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Development of Love wave resonators for biological sensing

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► **To cite this version:**

Caique Veras, Alice Joulie, Alexandre Reinhardt, Thomas Alava, Marie Bousquet, et al.. Development of Love wave resonators for biological sensing. 66th International Conference on Electron, Ion and Photon Beam Technology and Nanofabrication (EIPBN NO-LA 2022), May 2022, New Orleans, United States. 2022. cea-03846230

HAL Id: cea-03846230

<https://cea.hal.science/cea-03846230v1>

Submitted on 10 Nov 2022

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LOVE WAVE RESONATORS FOR BIOLOGICAL SENSING

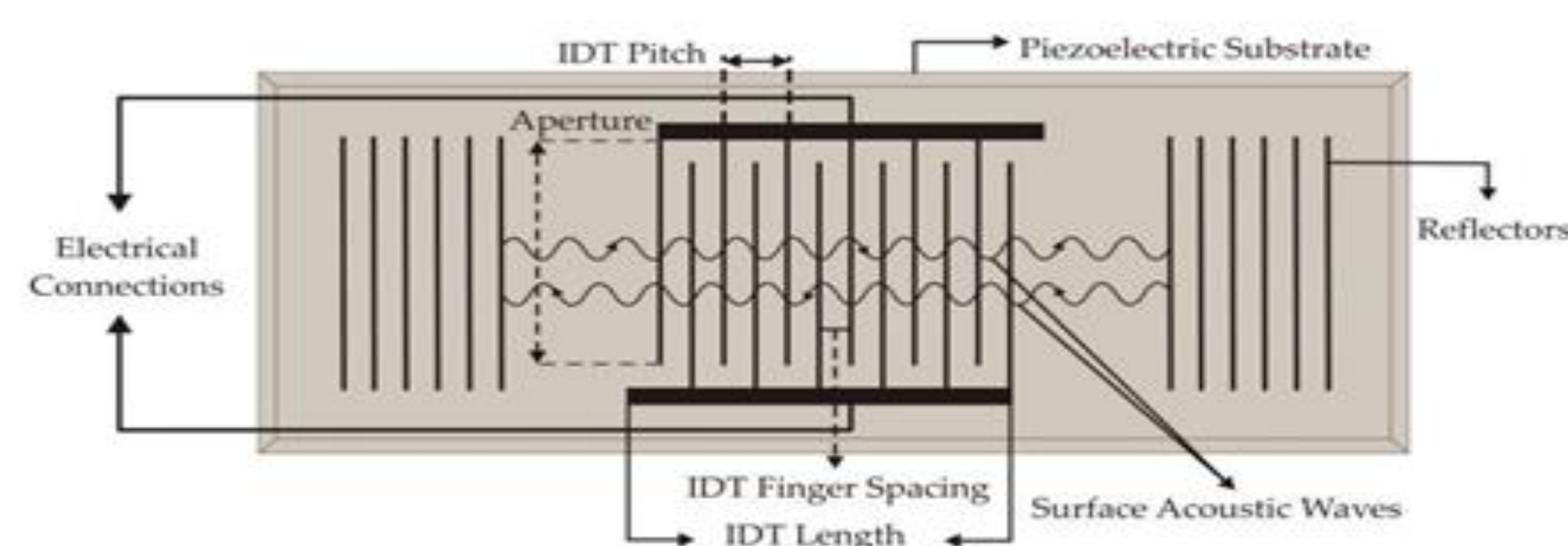
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INTRODUCTION

The development of a biosensor can be challenging. Notably, the transducer must operate in a water-based complex media that often introduce system losses. Good performance in liquid media is however required for biological applications. This work focuses on the development of a transducer aimed to be used as a biosensor.

TRANSDUCER

- Surface acoustic wave device
 - More sensitive to surface perturbations
- Resonator architecture
 - Better electrical performance²
 - Smaller size



- Avoid acoustic radiation into water → Love wave (shear horizontal polarization)

