Progress towards an electro-acoustic resonance technique for determining quantitative material and geometrical properties in high contrast multi-layer elastic structures.

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Overview

- Background
- Development
- Experimental
- Current Results

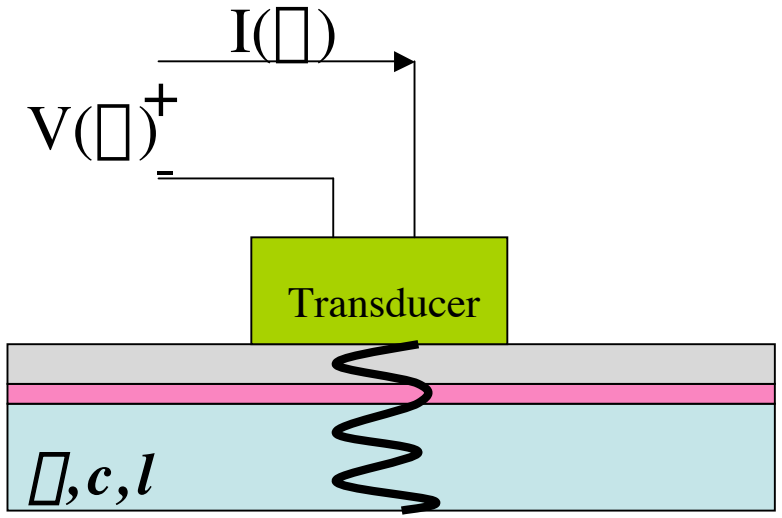
Background

Basic Concept: By driving the Transducer at a sinusoidal voltage, V(ω) an elastic standing wave pattern, (mechanical mode) is created in each layer. The current, I(ω) into the transducer can be simultaneously measured. The resulting *ratio* is the total electrical impedance, $Z_{TOTAL}(\omega)$ of the **entire** system.

$$Z_{TOTAL}(\omega) = \frac{V(\omega)}{I(\omega)}$$

$$Z_{TOTAL}(\omega) = \left[\frac{1}{\omega C_o} + f_n \left[\tan\left(\frac{\omega}{c_n} l_n \right) \right] \right]$$

"electrical" "mechanical"

