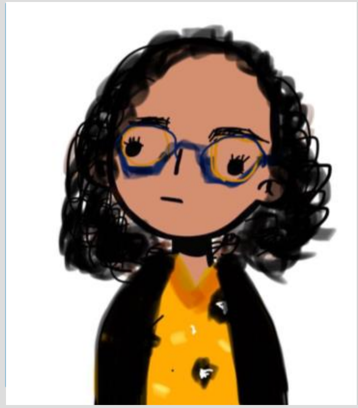
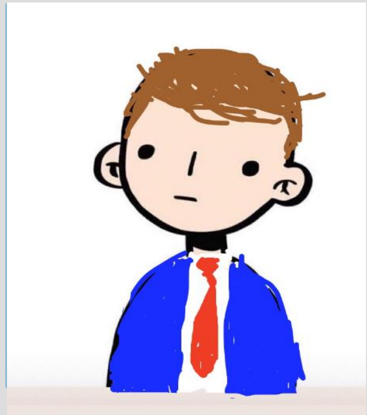
SPINAL ULTRASOUND PROBE

Group 11: Megan Fudge, Graeme Larsen, Alexa Manderville,
Sierra Sparks

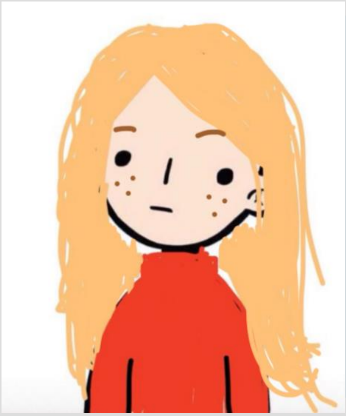
MEET THE TEAM



Sierra Sparks



Graeme Larsen



Alexa Manderville

Megan Fudge

OUTLINE

- Introduction and Background
  - Objectives, Deliverables, and Goals
- Project Management
  - Schedule
  - Task Management
  - Budget
- Detailed Design
  - Physical Modifications to the PCB
  - Cost Reduction
  - Supporting Fixtures
  - Simulations
  - Assembly Plan
- Results and Testing
  - Final PCB Images
  - PCB Production
  - Impedance Testing
  - Wrist Imaging Capability
- Analysis and Discussion
  - Successes and Limitations
  - Recommendations
- Conclusion

INTRODUCTION AND BACKGROUND

INTRODUCTION

Ultrasound imaging uses high-frequency sound waves, produced by a transducer, to view inside the body

The physical (compressive) state of nerves in the human body is used in diagnostics following spinal surgery

This surgery for the decompression of nerves in the spine has a 2-10% revision rate due to insufficient compression

Current standard of care:

- Invasive to the patient
- Blunt dissecting instruments

Project seeks to address the gap

- Imaging Probe for intraoperative use
- Enabling a minimally-invasive approach for visualization of nerve rootlets

