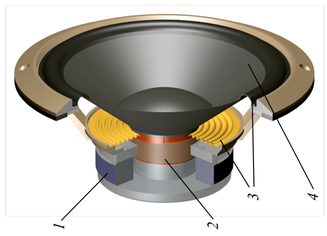
# DIELECTRIC ELASTOMER LOUDSPEAKERS

Can we use silicone membranes as loudspeakers ?

## MOTIVATION

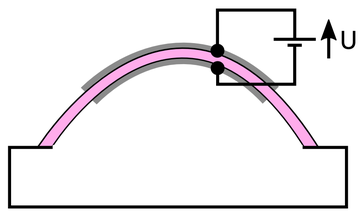
**STANDARD LOUDSPEAKERS**

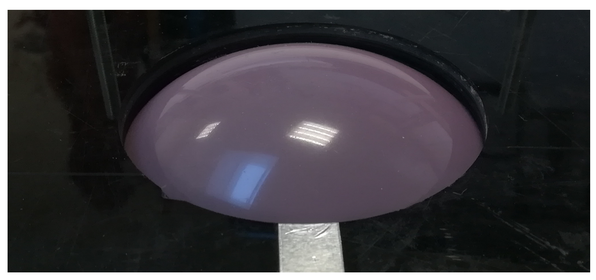



KG

Heavy & Thick

**DIELECTRIC ELASTOMER LOUDSPEAKERS**

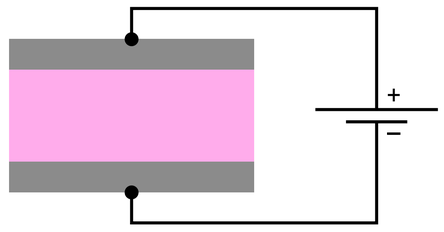


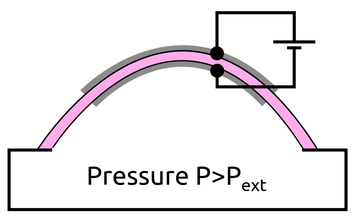



Thin & Lightweight

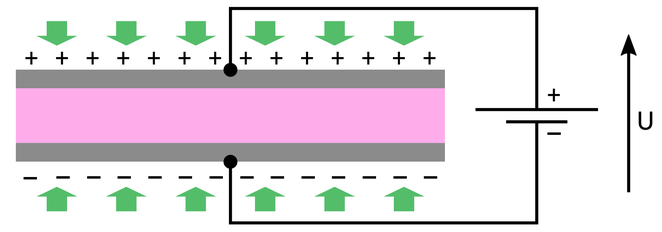
## DIELECTRIC ELASTOMER PRINCIPLE

**VOLTAGE OFF**

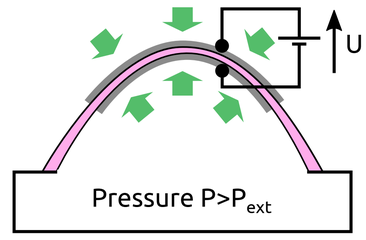



**VOLTAGE ON**




Voltage




Increased volume

Acoustic volume source

Electro-static pressure

Silicone membrane

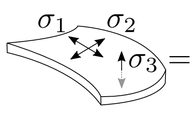
Conductive grease

## MODEL

**TOTAL CAUCHY STRESS TENSOR**

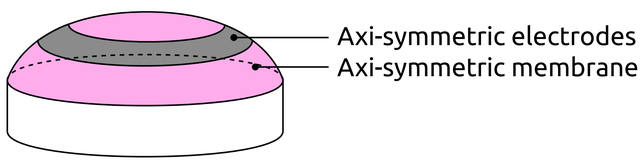
$$\boldsymbol{\sigma} = \underbrace{2\rho_0 \boldsymbol{F}.\frac{\partial \phi_0}{\partial \boldsymbol{C}}.\boldsymbol{F}^T}_{\text{Mechanics}} + \underbrace{\epsilon \boldsymbol{e}\otimes\boldsymbol{e} - \frac{\epsilon}{2}\boldsymbol{e}.\boldsymbol{e}\boldsymbol{I}}_{\text{Electrostatics}} - \underbrace{\lambda \boldsymbol{I}}_{\text{Incompressibility}}$$

**MEMBRANE MECHANICS**




$= 0$ : Plane stress

**AXI-SYMMETRIC MODEL**



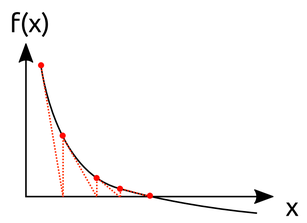

## NUMERICAL SOLVING

**STATIC EQUILIBRIUM**

(Applied pressure P and voltage U)

