, vol 64, 1361-1367, 2017
2. Y. Cho and K. Yamanouchi, Nonlinear, elastic, piezoelectric, electrostrictive, and dielectric constants of lithium niobate, J. Appl. Phys., vol. 61, no. 3, 875-887, 1987.