- Sponsors/Supervising Group
  - NSHA, Daxsonics, Dalhousie Ultrasound Group

Daxsonics Endoscopic US imaging probe

OBJECTIVES & DELIVERABLES

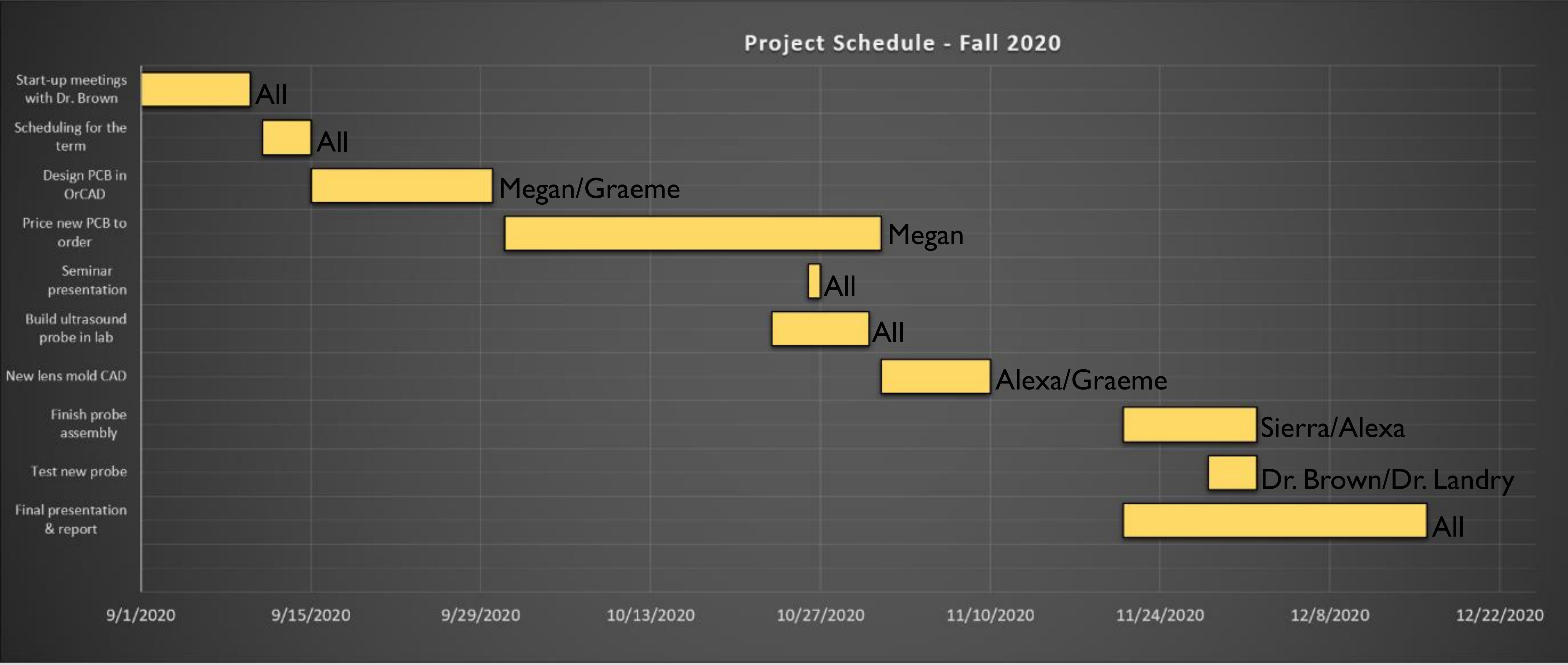
DESIGN OBJECTIVES

- 36 MHz Miniature Ultrasound Transducer
  - Altered viewing angle
  - Increased length
  - PCB cost minimization via alternative production methods
- Supporting fixtures
  - New silicone application process
  - Increased size of lens mold

PRODUCT DELIVERABLES

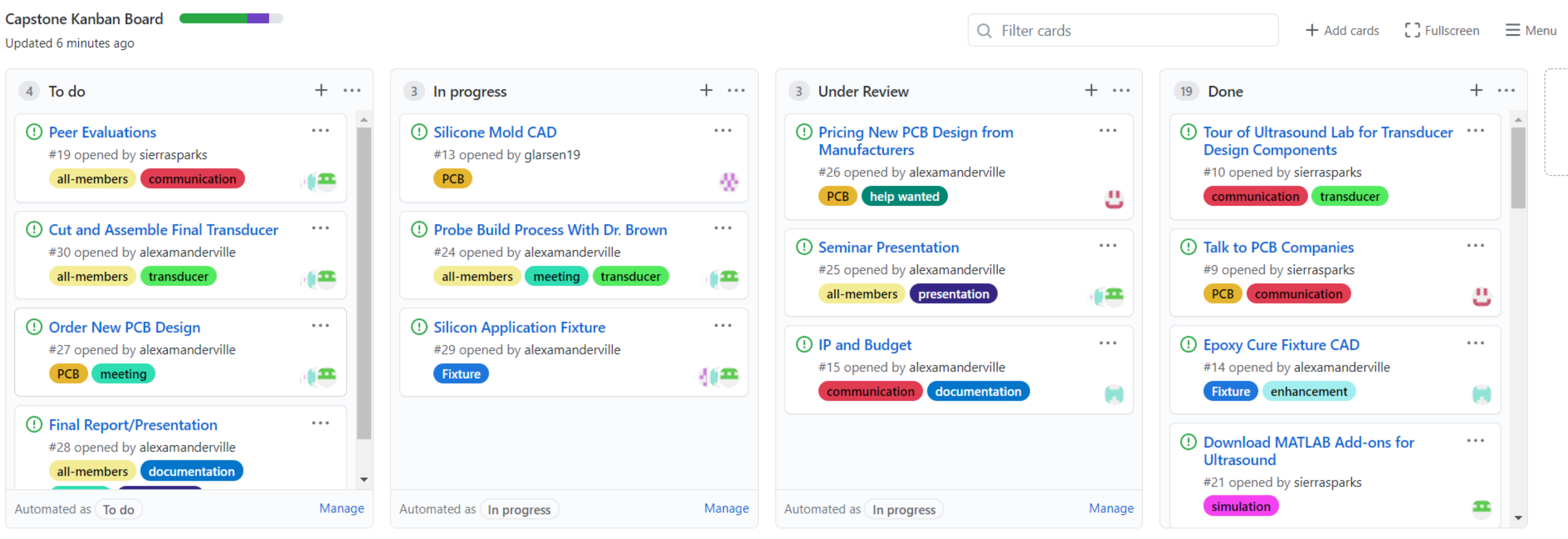
- Updated PCB
- New lens mold
- Fully-assembled transducer prototype
- Real and simulated impedance and pulse shape analysis

PROJECT MANAGEMENT



PROJECT SCHEDULE – FALL 2020

TASK MANAGEMENT



- GitHub and the ‘Kanban’ method used to organize project tasks
- Communications were facilitated via email and Microsoft Teams
- Probe build is being completed in Dr. Brown's ultrasound lab

Item	Quantity	Unit Cost	Total Cost
PCB Fabrication	5	$300 - $1000	$1500 - $5000
Teflon Mold	1	$200	$200
Piezoelectric Wafer	1	$120	$120
Resin	1 bucket	$50	$50
Booking 3D Printer	1	$80	$80
TOTAL			$1950 - $5450