Large deformations

Non-linear finite elements in FreeFem ++ (Newton-Raphson method)



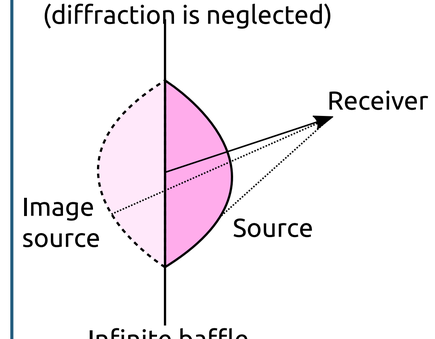

**DYNAMICS**

Linear modal analysis around the non-linear static equilibrium

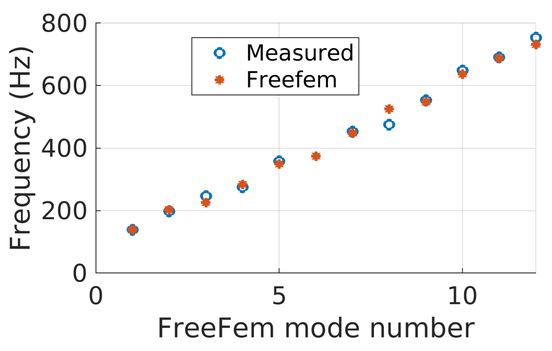
- Eigen-frequencies
- Modeshapes
- Electrostatic modal forces

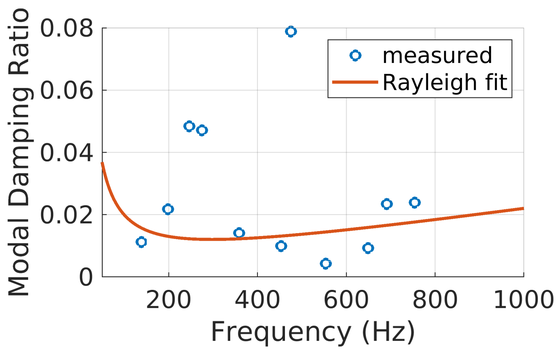
**ACOUSTICS**

Modified Rayleigh integral for the radiation of curved surfaces (diffraction is neglected)

