Ultrasound Imaging of Brain Shunts

Team 1

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Outline

- Project Summary
- Progress: Phantom Construction
- Progress: Imaging
- Deliverables
- Revised Timeline
- Milestone Validation
- Dependencies
- Reading list

Project Summary

Problem: Brain shunts suffers from high incidence of occlusion that the in-grown tissues block the CSF flow.

Project Goal: Use external US probe, together with photoacoustic excitation to image occlusions and brain shunts inside the skull.

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Phantom Construction

Two parts : Brain & Skull

▶ Brain part : model the environment of the brain

support the shunt tube

▶ Skull part : model the real effect of bone on US imaging

▶ This two parts will be assembled to model a human head

Phantom Construction

What We Did …

▶ A Short Study Report For Phantom Investigation

- Materials

- Advantages and Disadvantages

- Construction approach

- Criterion (if necessary)

- (pasted on the wiki page)

▶ Several simple shaped brain phantoms has been made

▶ A human skull has been created in Solidworks

Phantom Construction

Brain Phantom

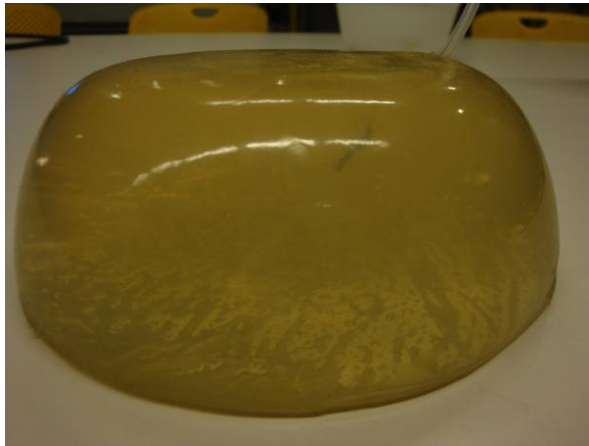| PVA-C (polyvinyl alcohol cryogel)	Gelatin and Sugar-free Fiber
✓ Typical tissue-mimicking material ✓ Optical and Mechanical properties can be modified by Freeze-thaw (F/T) cycles ✓ Can be used in a permanent way under humidity-controlled condition X Construction process: complex and long X Expensive ($135/kg)	✓ Materials: easy to get and cheap($24/kg) ✓ Construction process: easy and fast ✓ Reasonable properties for US imaging X Not as good as PVA-C X Only last for a short period, cannot guarantee the same acoustic and the mechanical properties
Preferred solution	Fast solution

Phantom Construction

What we did …

- Several simple shaped phantoms …

Pure gelatin phantom
(Very Stiff)

Gelatin and Fiber phantom
(Relatively soft, Tissue-like)

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Phantom Construction

Skull Phantom

▸ Three Dimensional Printing (3DP) for complex structure

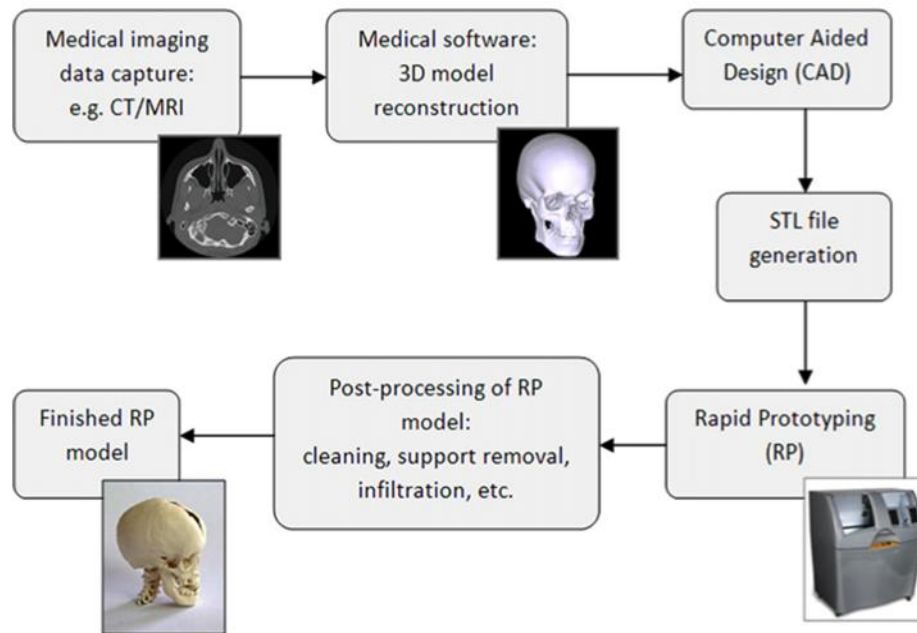▸ New material combination : ZP130™/ZB58™ based

