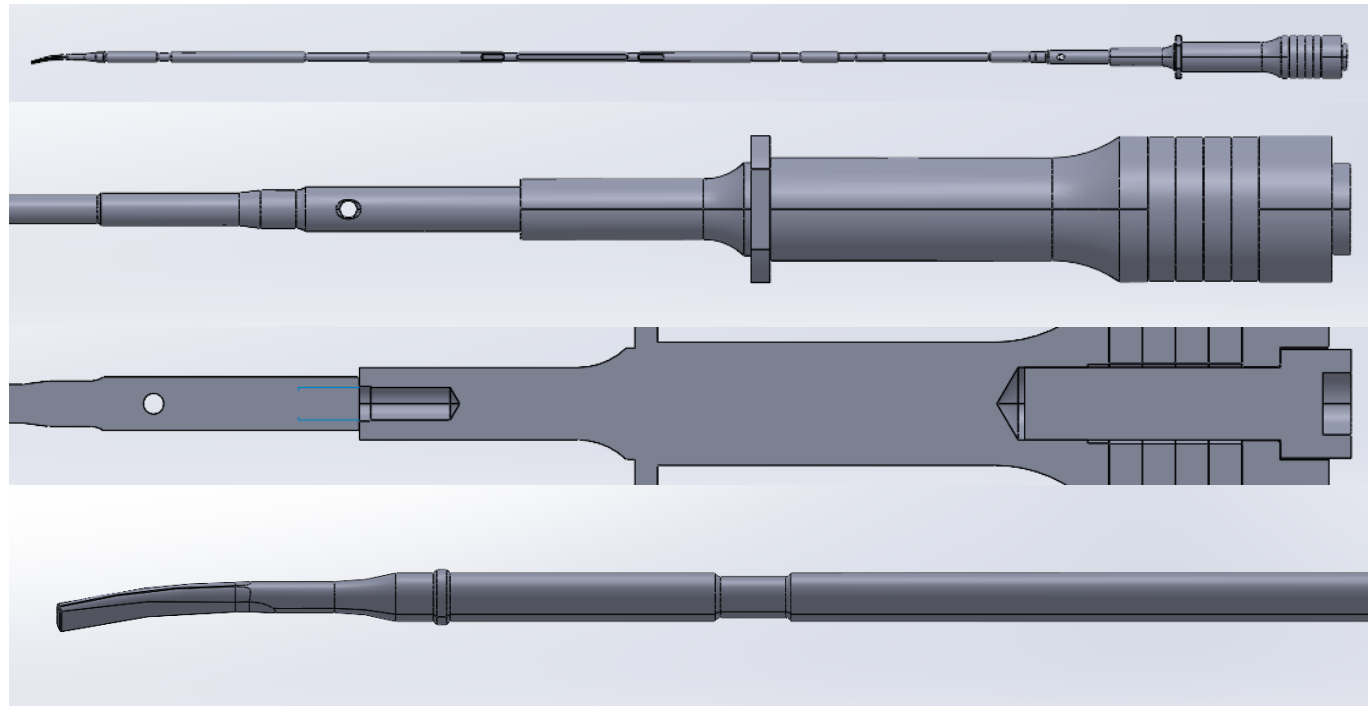
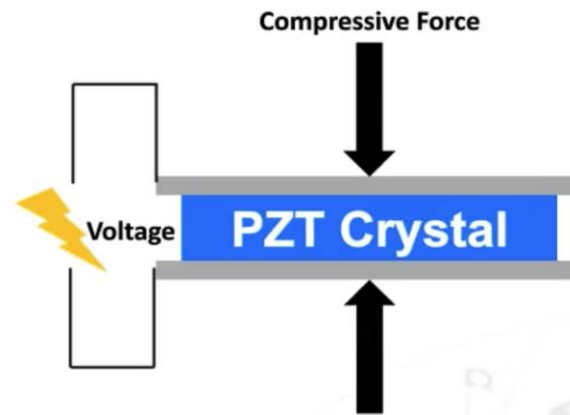