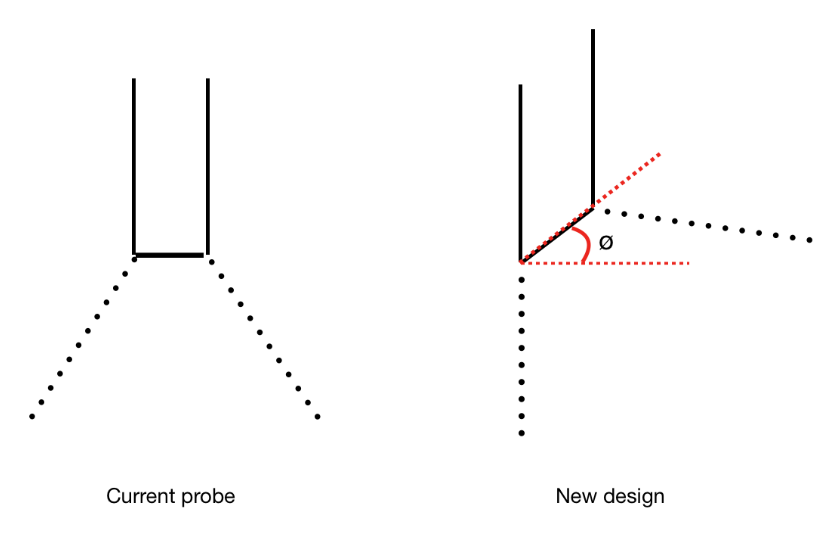
BUDGET

DESIGN

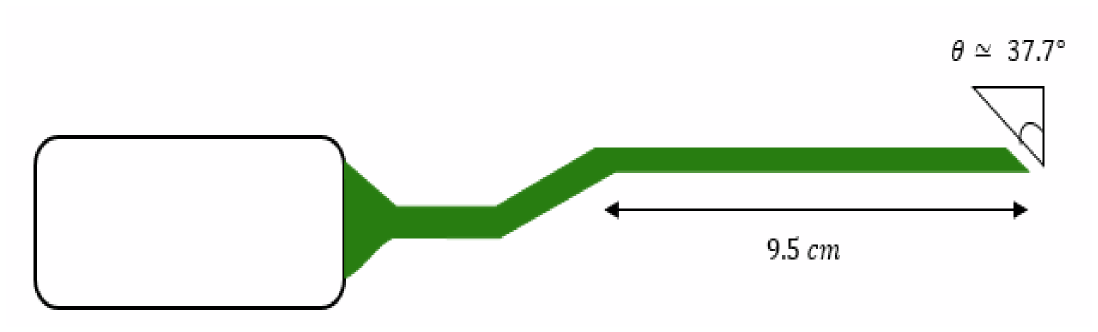
PHYSICAL MODIFICATIONS

- Minimum line separation: 38µm
- Desired actual pitch: 48µm

$\Theta = \cos^{-1}(38/48) = 37.7°$



- Required modifications for production
  - New PCB design
  - Changes to supporting fixtures



MAJOR OBJECTIVE: REDUCE FLEX PCB COST

- Constraints on PCB manufacturing are:design requires
  - Trace space of 3 mills
  - Copper inner layer 1 ½ ounce thick
- Purpose: require thicker pad for wire bonding once PCB is cut
- Need alternative fabrication methods or manufacturers

Option 1

- Explore other companies to determine manufacturing abilities.

Option 2

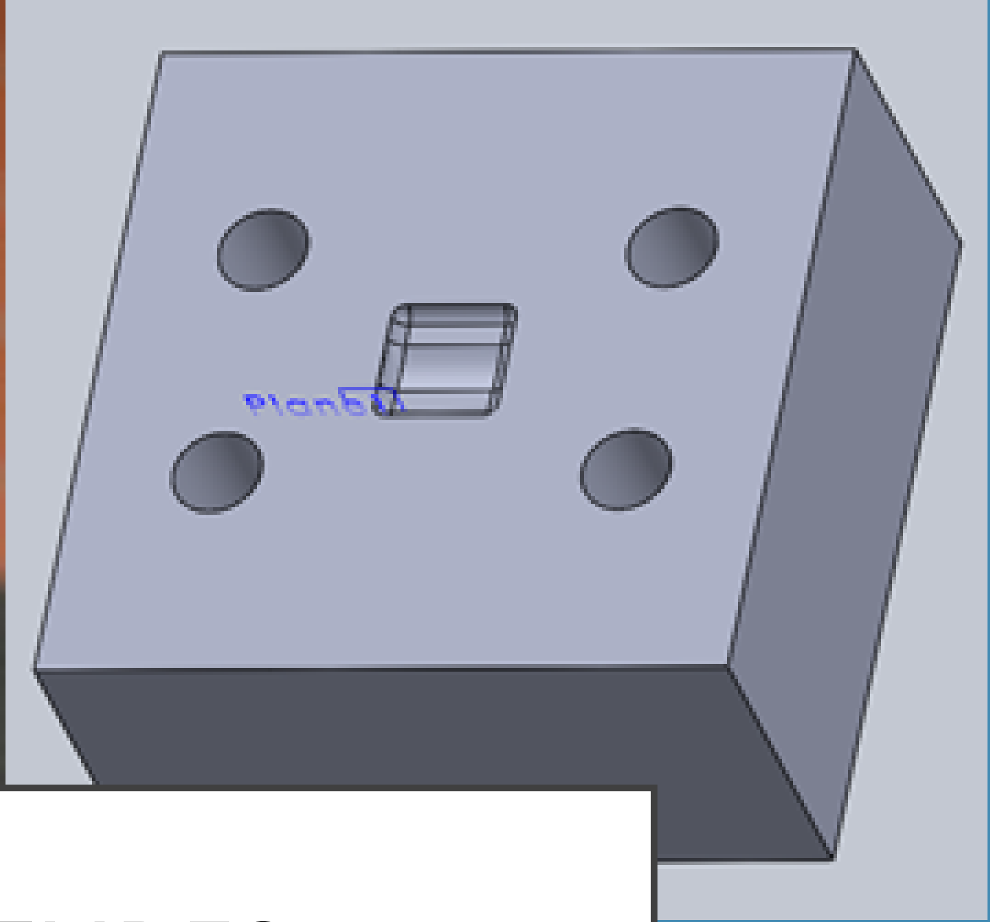
- Split into 2-layer design so there are no inner layers during manufacturing, combine the layers manually in probe fabrication.

Option 3

- Extend inner PCB layers so protruding section can be coated up to 1.5oz in finishing process.

Option 4

- Bring inner traces to edge of pcb and gold plate ends of traces for wire bonding pads.