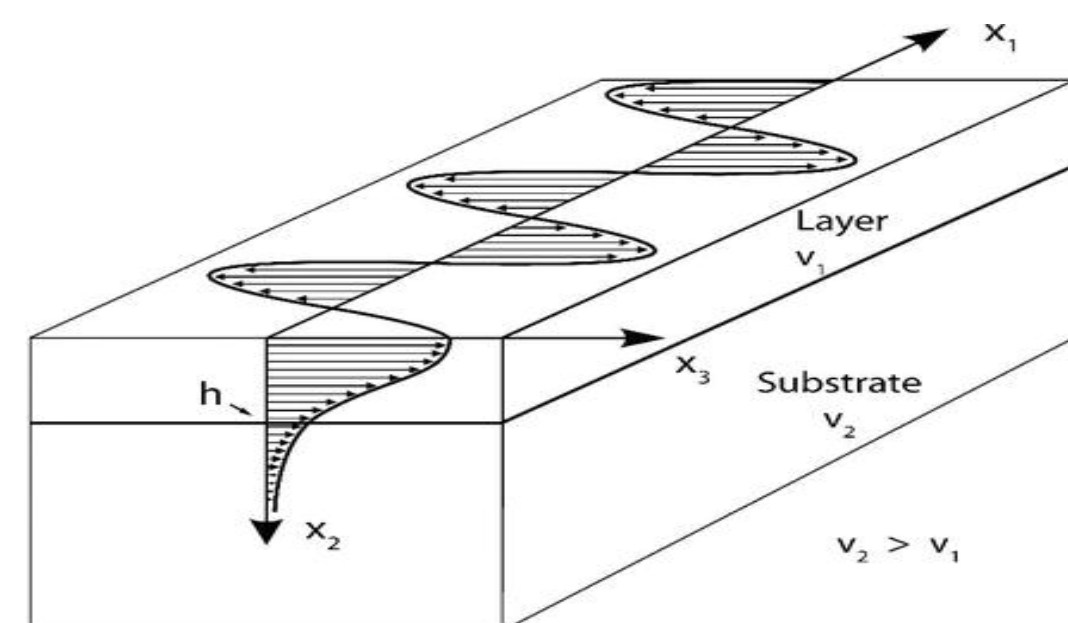
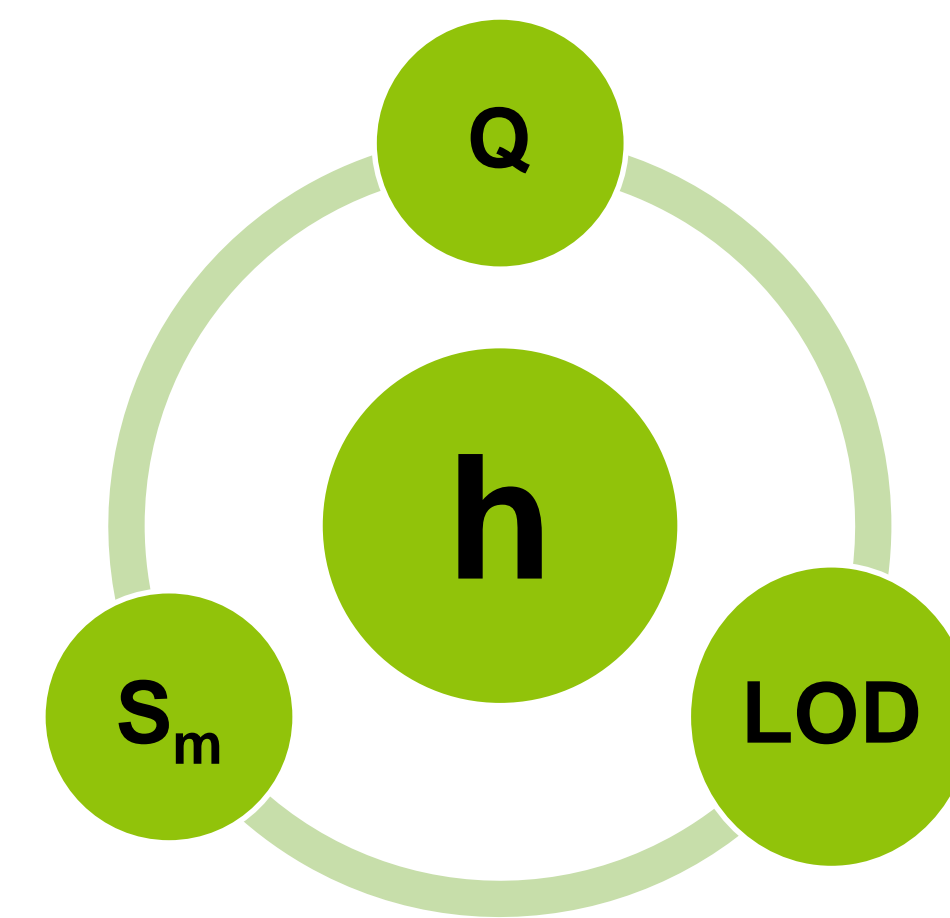


Figure 1: (top) Schematic of a surface acoustic wave device. (bottom) Love wave displacement field. The structure considered has a layer of thickness h on top of a semi-infinite substrate.