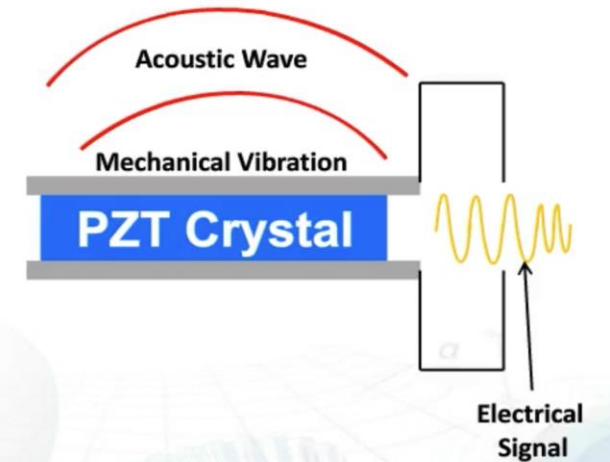
Transducer Design



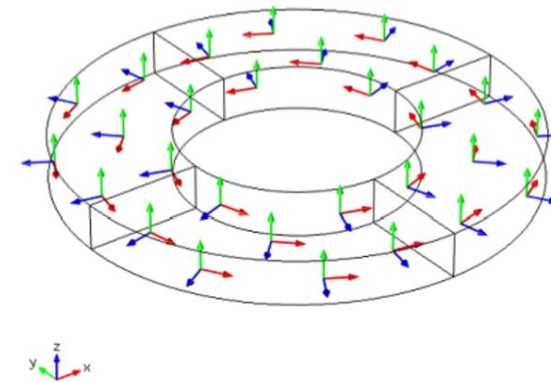
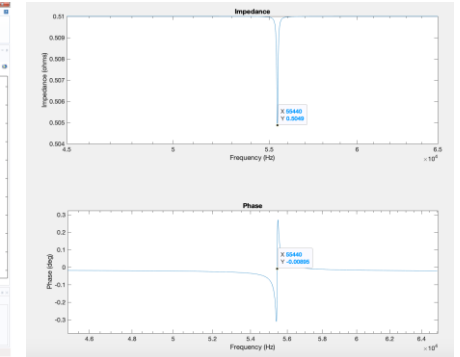
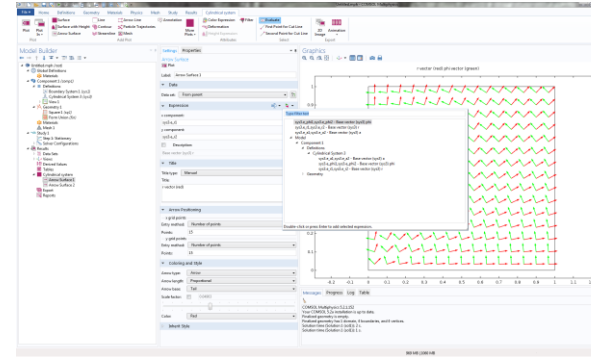
Direct Effect



Inverse Effect



COMSOL Simulation



Base Vector System

Coordinate System Identifier

Identifier: sys2

Settings

Coordinate names

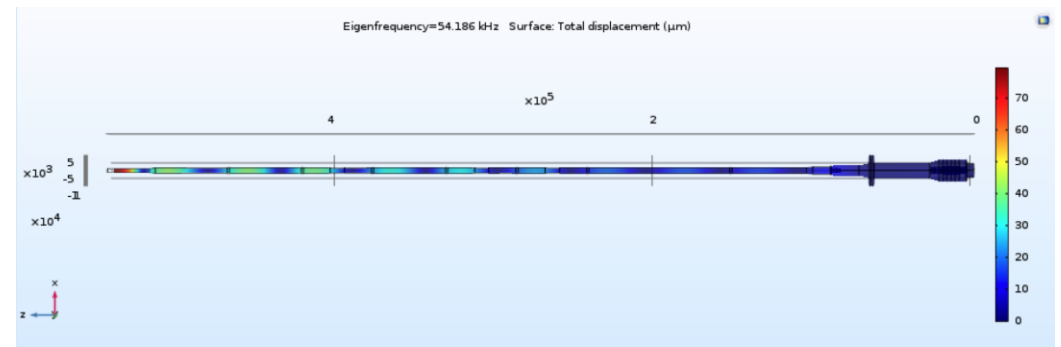
First (x1)	Second (x2)	Third (x3)
x1	x2	x3