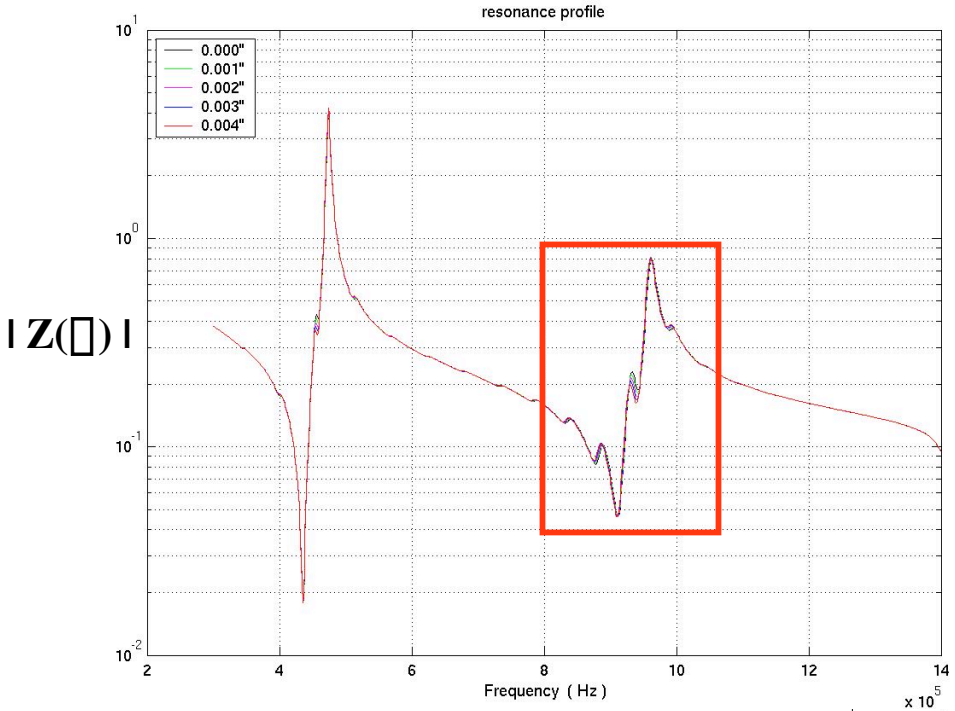


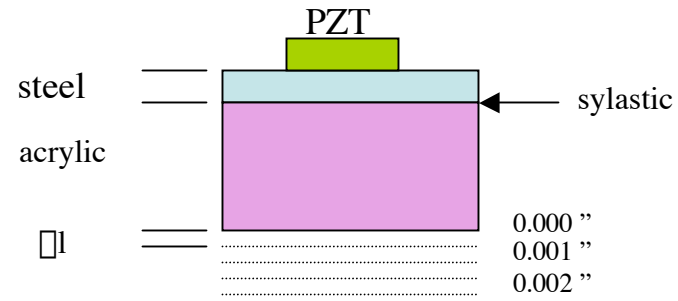
elastic standing-wave pattern

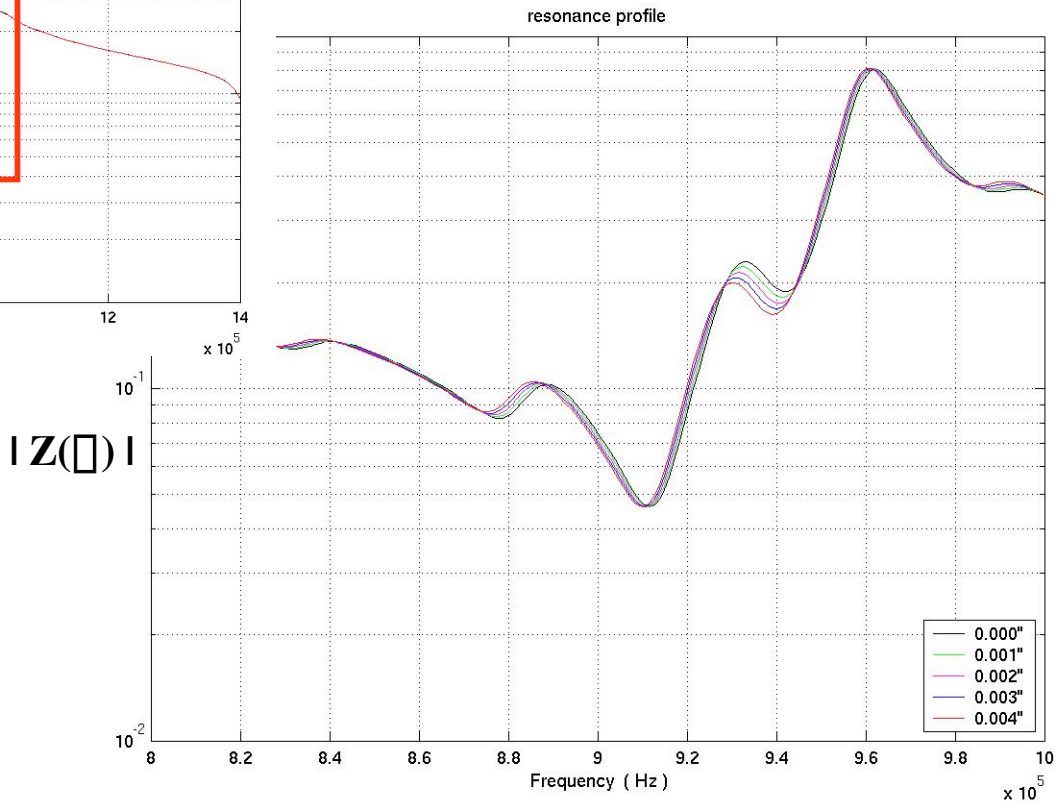
- At a mechanical resonance

$$\frac{\omega}{c_n} l_n = \pi(2m+1) \qquad I(\omega_n) \longrightarrow 0, \text{ and } Z_{TOTAL}(\omega_n) \longrightarrow \text{'BIG'}$$