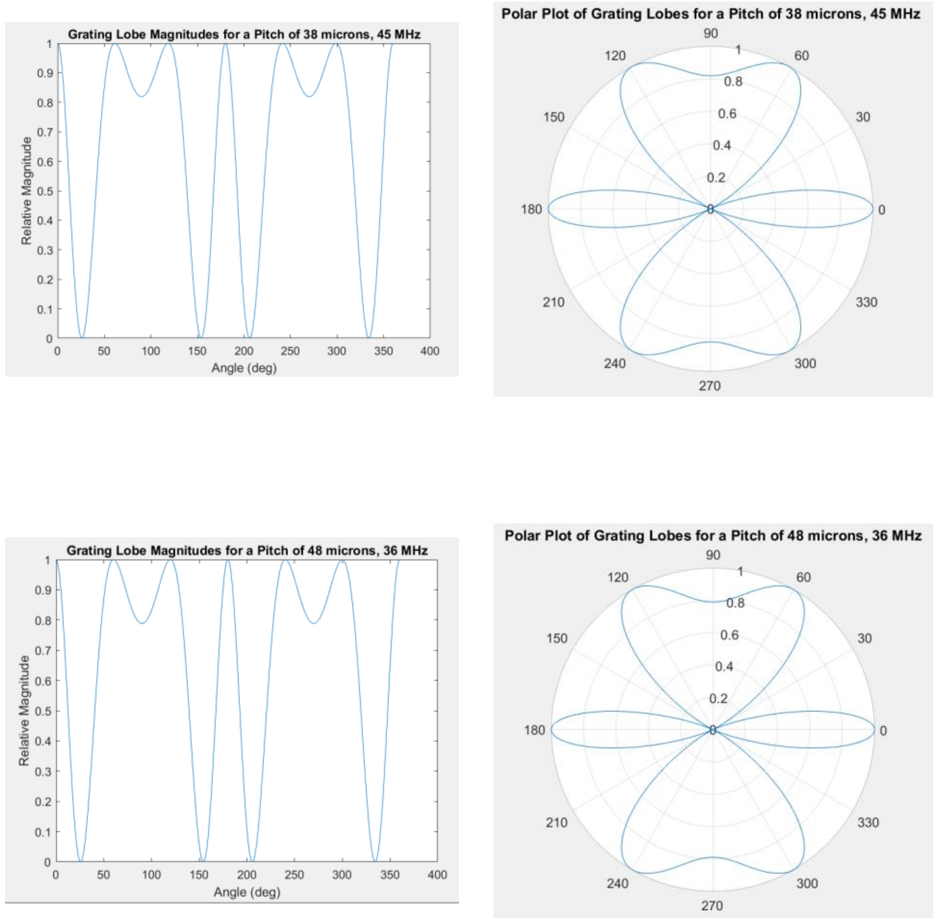


SUPPORTING FIXTURES

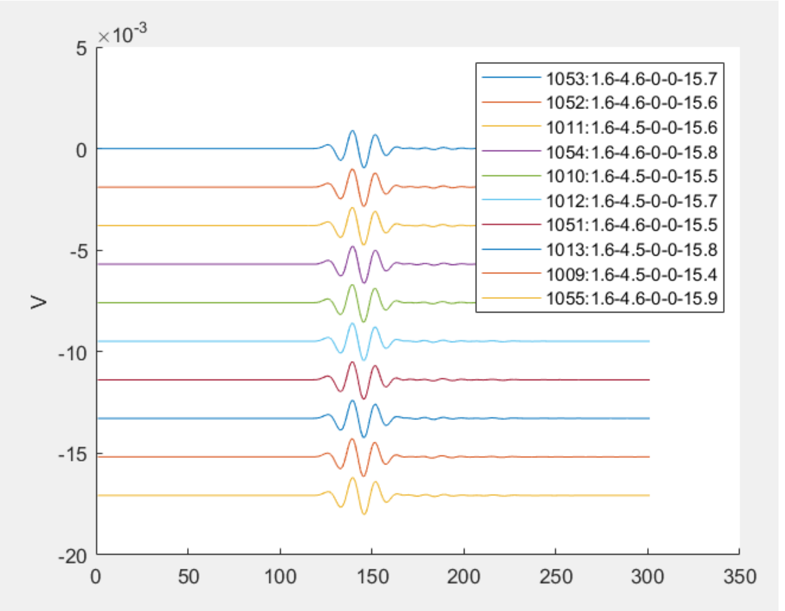
OLD LENS MOLD FIXTURE (L) AND MODIFIED VERSION (R)