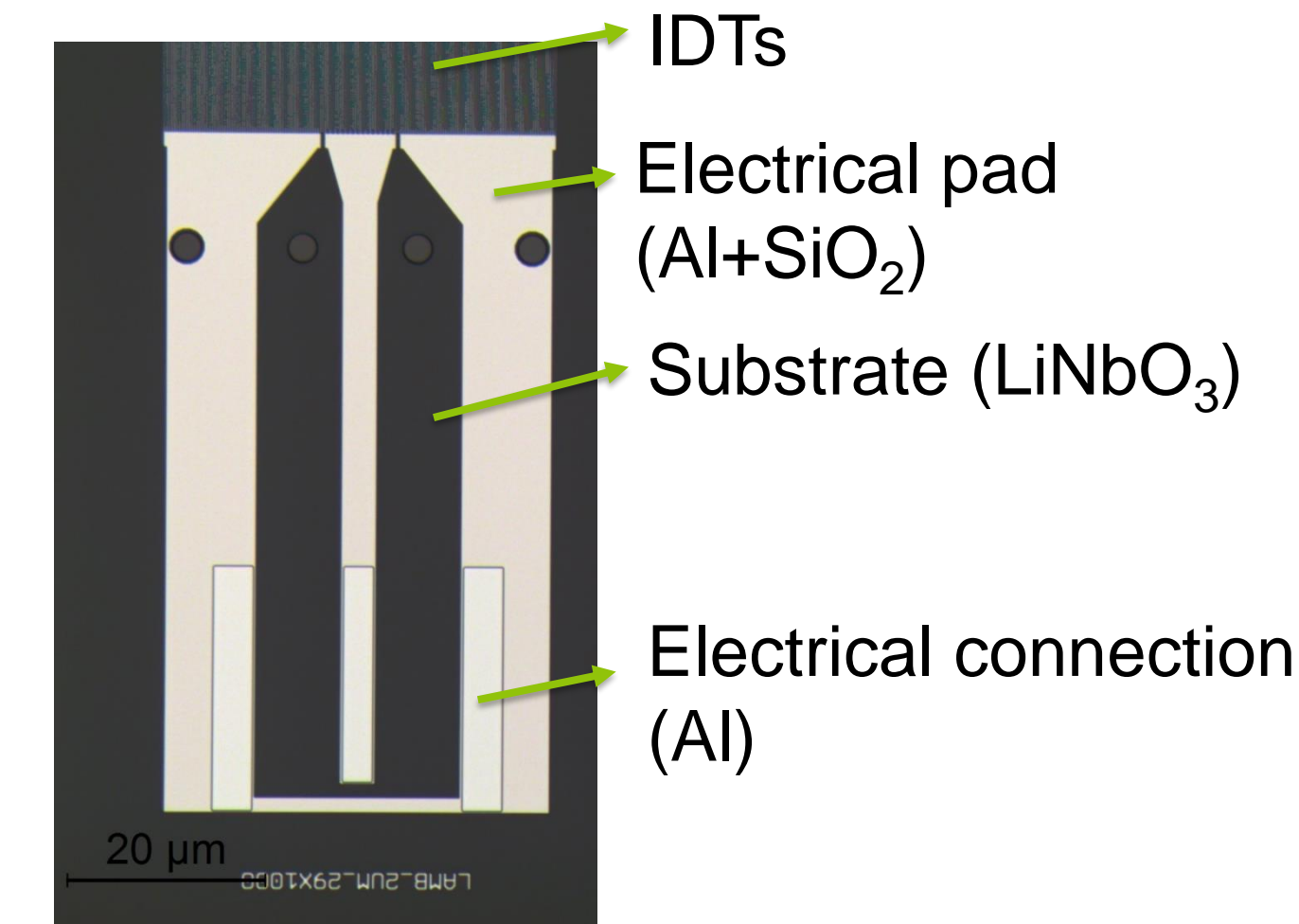
FIGURES OF MERIT

Performance parameters:

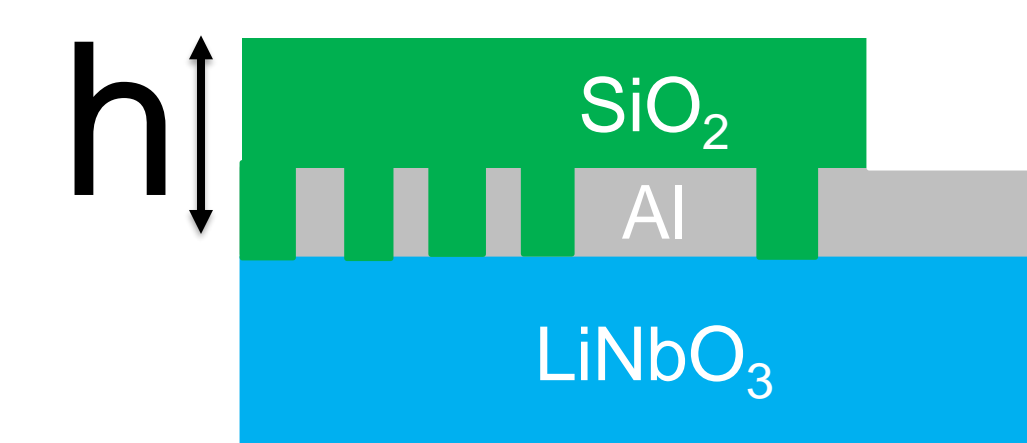
- Mass sensitivity $S_m = \frac{\delta f}{\delta m} = \frac{f_0}{m_{eff}}$
- Limit of detection $LOD \propto \frac{m_{eff}}{Q}$