Base vectors

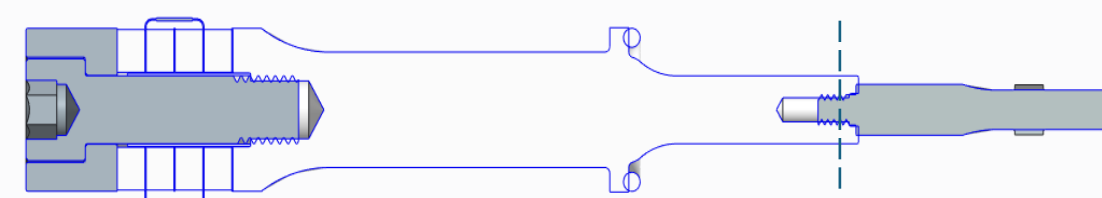
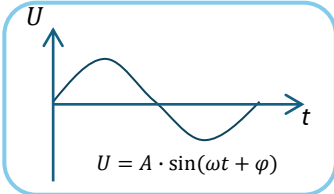
	x	y	z
x1	$-\sin(\text{atan2}(Y,X))$	$\cos(\text{atan2}(Y,X))$	0
x2	0	0	1
x3	$\cos(\text{atan2}(Y,X))$	$\sin(\text{atan2}(Y,X))$	0

Simplifications

Assume orthonormal

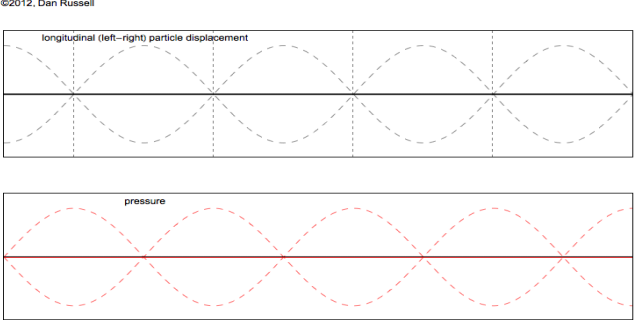
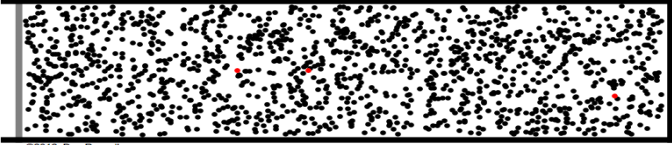


Acoustic Components

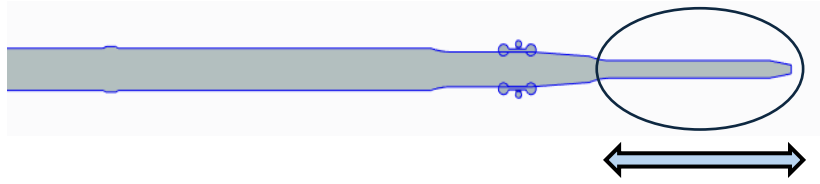
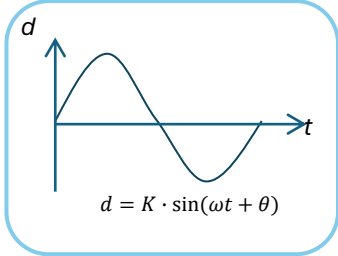


↔
Inverse Piezoelectric Effect

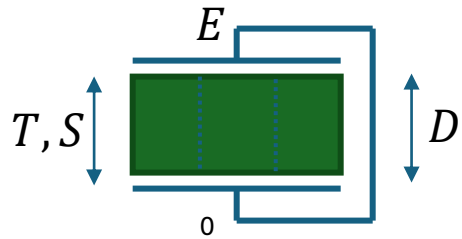
TRANSDUCER



WAVEGUIDE (PROBE)



Piezoelectric Equation



- T Stress
- S Strain
- E Electric Field Intensity
- D Electric Displacement

Equation Type	Mechanical	Electrical	Variables	Value	Expressions (Tensor Form)
1	Free	Short Circuit	T, E	S, D	$S_k = s_{ki}^E T_i + d_{kj} E_j$ $D_l = d_{li} T_i + \epsilon_{lj} E_j$
2	Constrained	Short Circuit	S, E	T, D	$T_i = C_{ik}^E S_k - e_{ij}^E E_j$ $D_l = e_{lk} S_k + \epsilon_{lj} E_j$
3	Free	Open Circuit	T, D	S, E	$S_k = s_{ki}^D T_i + g_{kl} D_l$ $E_j = g_{ji} T_i + \beta_{jl} D_l$
4	Constrained	Open Circuit	S, D	T, E	$T_i = C_{ik}^D S_k - h_{il} D_l$ $E_j = h_{jk} S_k + \beta_{jl} D_l$

Piezoelectric-Strain Const.

$$d_{li} = \epsilon_{lj}^T g_{ji} = e_{lk} s_{ki}^E$$

Piezoelectric-Stress Const.

$$e_{li} = \epsilon_{lj}^S h_{ji} = d_{lk} C_{ki}^E$$

Piezoelectric-Voltage Const.

$$g_{li} = \beta_{lj}^T d_{ji} = h_{lk} s_{ki}^D$$

Piezoelectric-Stiffness Const.