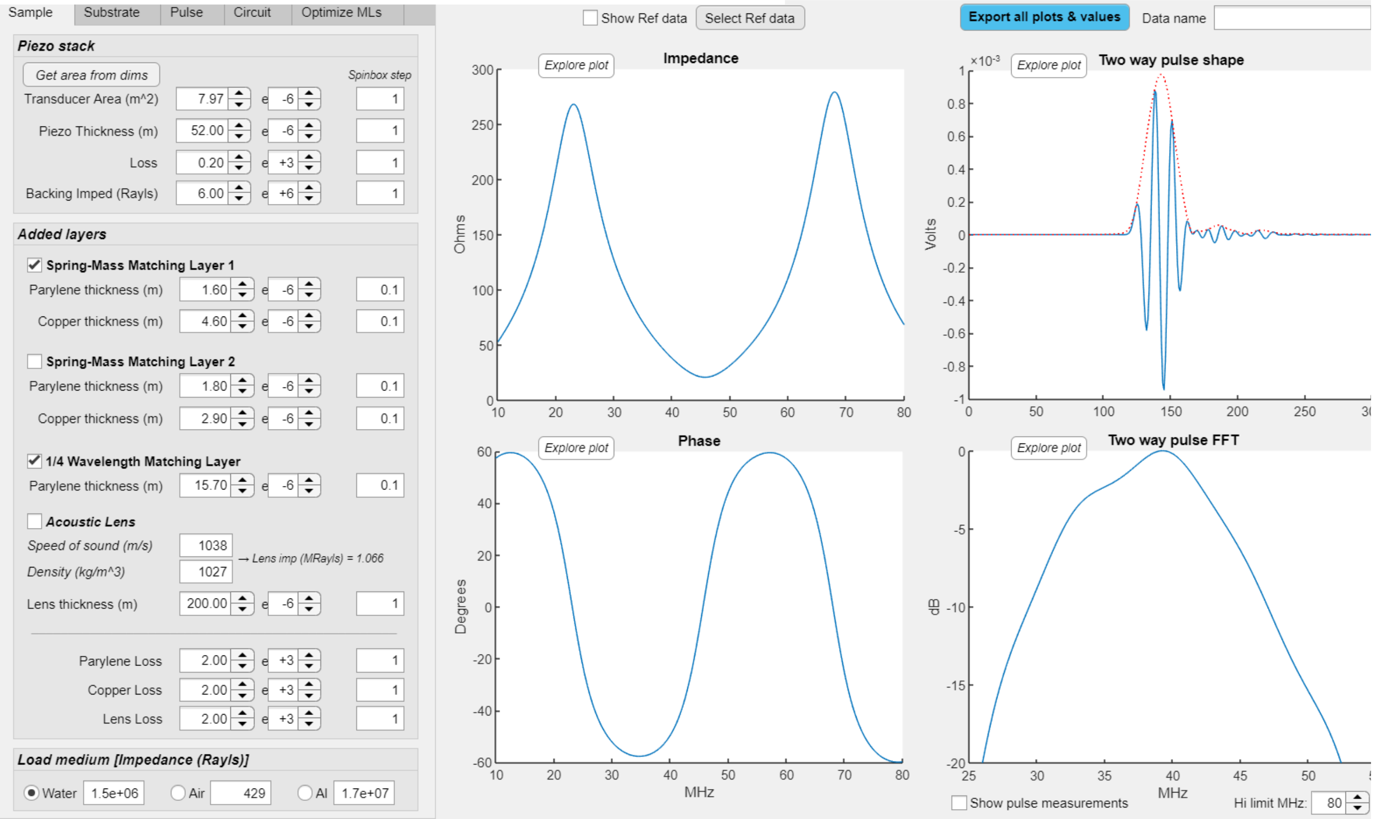
GRATING LOBE SIMULATIONS

- Simulations were run to compare the grating lobes of the original, forward-facing design (top) to the new, angled design (bottom)
- Goal was to achieve approximately the same grating lobe profiles as the original design, which can be seen from the nearly identical plots.
- The grating lobes were expected to be at an angle of $\theta = sin^{-1}\left(\frac{\lambda}{p}\right) = sin^{-1}\left(\frac{33.33um}{38um}\right) =$ 61.3°, which is what is seen in the plots



MATCHING LAYER SIMULATIONS





Matching layer values were optimized by running through various combinations of mass-spring layer parylene, copper, and ¼ wavelength parylene thicknesses (in um)

Key plot produced shows the voltages across time for the most optimal combinations, in the form of:

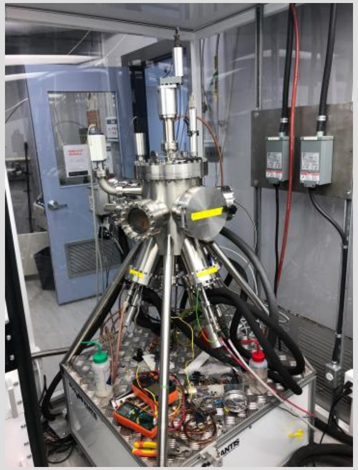
[index #: parylene-copper-0-0-1/4 wavelength]

- Optimal combination was found to be:

  [1.6-4.6-0-0-15.7]

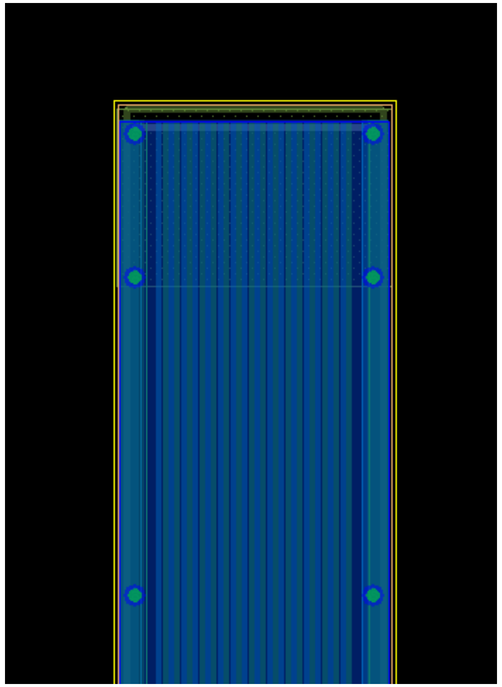
- Desired specifications were changed to match these values from the matching layer optimization
- The goal: to make the width and tail peak as small as possible, while maintaining a high enough peak voltage

PROBE ASSEMBLY

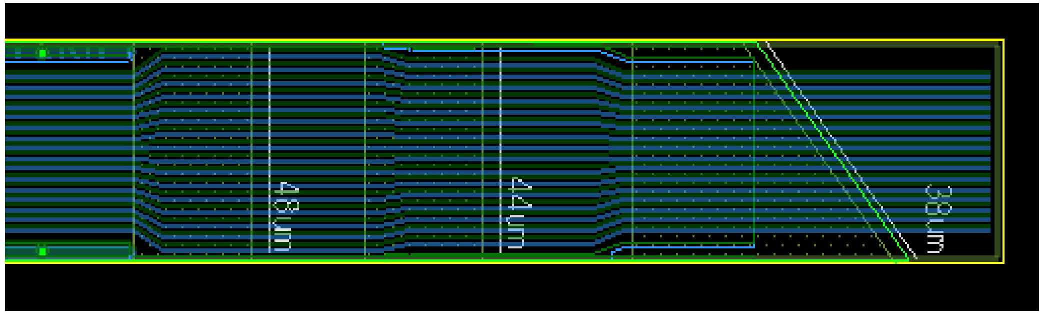


- Steps completed for the transducer assembly, in-lab:
  - Mounting piezo samples
  - Lapping the samples to desired thickness
  - Depositing the copper in the "sputtering machine"
  - Coating the samples with parylene
  - Applying the matching and backing layers
  - Wirebonding and laser etching the copper
  - Laser-cutting the PCB at the desired angle