Top view of the device



Resonator cross section



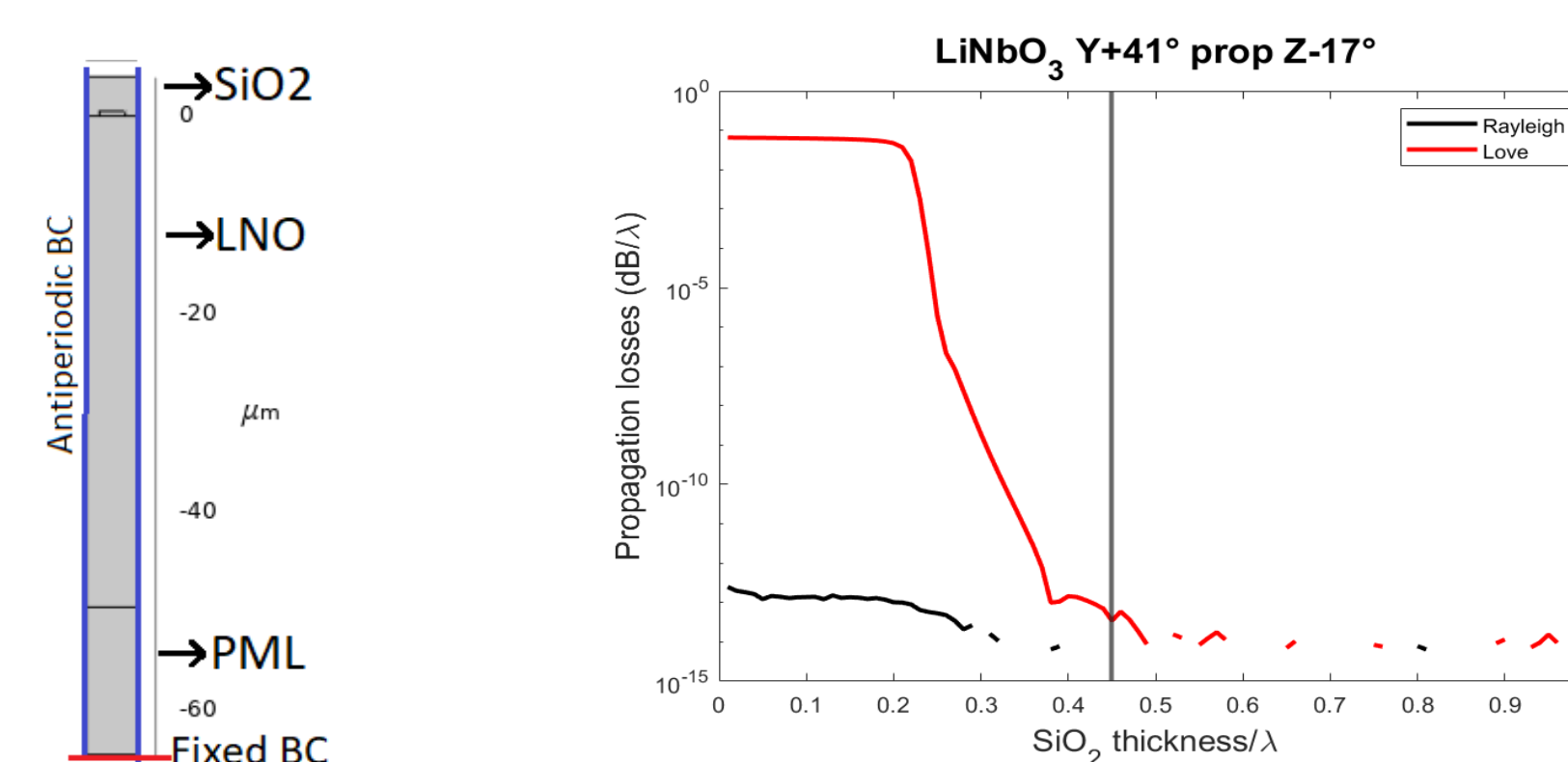
SiO₂ film thickness controls confinement of the mode in the vicinity of the surface → affects all performance parameters⁴

- Reduces radiation in the substrate → improves quality factor (Q)
- Brings acoustic energy closer to the surface → reduces m_{eff}