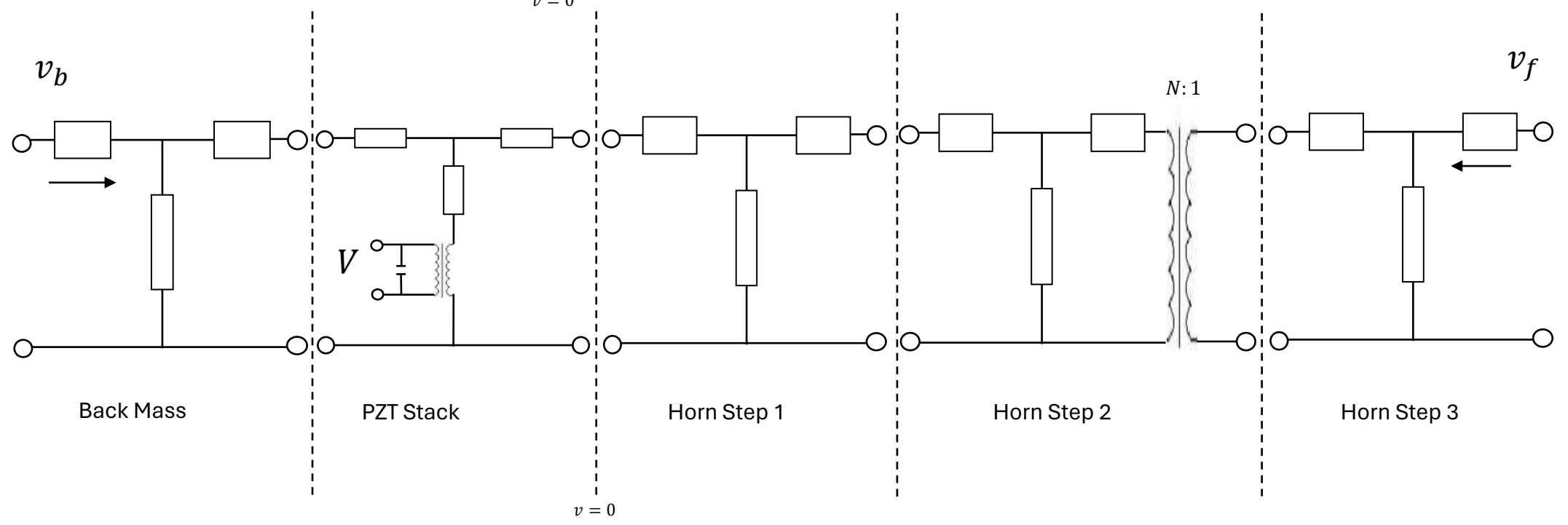
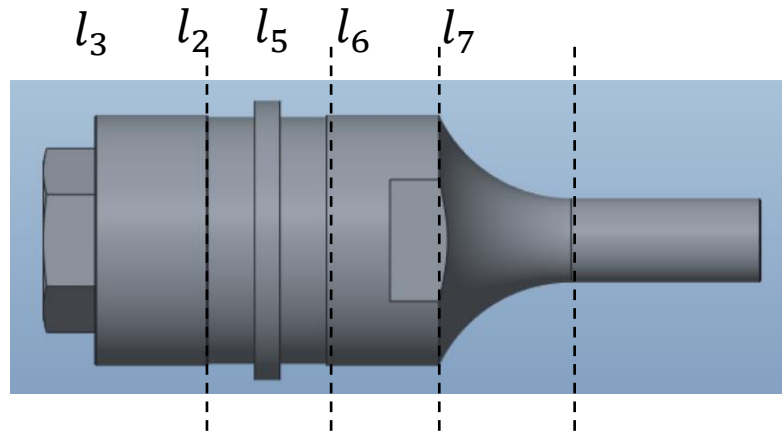
$$h_{li} = \beta_{lj}^S e_{ji} = g_{lk} C_{ki}^D$$

* $k = 1, 2, \dots, 6$; $i = 1, 2, \dots, 6$; $l = 1, 2, 3$; $j = 1, 2, 3$.