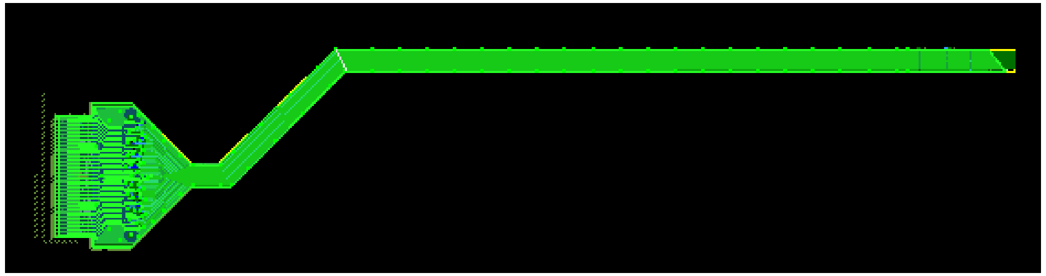
RESULTS AND TESTING



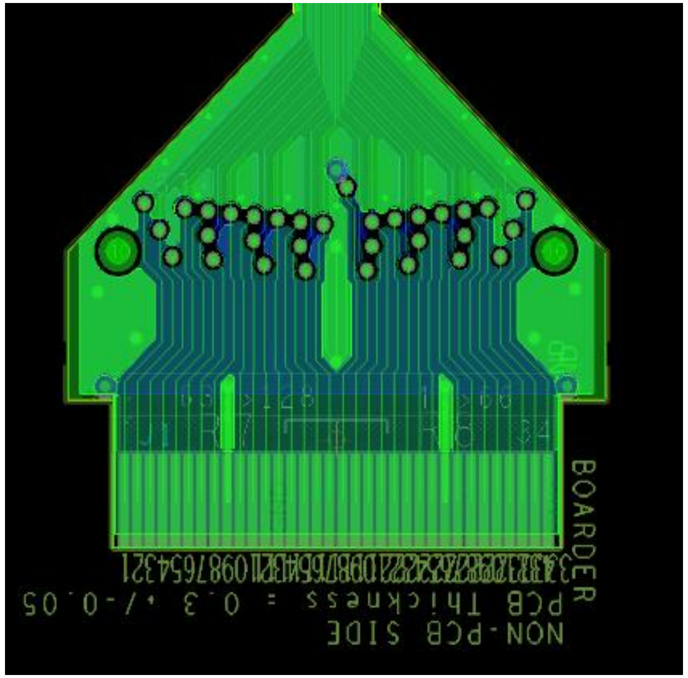
Original Tip



Modified Tip



Full View



Base (single layer)

PCB IMAGES

PCB RESULTS

- Overall thickness of the board
  - 0.44944mm
  - Fits the requirement for the ZIF connector used at the base of the PCB

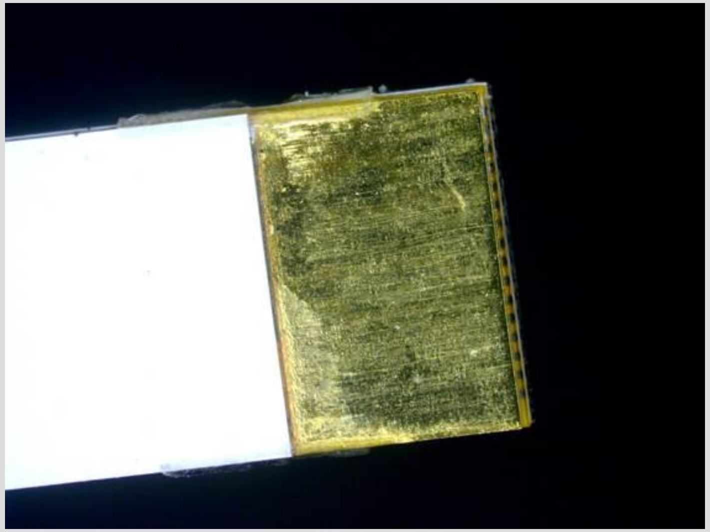
- Trace Impedance: 50 to 75 Ω
  - Actual = 49.879 Ω
  - Slightly different values than estimated by OrCAD
  - Probe used for fabrication and testing contained the original model PCB, not the new design.

Case	Length of Arm (mm)	Total Length (mm)	Pitch (μm)	Angle (˚)	Effective Pitch (μm)	Frequency (MHz)	Wavelength (μm)
1	97.348	138.092	38	37.7296	48.046	35.591	42.146
2	93.812	134.556	38	0	38	45	33.333
3	90.544	131.388	44	0	44	41.250	36.364
4	86.776	127.520	48	0	48	35.625	42.105

TWO LAYER OPTION

- 2-layer board received from Daxsonics
  - Similar dimensions and trace width to new design
  - Must be connected via epoxy

- Successful assembly
  - Good alignment, minimal trace overlap
  - Adds production complexity