TRANSDUCER DESIGN

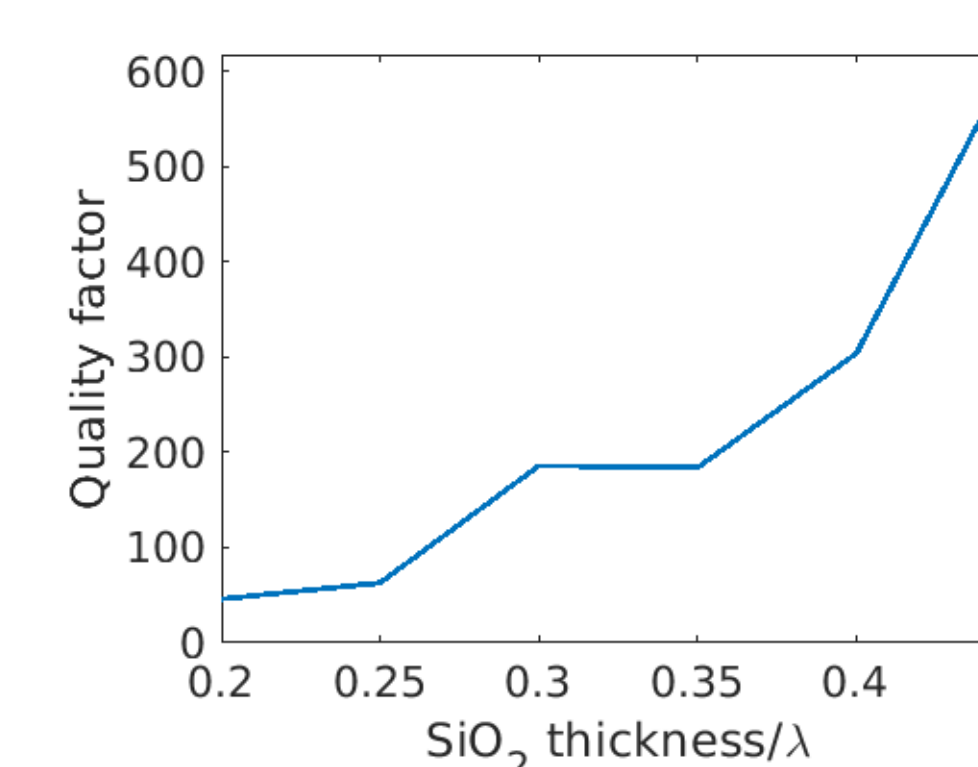
Love wave propagation properties evaluated using periodic models:

- Calculate propagation
 - Evaluate Love wave radiation into the substrate



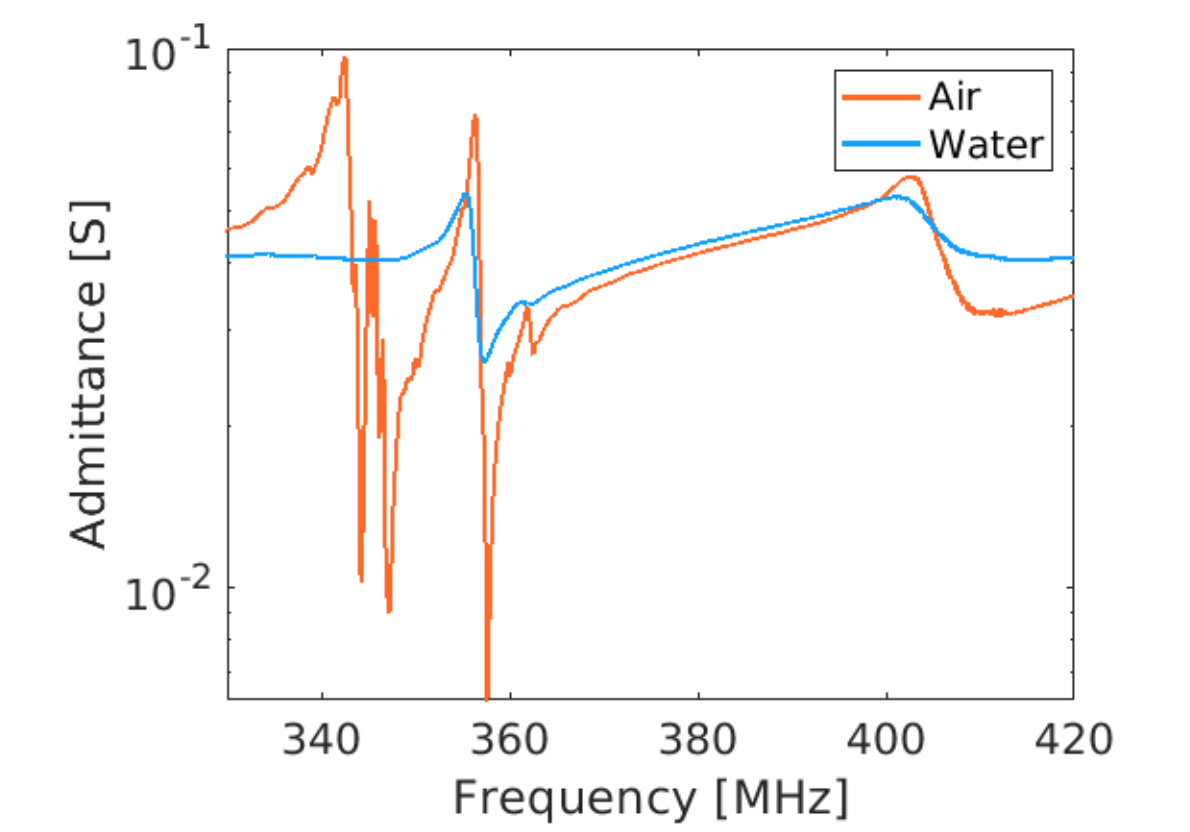
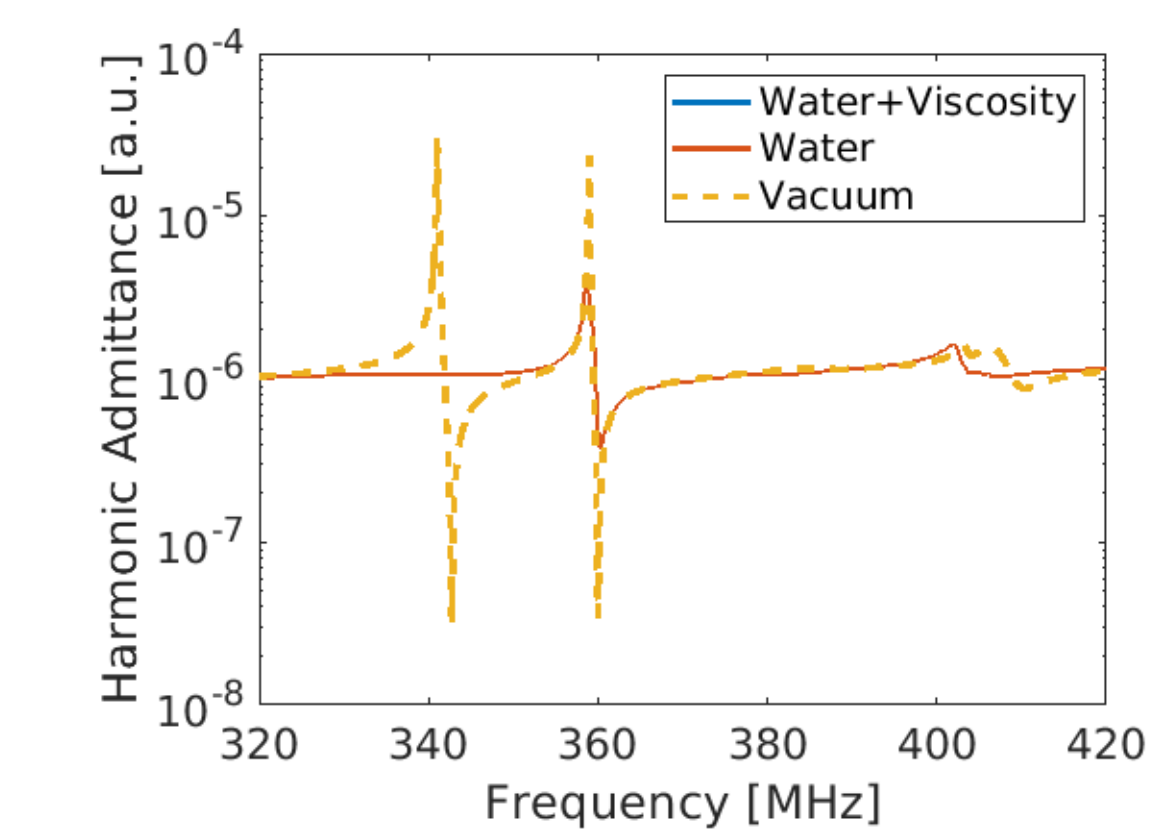
$h/\lambda > 0.4$ to fully confine wave into the layer