* s_{ki}^E Compliance Matrix

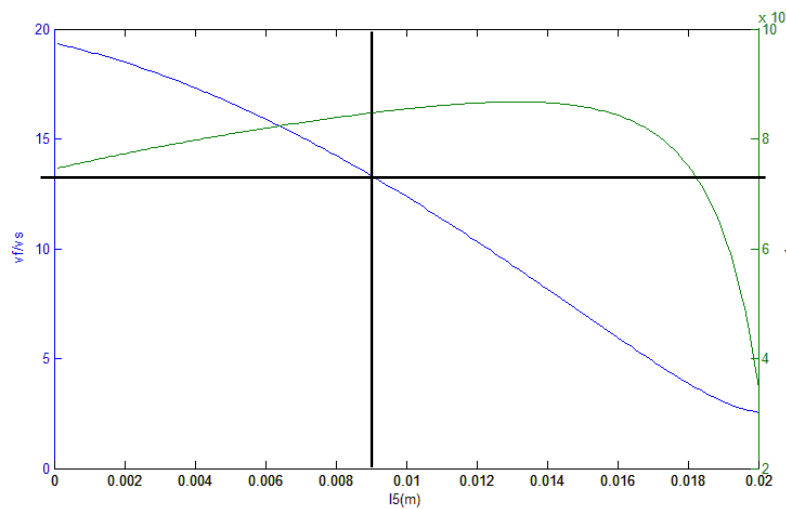
* C_{ik}^E Stiffness Matrix * β_{ij} Dielectric Impermeability Matrix

Equivalent Circuit----- $\frac{\lambda}{4}$ Wave Length Transducer

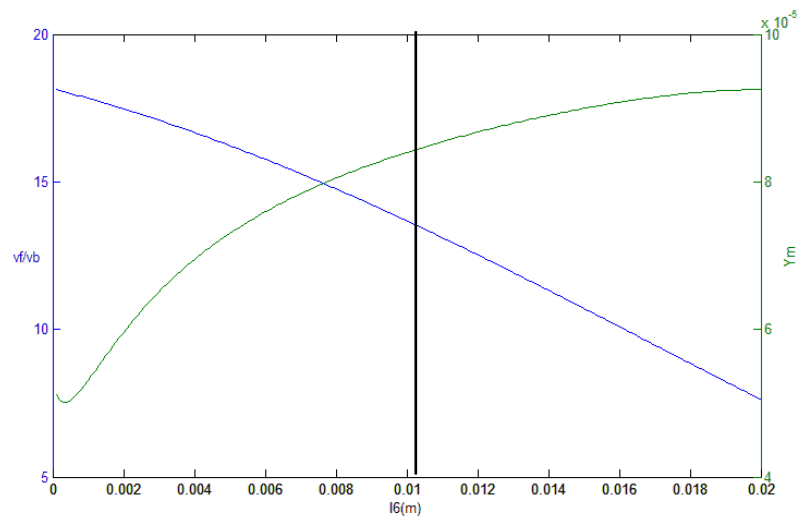


Matlab Iteration

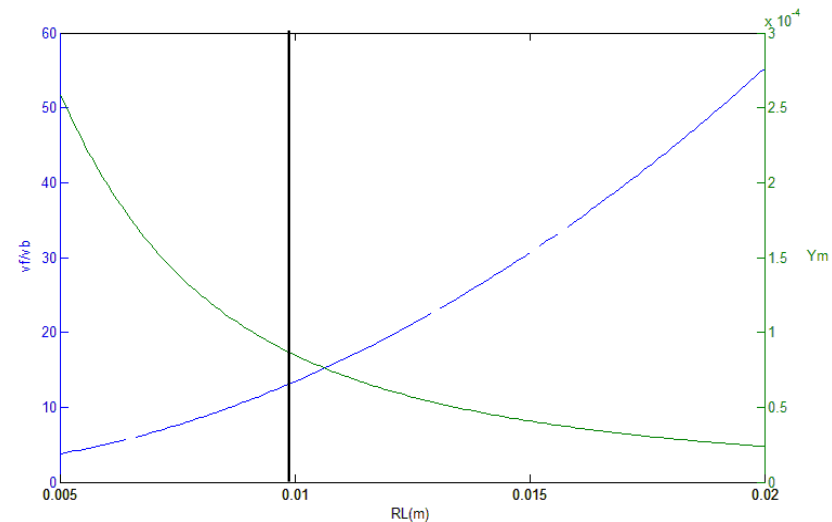
$v_f/v_b \approx 13.4$



$l_5 = 8.8\text{mm}$



$l_6 = 10.4\text{mm}$



$RL = 9.4\text{mm}$