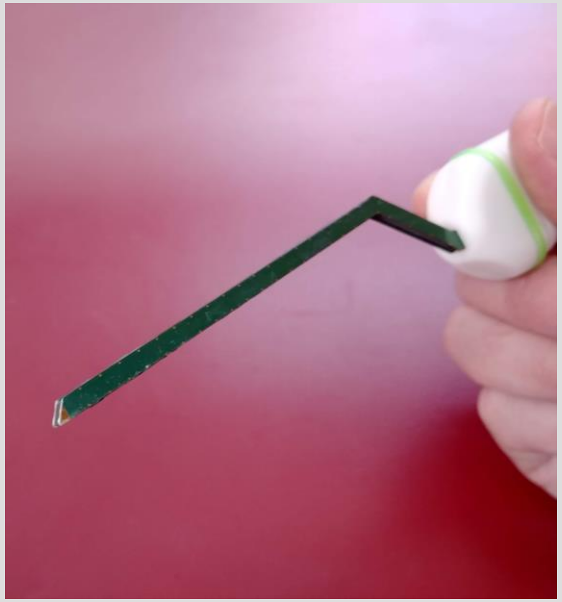


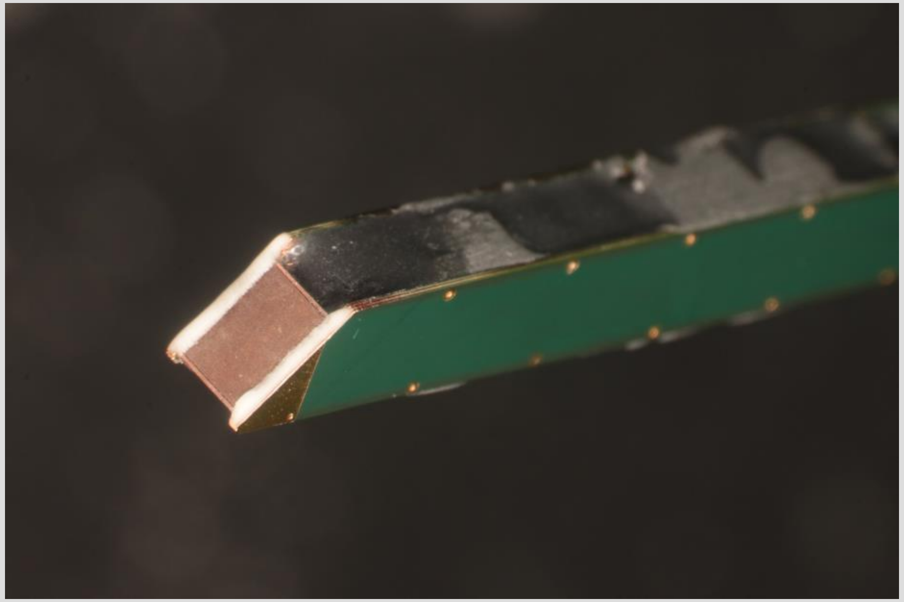
PCB PRODUCTION RESULTS

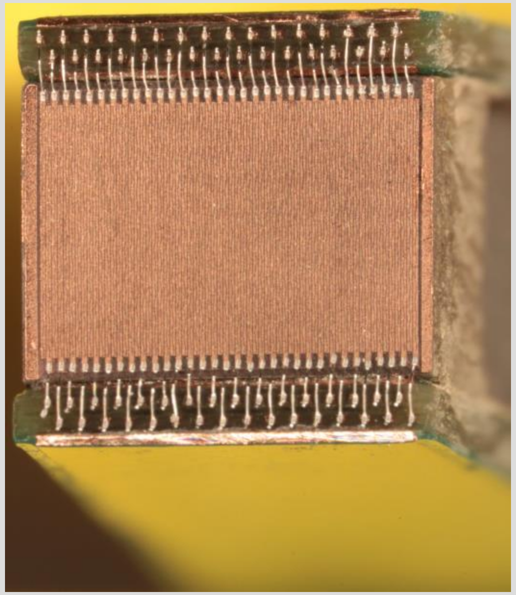
- ALLPCB
  - Confirmed in review processes they could produce the 4-layer design
  - Order was finalized and placed
  - during manufacturing, discovered the 1.5oz inner Cu and 3 mil spacing was not possible
  - Could not produce 2-layer design
- Impact on Objectives
  - Objective to decrease the PCB cost has not been fully met
  - Probes can still be fabricated using the old model of the PCB
- Other Options
  - Advanced Circuits
    - Sent both the 2- and 4-layer designs
    - Not previously been contacted in the scope of this project
    - Been used in the past by Daxsonics
    - Can only do 1 oz or 2 oz copper
  - Microconnex
    - Back-up: can be sent the 2-layer design and 4-layer design to compare to original quote.