Fig. 1. Sequence of steps followed during the Rapid Prototyping (RP) of a medical model.

Image from:
Matteo Gatto, Gianluca Memoli, Adam Shaw, Neelaksh Sadhoo, Pierre Gelat, Russell A. Harris: Three-Dimensional Printing (3DP) of neonatal head phantom for ultrasound: Thermocouple embedding and simulation of bone. Medical Engineering & Physics 34(2012) 929-937.

Phantom Construction
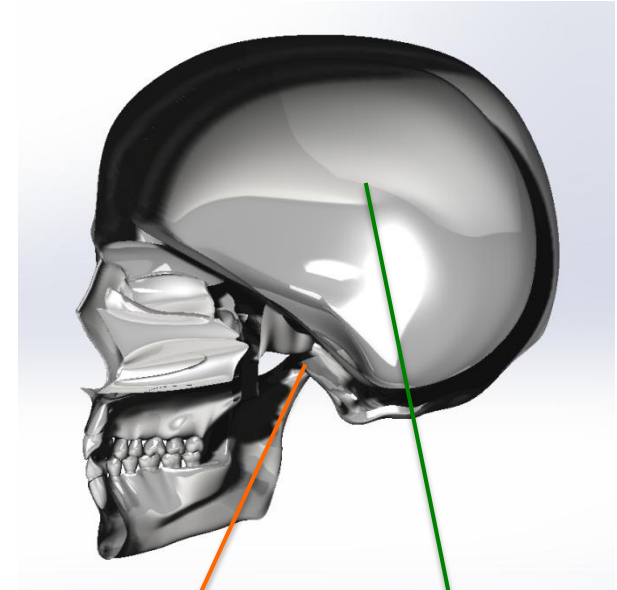
What we did …

Problem: How to control the thickness without affect the curved surface ??
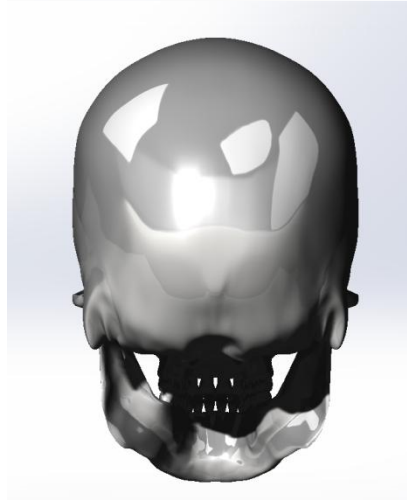
The skull surface

Mold for the brain phantom

Phantom Construction

What we are doing …

▸ More complex and realistic mold for the brain

▸ PVA-C phantom (materials have arrived)

Project Summary · Progress: Phantom · Progress: Imaging · Deliverables · Milestones · Dependencies · Reading list