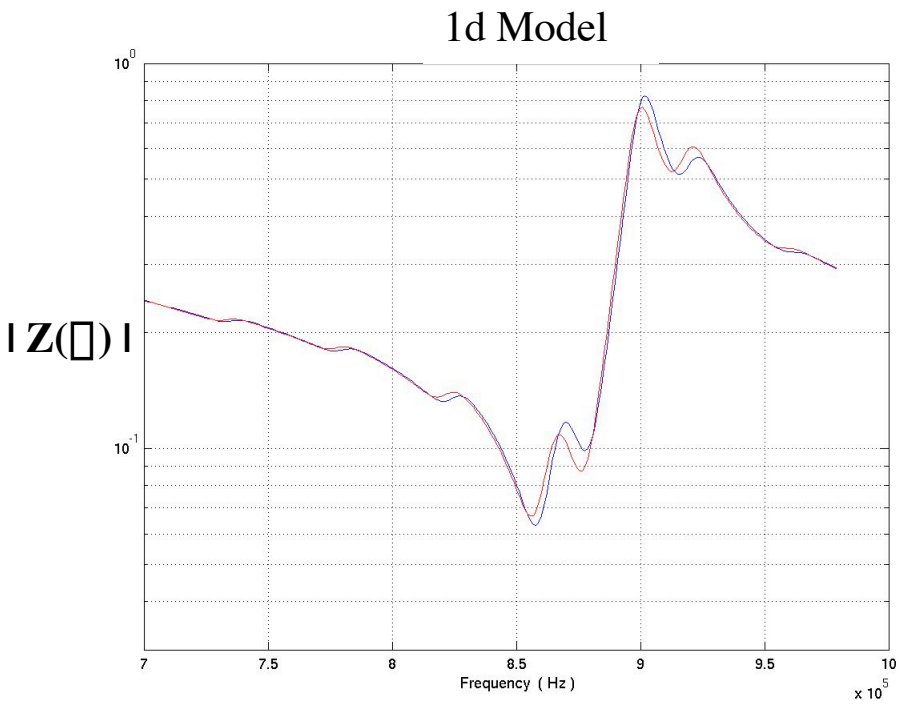
Impedance sizing study

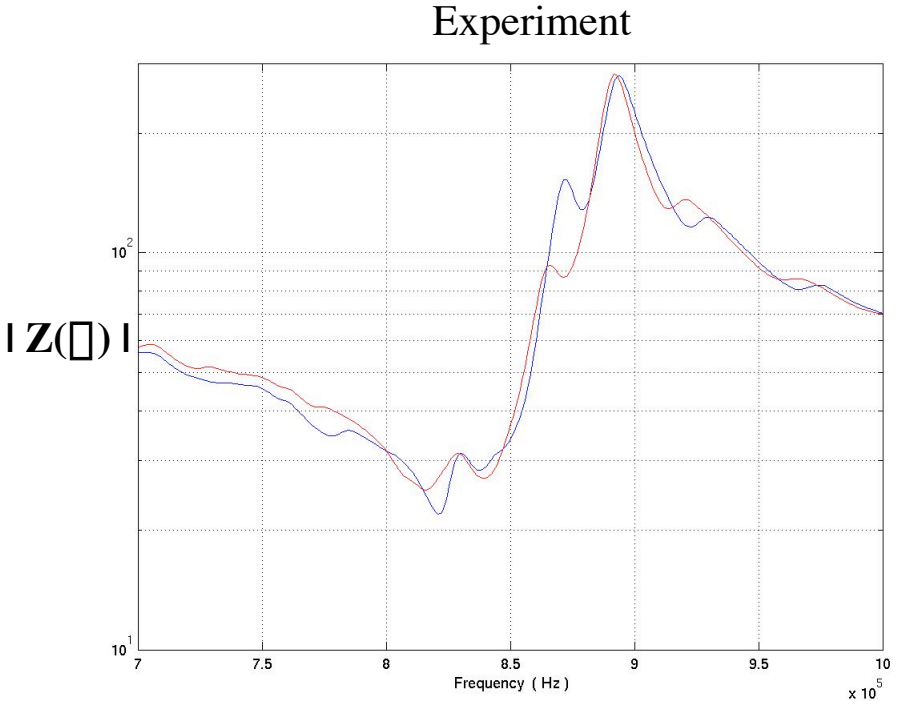






1d Model and 3d Measurements

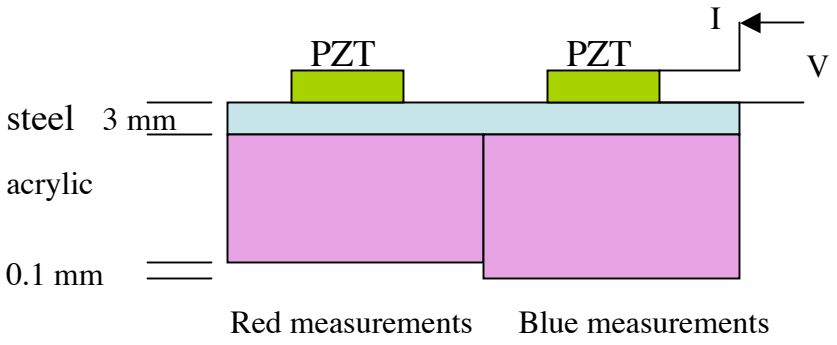




Acrylic Thickness

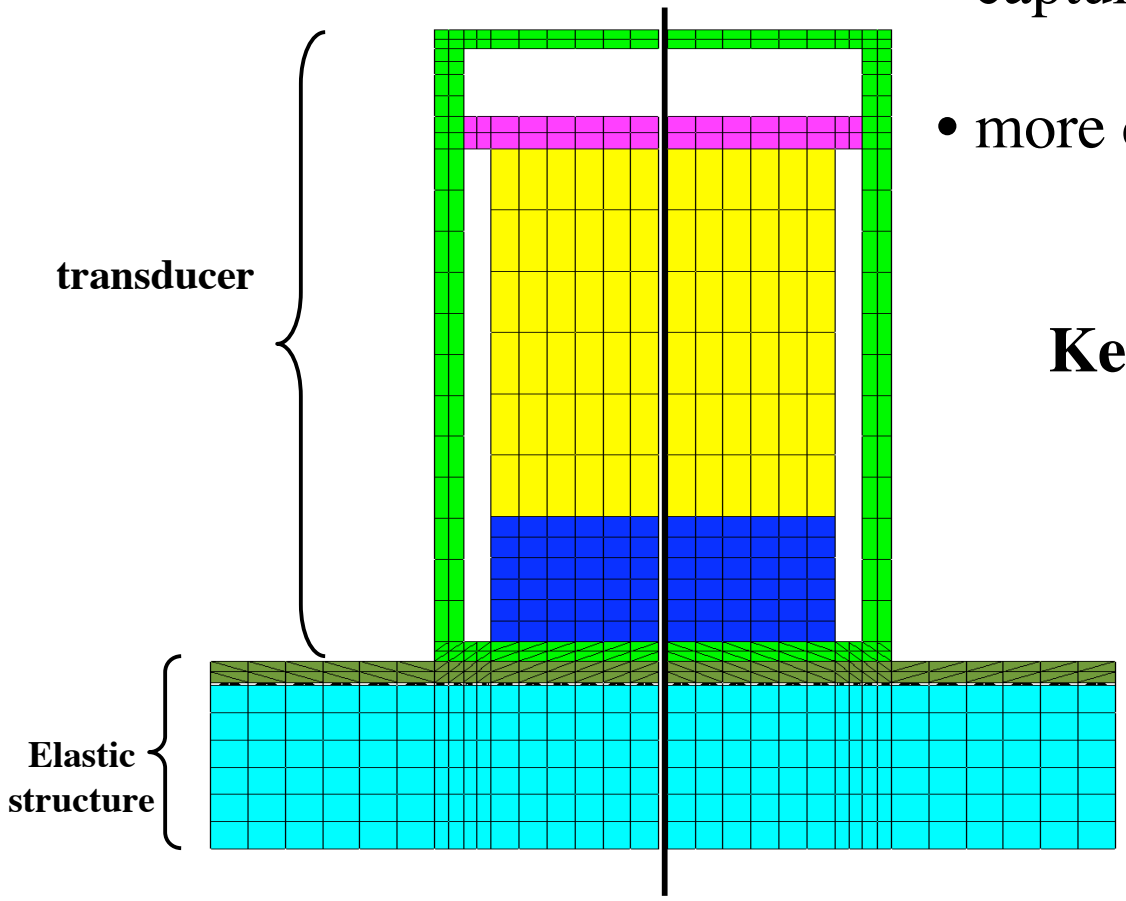
Blue line : 30.0 mm