Love wave Q in water vs. h



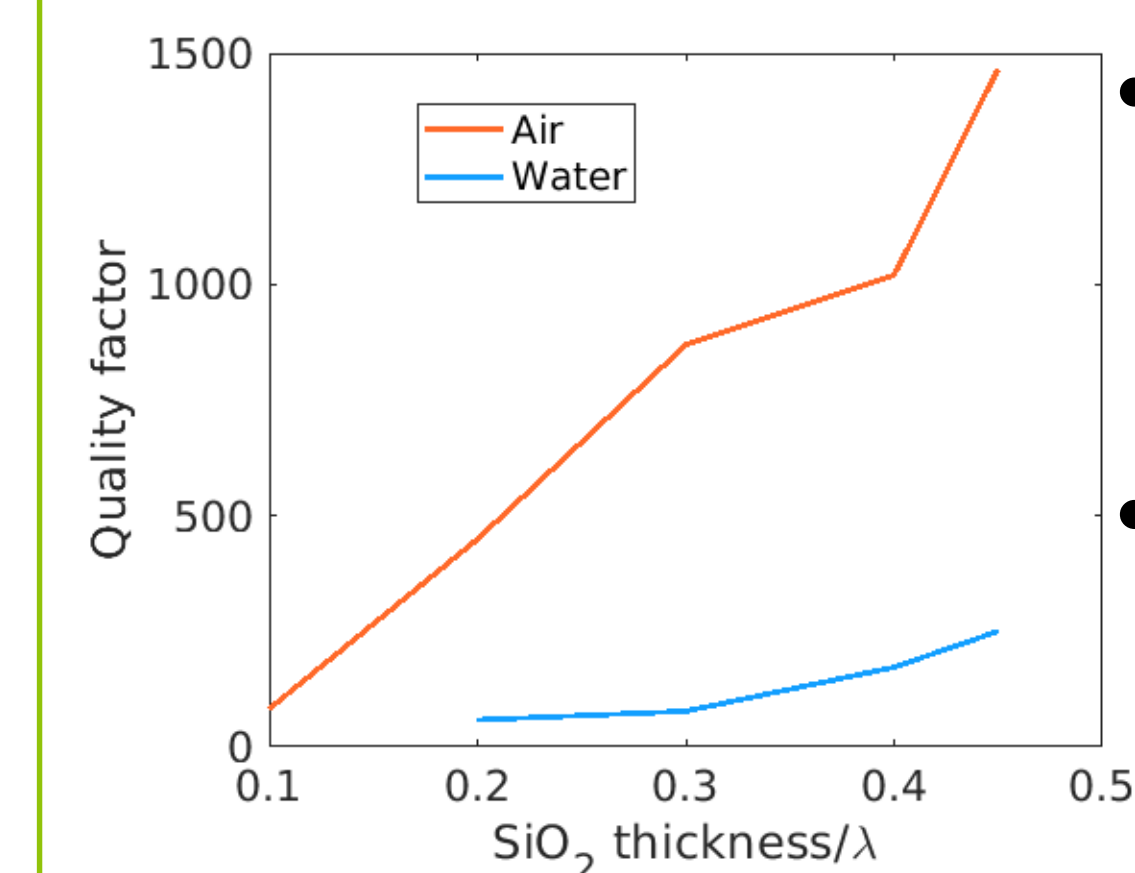
RESULTS

Love Resonator electric response
Simulation Experiment



Comparison of the calculated harmonic admittance with the electric response of Love wave resonators when operating in air/water. Rayleigh wave heavily attenuated in liquid environment, as expected, given its vertical displacement at the fluid/structure interface.