Progress: Imaging

- **Ultrasound generation**
  - laser
- **Data collection**
  - SonixRP & DAQ
- **Data processing**
  - Beamform
- **Image formation**
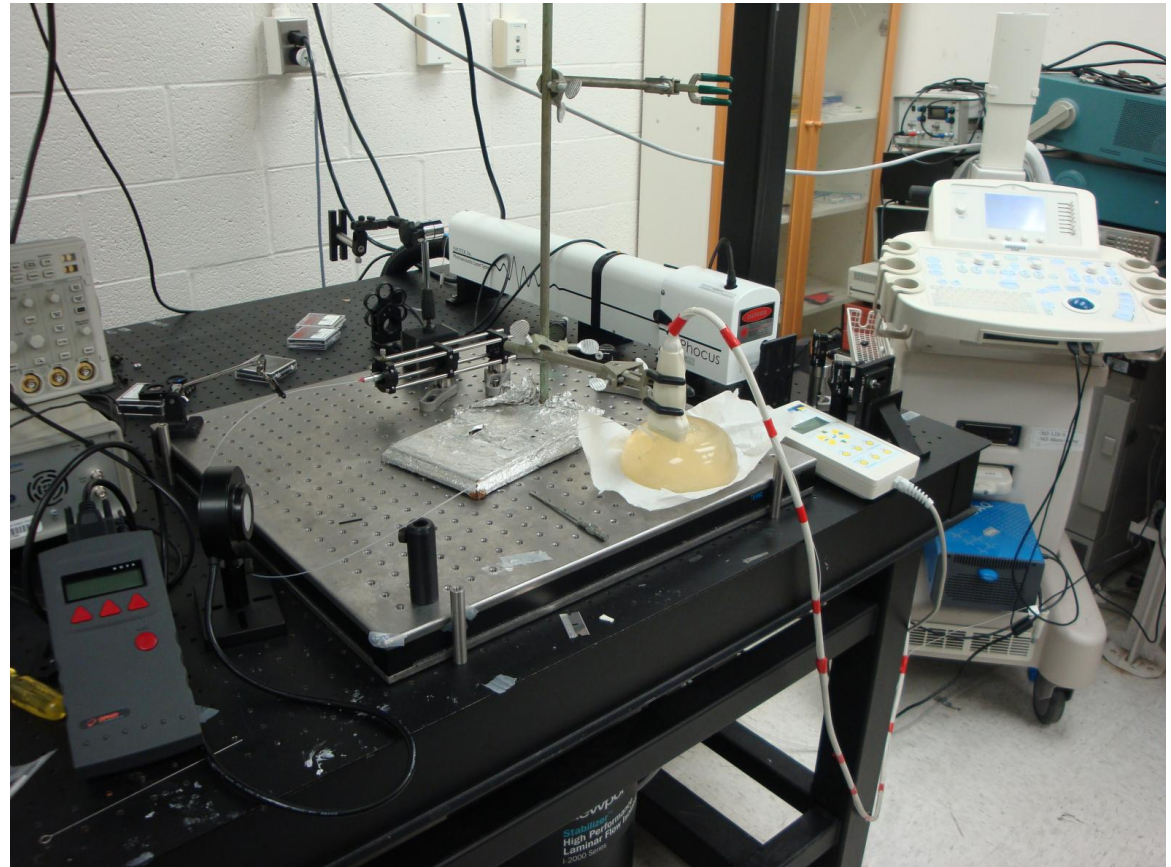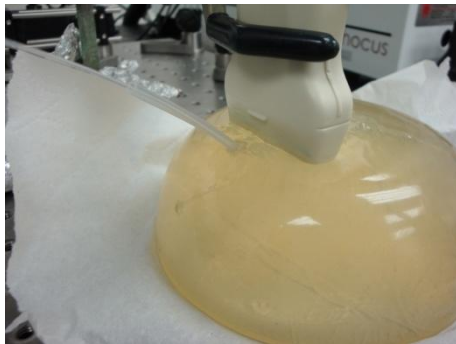
Progress: Imaging