Red line : 29.9 mm



Impedance measurement: consisting of a transducer and a network analyzer

2d Axisymmetric Transducer model

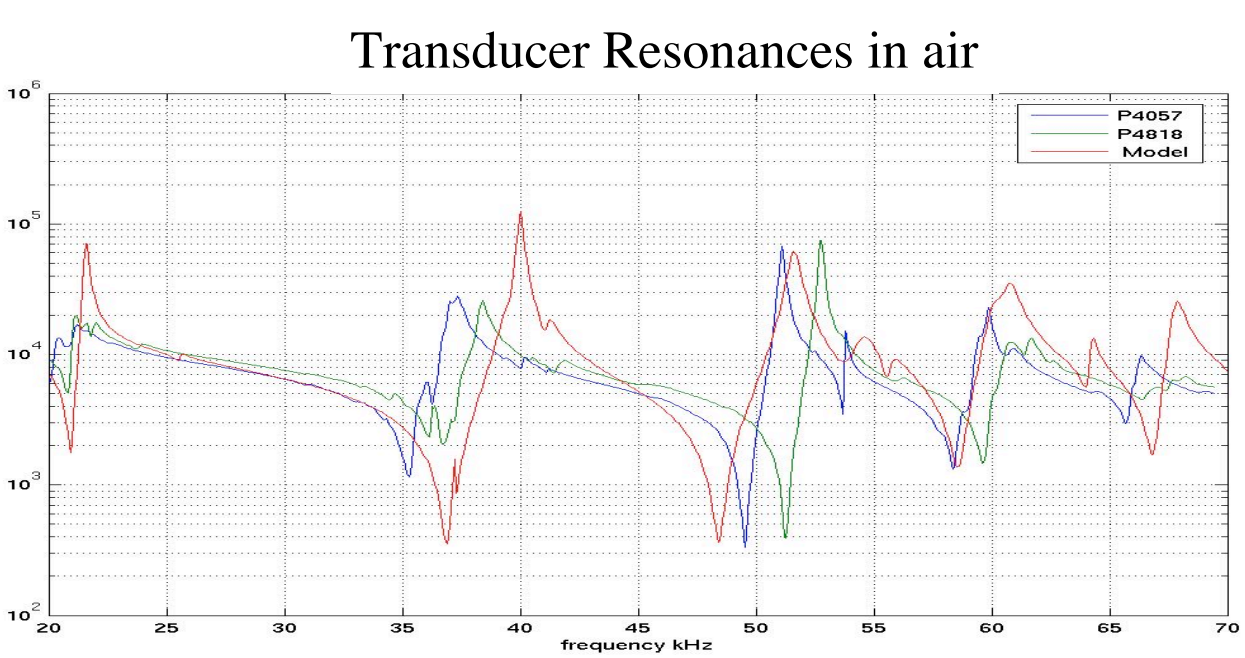


- improved lateral mode model
- capture more ‘physics’
- more computationally expensive

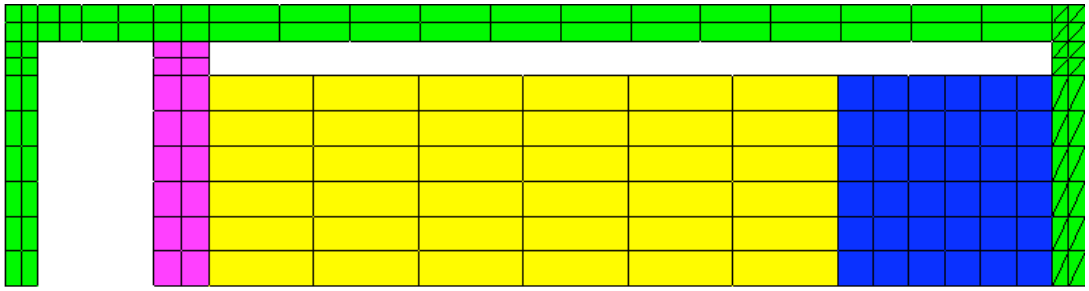