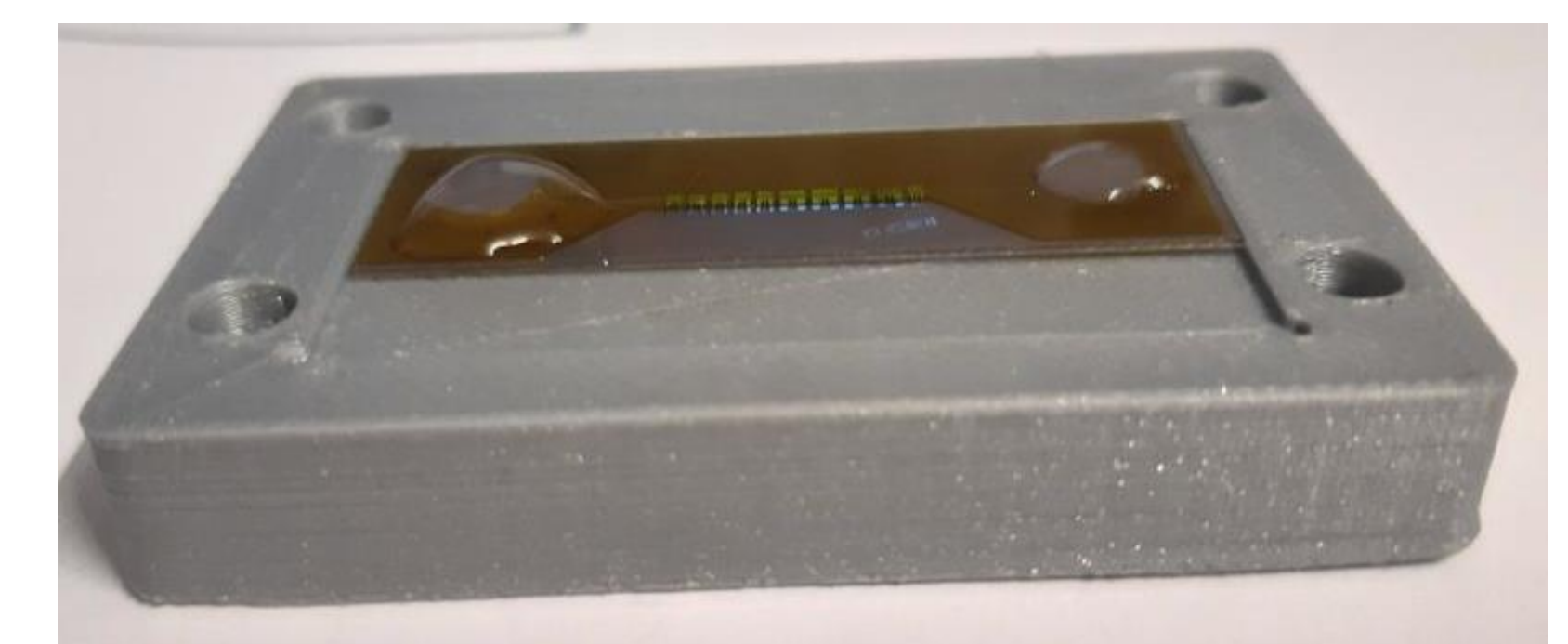
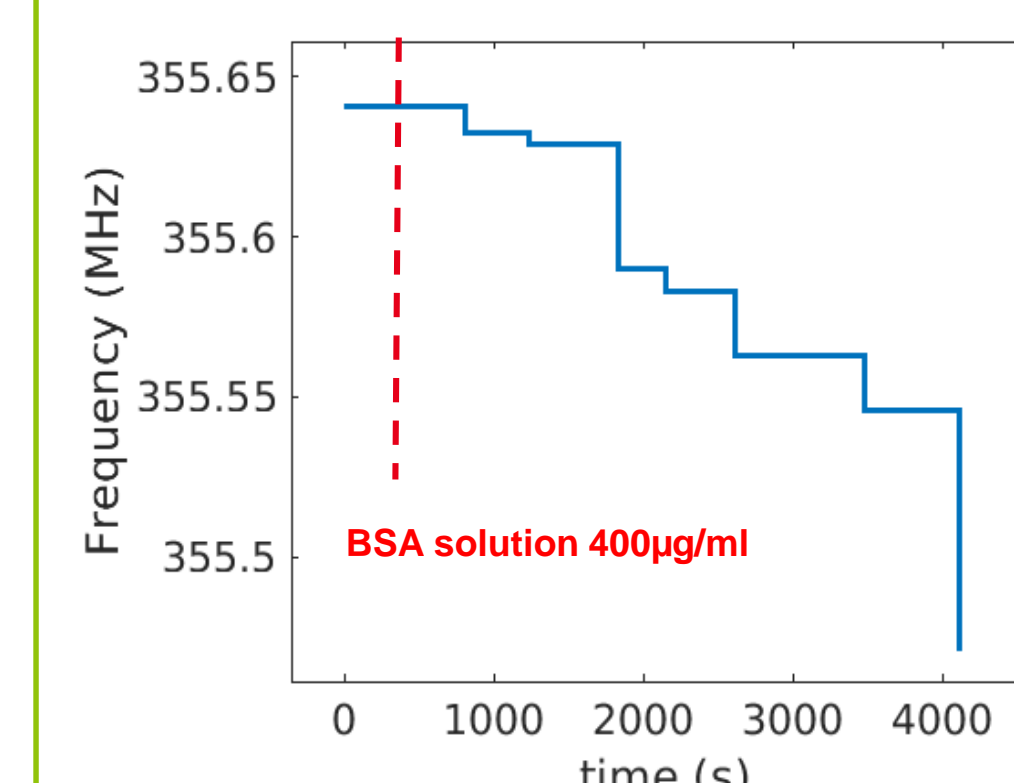
Love wave Q vs. h



- Q reduces by a factor of 10 from air to water because of viscosity
- Confirmed positive influence of increasing the SiO₂ thickness on Q-factor.

CONCLUSIONS AND PERSPECTIVES

We evaluated the electric response of the resonator in water, which heavily affects the Rayleigh wave and has a smaller impact on the Love wave. A protein detection experiment (Figure below) is in development to evaluate if the increase in Q yields better mass sensitivity/LOD. Next steps towards the biosensor are the implementation of a microfluidic channel passing over the active surface.



Biodetection experiment. Tracking the resonance frequency change during exposition to a BSA+PBS solution of 400 μg/ml