

Acoustic Wave Actuator On Thin Film Lithium Niobate For Acousto-optic Modulators

Florian Fernand Hartmann¹, Dara Bayat², Silvan Stettler¹, Ivan Prieto², Hamed Sattari², Guillermo Villaneuva¹

¹EPFL

²CSEM

Abstract

Lithium niobate (LiNbO₃) possesses unique combination of material properties such as: high electro-optic and elasto-optic coefficients and strong piezoelectricity, enabling integration of optical and acoustic functionalities within a single material, paving the way for advanced multifunctional devices such as acousto-optic modulator (AOM). AOM is an important optical component functioning a wide range of applications such as optical networks, internet of things (IOT) and quantum computing systems through frequency shifting, microwave to optic modulation, tunable filters, and nonreciprocal transmission. The fundamental principle of integrated AOM relies on the interaction between electrically induced surface acoustic waves (SAW) in LiNbO₃ and optical modes (shown in Figure 1). This interaction, driven by the photo-elastic effect, changes the refractive index of the optical waveguide, resulting in modulating the light. The conventional integrated AOM method has relied on the use of Ti-indiffused bulk LiNbO₃ crystals, which suffers from poor light confinement and large optical mode, thereby restricting scaling down for PIC platform applications. The emergence of single crystal thin films lithium niobate on Insulator (LNOI) substrates and advancement on its micromachining enabled reduction of optical modes to submicron dimensions leading to fabrication of compact optical devices and higher integration density.

This work focuses on the realization of AOM designs within a standard thin film LNOI PIC platform, applicable in an integrated gyroscope. Three different Multiphysics are involved in this project including electro-acoustic, acousto-optic and electro-optic interactions. COMSOL Multiphysics has been employed to better understand the behavior of these interactions and to preserve time and fabrication cost. In simulating the AOM, acoustic and optical modes are initially simulated independently, and then their coupling coefficients are applied manually using equation-based modeling in COMSOL Multiphysics to calculate the interaction. The piezoelectric Multiphysics module is used for simulating acoustic modes, while the electromagnetic, frequency domain module is used for optical modes. During the initial phase of this study, AOM has been simulated and analyzed using Finite element method (FEM) in COMSOL Multiphysics 6.2 software. Following this, various SAW resonator designs have been fabricated in LNOI within frequency range of 400 MHz to 3.5 GHz. The experimental results from the fabrication validated the simulation results of the SAW resonator in LiNbO₃.

Figures used in the abstract

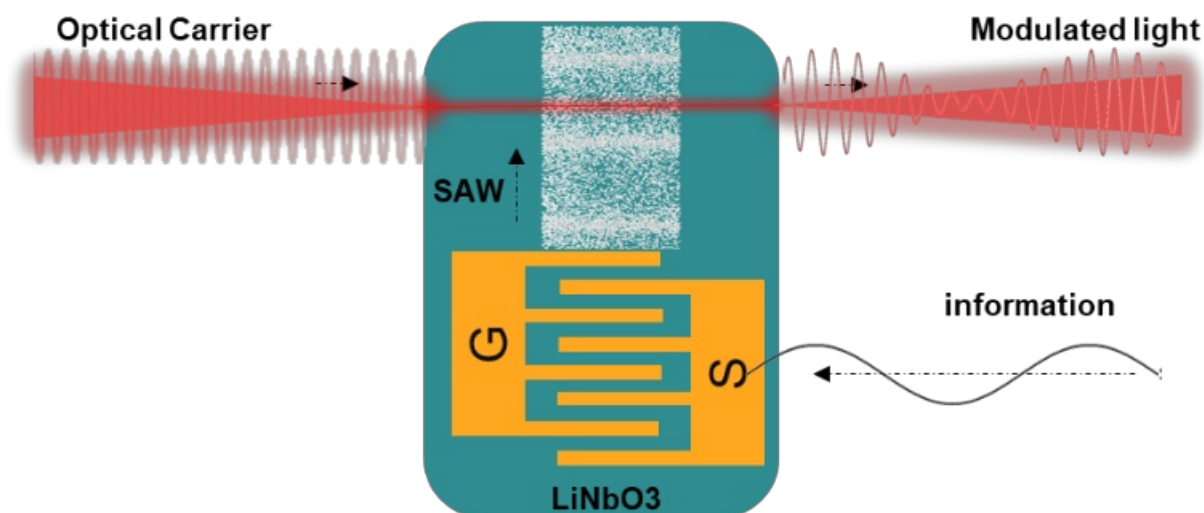


Figure 1 : Figure 1: schematic of acousto-optic modulator device.