Key:

- steel
- brass
- PZT4
- phenolic
- acrylic
- silicone rubber
- aluminum

Axi-symmetric Model and Experimental measurements



model
data set 1
data set 2



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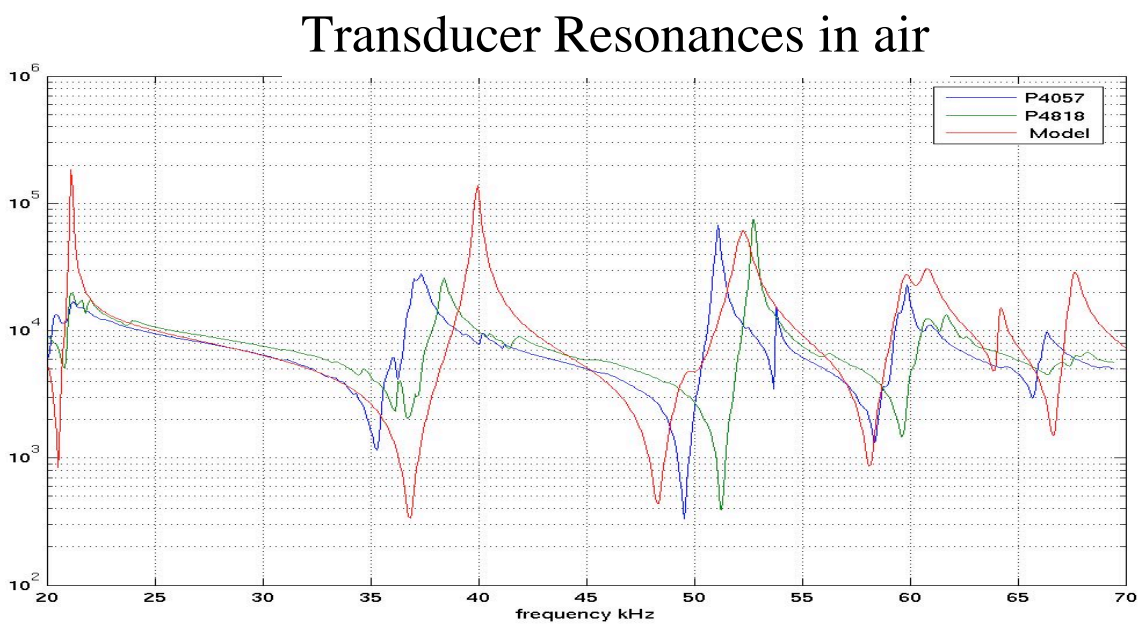