▸ **Test with DAQ data collection**

   ▸ Turn off the beam focusing

   ▸ Collect the raw data with DAQ

   ▸ Process the data with MATLAB
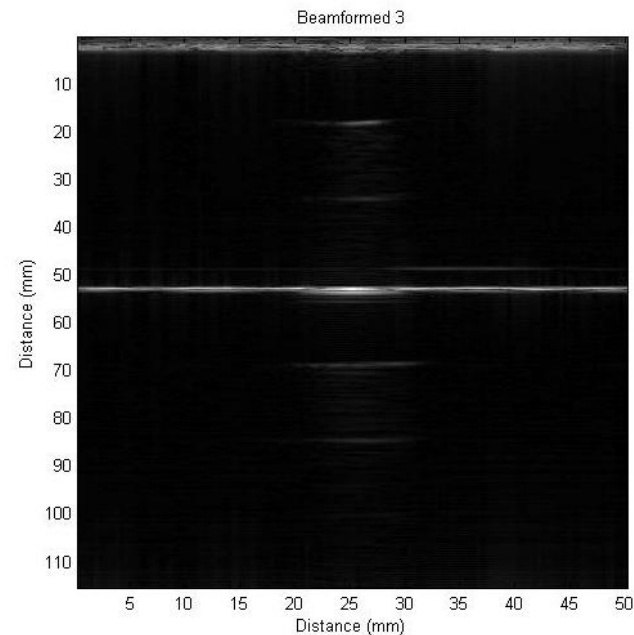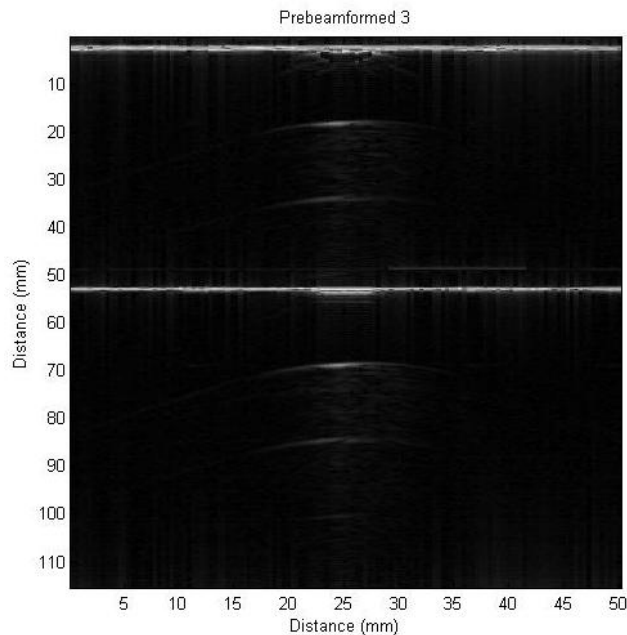
Progress: Imaging