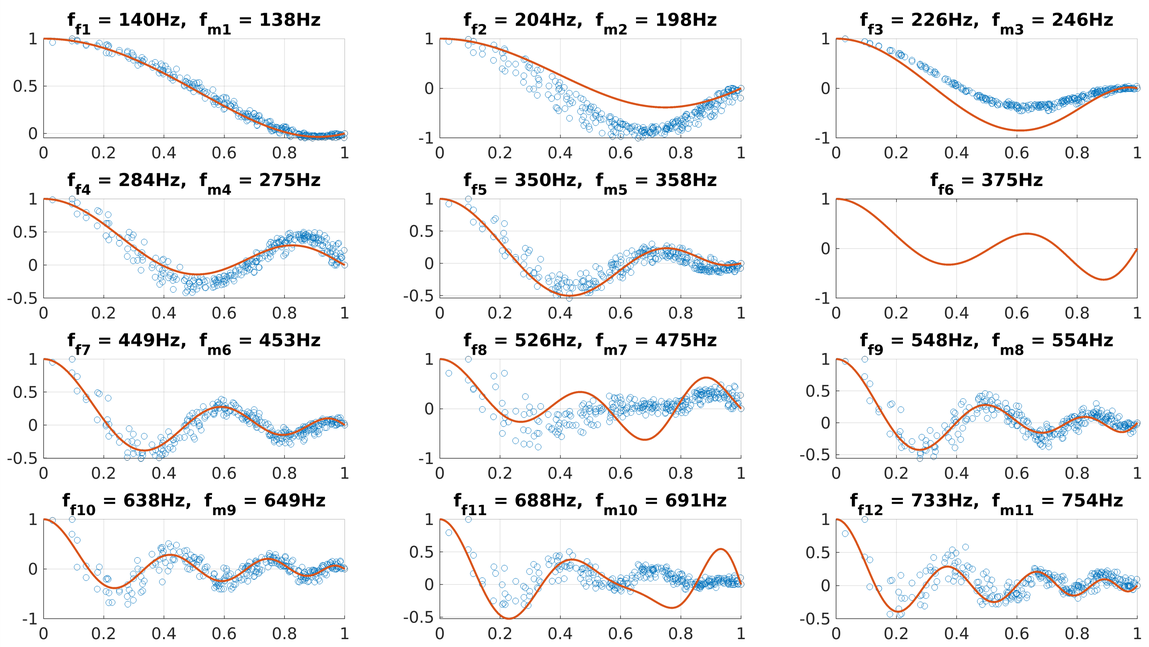



## MODAL PARAMETERS



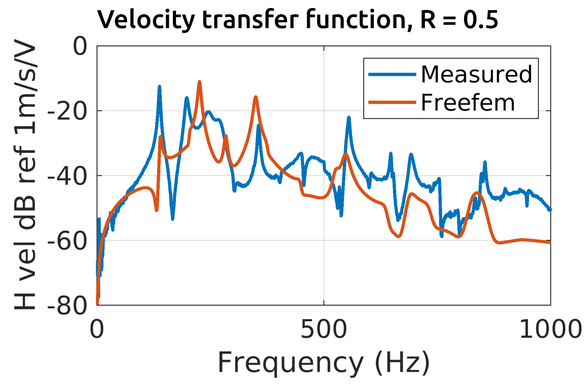

## MODESHAPES

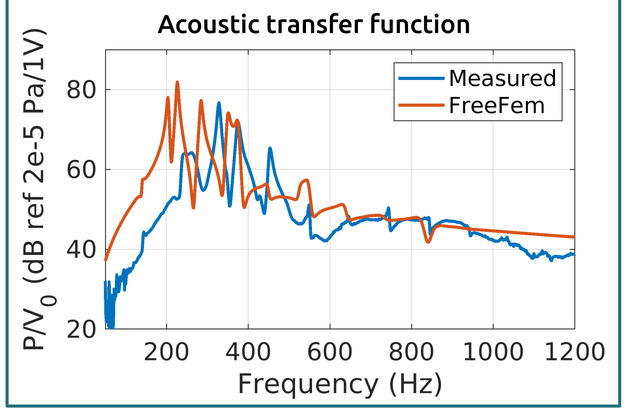



x-axis : Non-dimensional radius. y-axis : Normalized modeshape amplitude.

Measured modes, Computed modes $f_f$ : computed $f_m$ : measured

## FREQUENCY RESPONSE



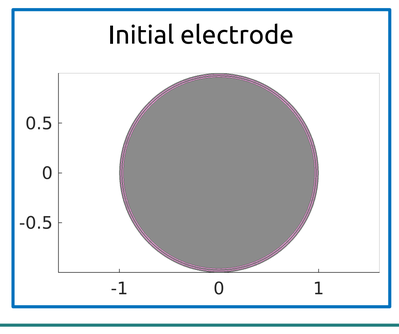



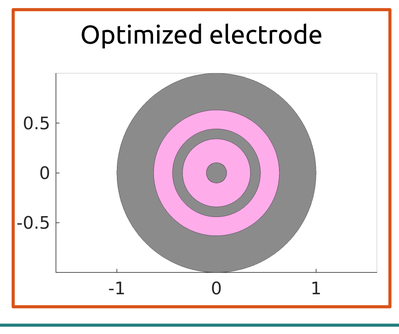

## OPTIMIZATION

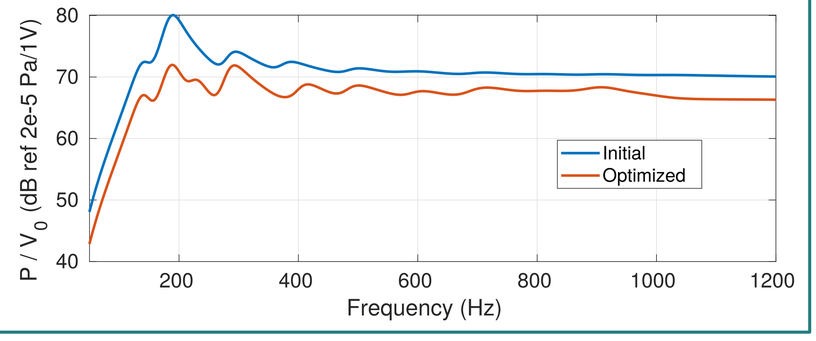
**OPTIMIZATION CRITERION**

Minimize the Sound Pressure Level fluctuations

$$\phi_{SPL} = \sqrt{\frac{\sum (SPL_{f_k} - SPL_0)^2}{N_{f_k}}}$$





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