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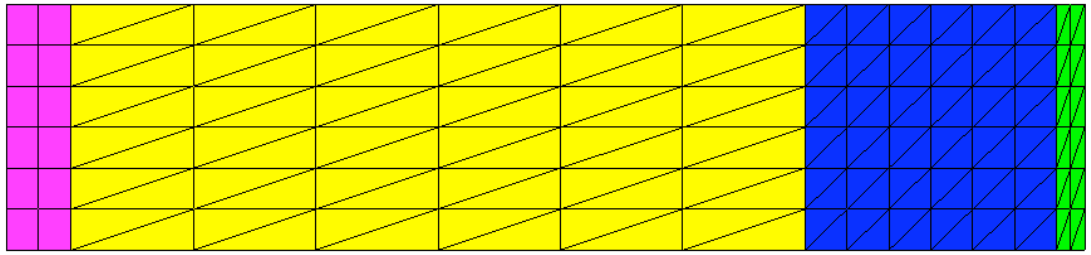
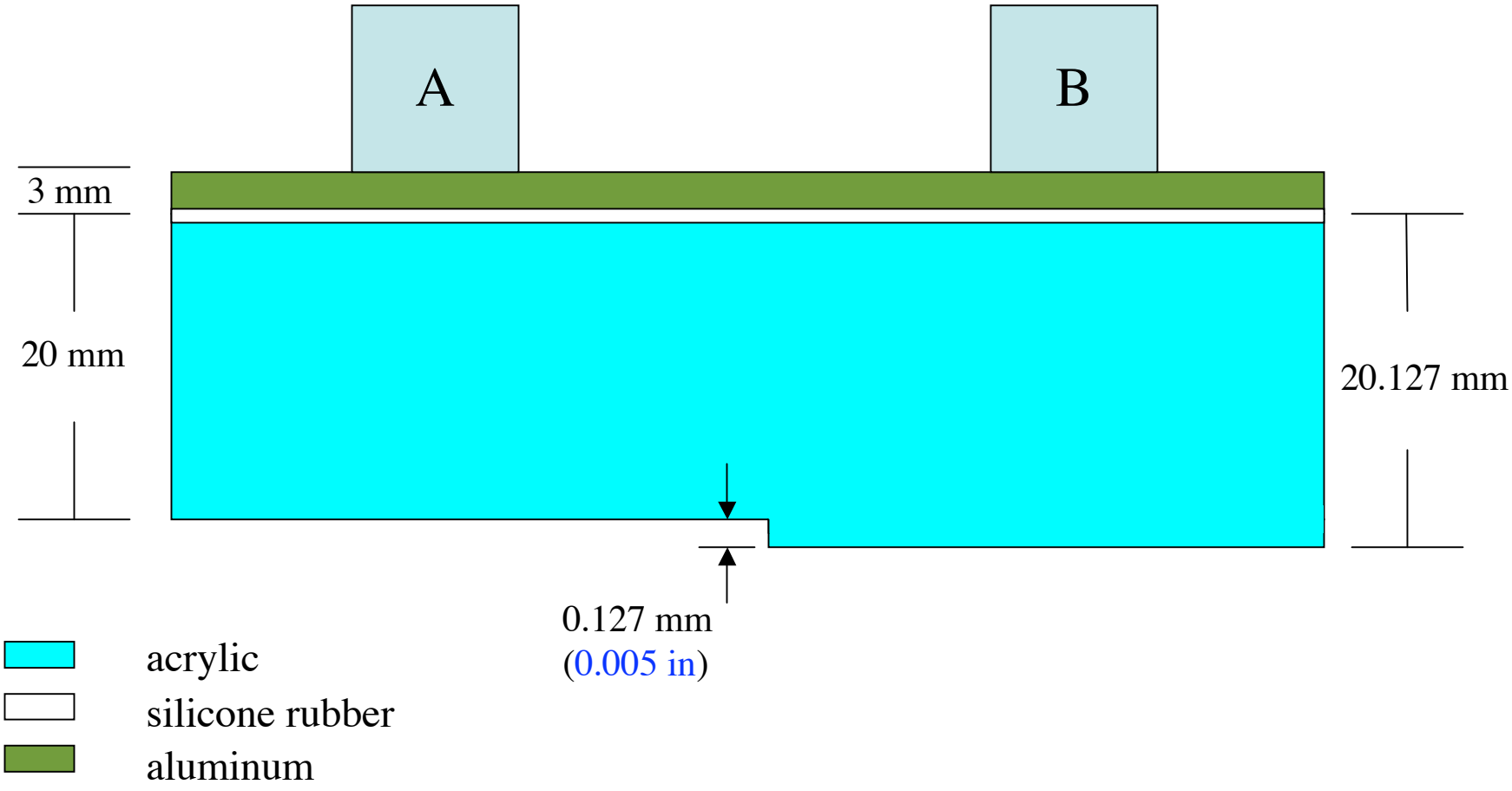
data set 2