▸ **Test with gelatin phantom w/o attenuation & scattering**

   ▸ Test with different fibers

Fiber diameter	energy
220 μm	0.15mJ
550 μm	2mJ
1000 μm	10mJ

Progress: Imaging

Prebeamformed 3 — Beamformed 3

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Progress: Imaging

Prebeamformed 2

Beamformed 2

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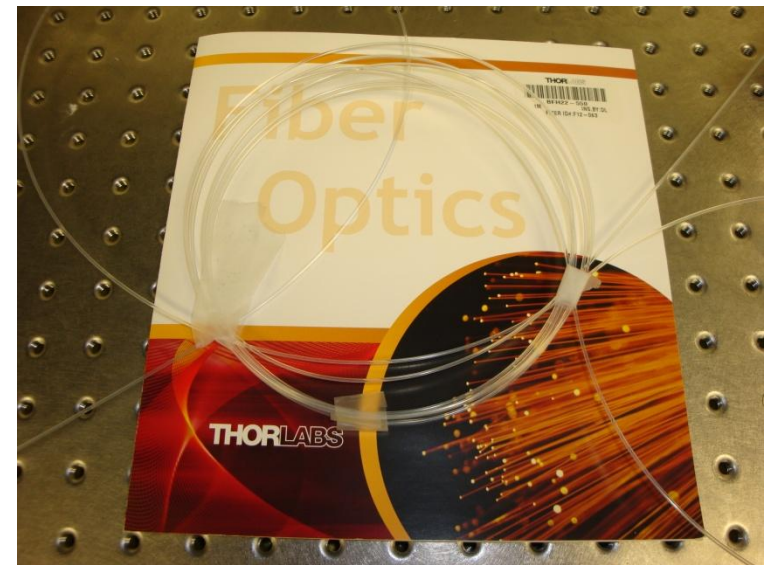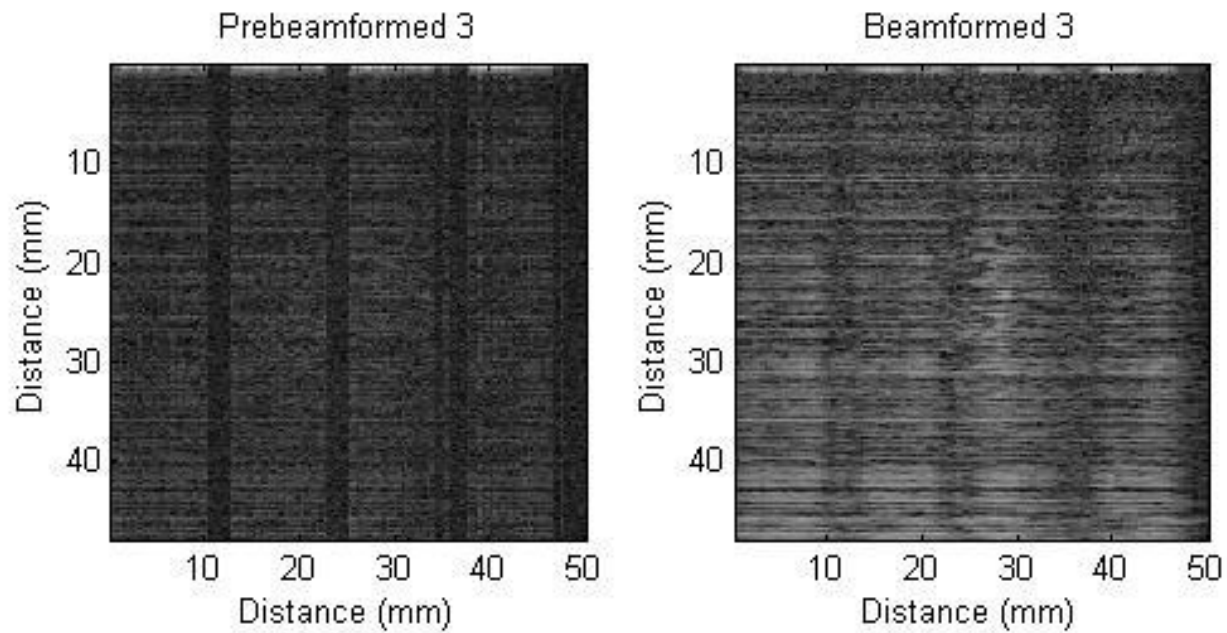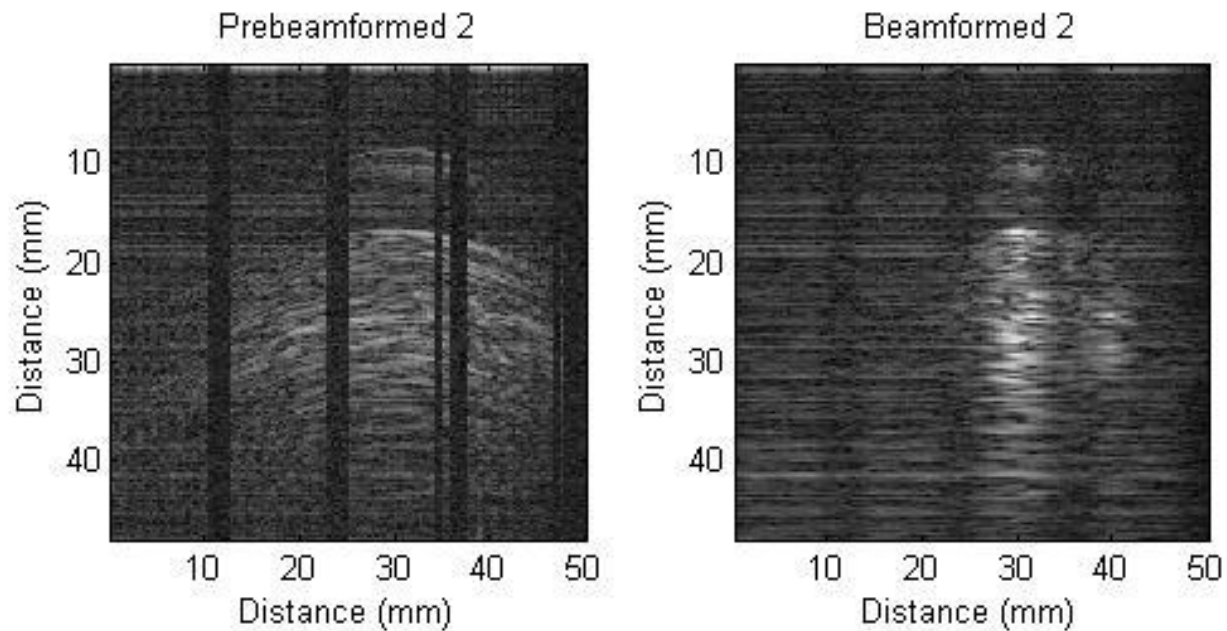
Progress: Imaging