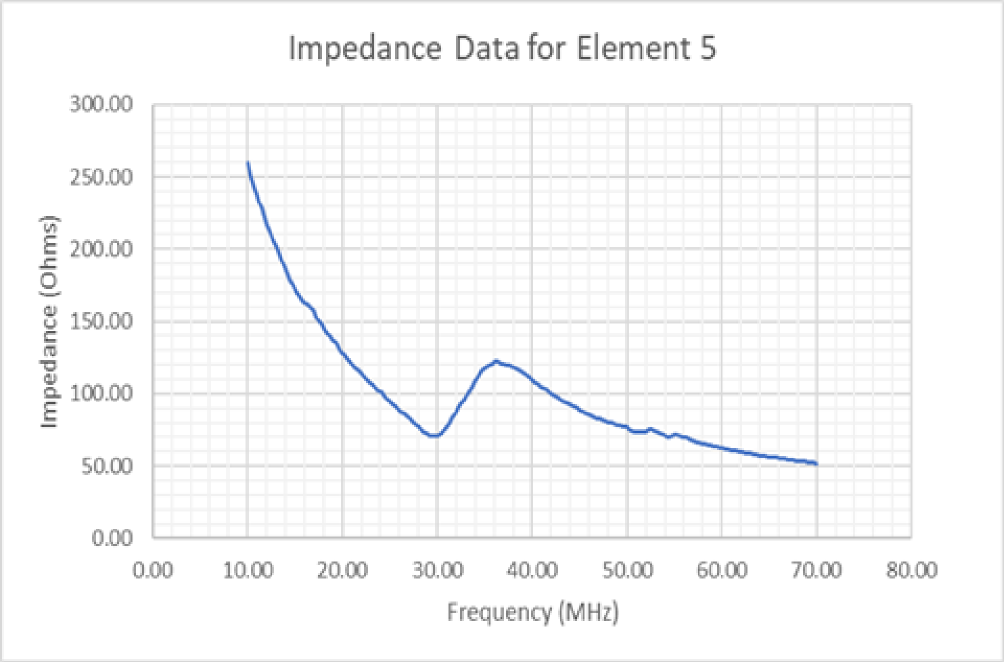
FINAL PROBE

- With help from Dr. Brown, assembly completed successfully
- Prototype built using old version of PCB from Microconnex
- Probe's shape did not significantly affect assembly process





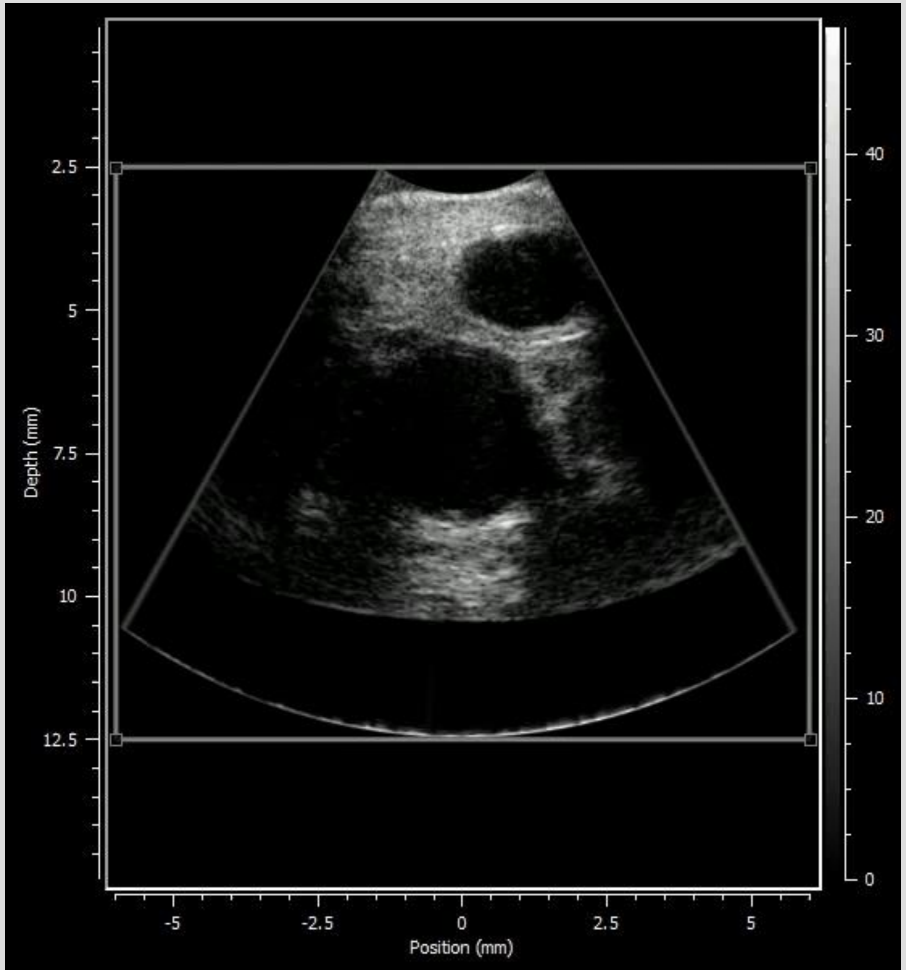




IMPEDANCE TESTS

- Five array elements were tested to show impedance measurements against frequency
- Resonant frequency of array elements was found to be ~30-32MHz
  - Expected frequency was 35.6MHz
  - Difference between resonant and anti-resonant frequencies is larger
- Impedances at resonant frequencies were 60-70Ω, as desired
  - Goal was 50-70Ω

WRIST IMAGING TESTS



ANALYSIS AND DISCUSSION

SUCCESSES

- New, multi-purpose PCB design
- Identification and testing of novel production methods
  - 2-layer PCB
  - Paint-on silicone
- Impedance testing agrees with expected impedance value for centre frequency.

LIMITATIONS

- Ground planes on PCB cut back to allow wider pitch options
- Manufacturing difficulties persist
- Grating lobes focus only on centre frequency
- Discrepancy in resonant frequency
- Impedance simulations based on original 45 MHz design

RECOMMENDATIONS

COST REDUCTION AND PCB ORDER

- Contact PCB manufacturers for quotes
- Select company and place bulk order for new multi-purpose PCB design

FIXTURE DESIGN AND FABRICATION

- Assembly of prototype was completed with makeshift fixturing
- Fabricate new lens mold fixture with 3D printer
- Develop silicone paint fixture

CONCLUSION

- Design specifications for the new flex circuit board and transducer have been met, except for cost reduction
- Acoustic simulations have been completed, and were compared with impedance analyzer results
- We were able to enter the lab for fabrication and testing in-person, following Nova Scotia Public Health Guidelines
- Probe was fabricated and images collected successfully

THANK YOU!

REFERENCES

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[2] C.M.W. Daft et al., "System and Method for Statistical Design of Ultrasound Probe and Imaging System," *General Electric Company*. [Online]. Available: https://patentimages.storage.googleapis.com/80/b7/70/6a3c3d156cf52f/US7006955.pdf. [Accessed: 02-Apr-2020]

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[5] J.A. Brown, "NSHRF 2020 spine proposal," *Dalhousie Ultrasound Group.* [Word].