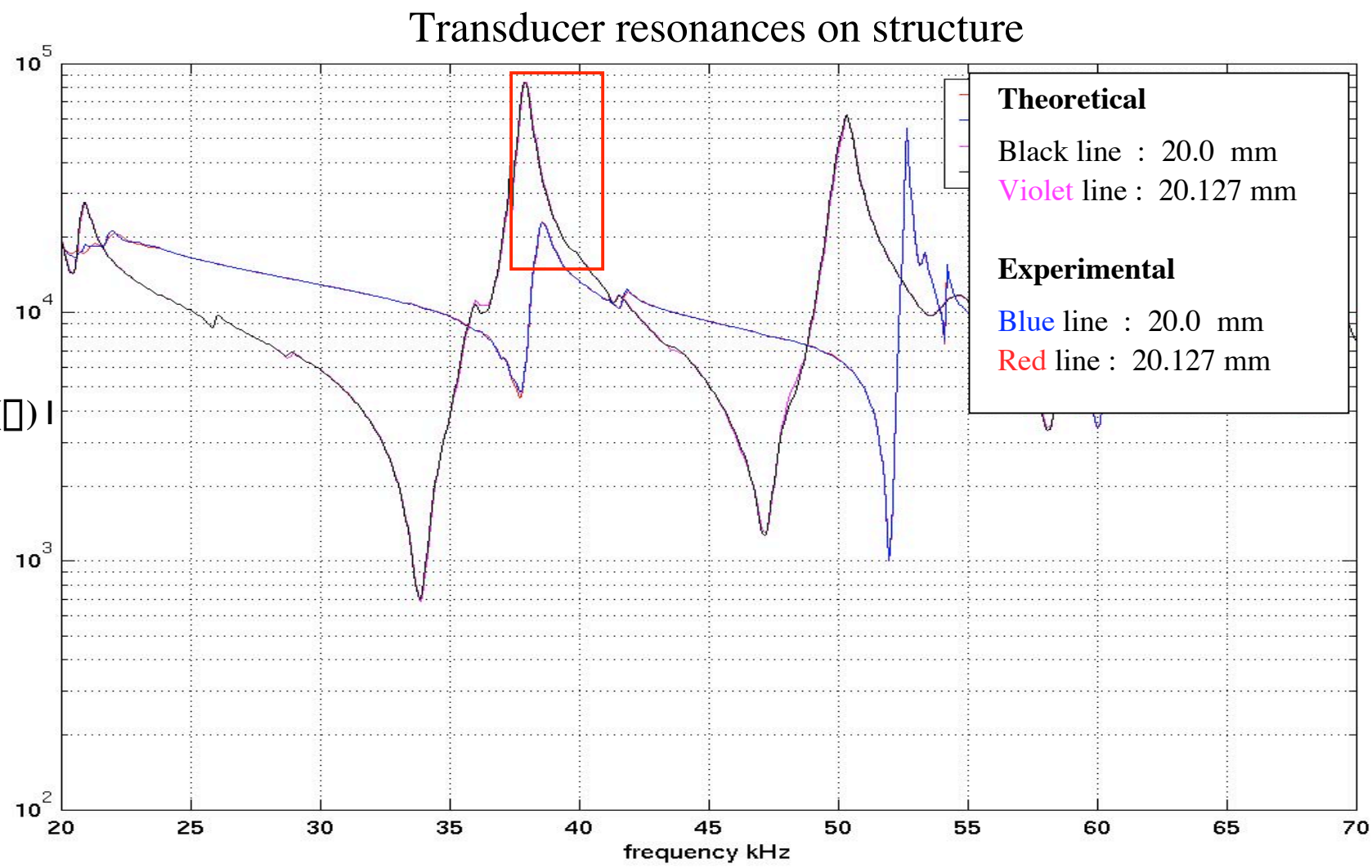


Calibrated Step Phantom

Lower acrylic layer has small step change (0.127 mm) in thickness



Experimental Measurements and Theoretical Predictions



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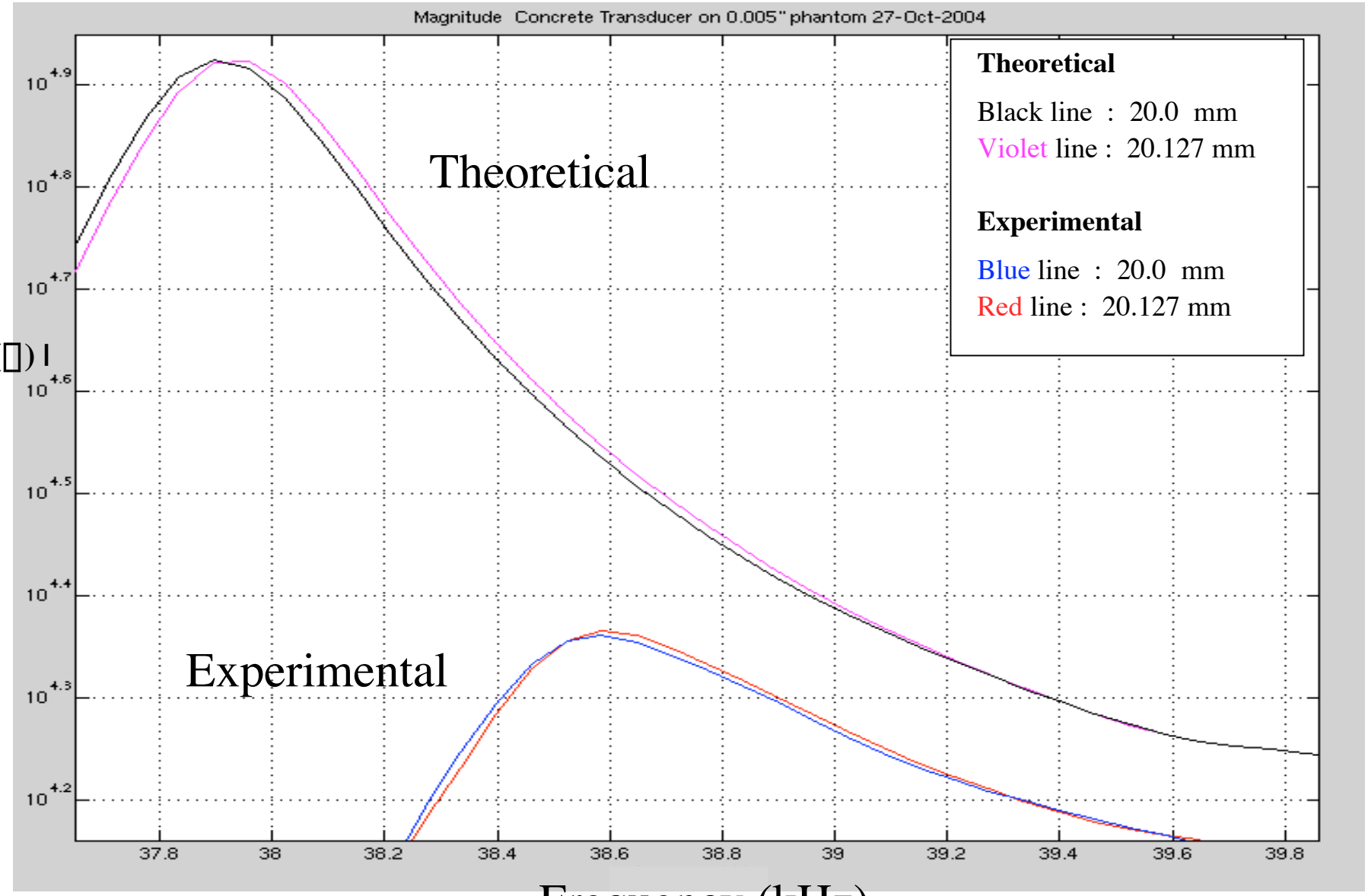

Future Work

- Develop a robust Impedance Model for the Transducer

- Used as a forward model for an *Inverse Problem*:

  Given a measured impedance profile, compute:

  - layer thicknesses in multi-layered part
  - bulk elastic properties in each layer of part