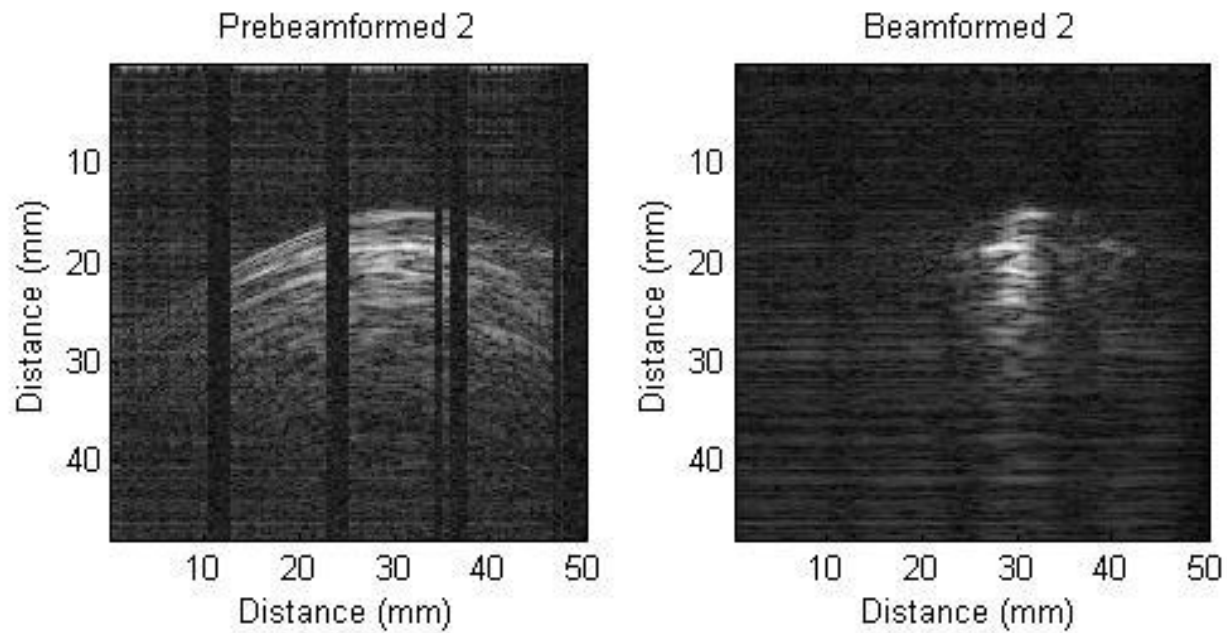
Deliverables

▸ ## Minimum – without skull

- ▸ Design and build a ultrasound friendly brain phantom and insert the shunts.

- ▸ Preliminary test of US probe for reflected PA signal detection

- ▸ Collect and process the data of the occlusion with brain phantom into delayed image (will be done this weekend..).

Deliverables

▶ **Expected – with skull**

  ▶ Collect and process the data of the occlusion into delayed image

  ▶ Capability to distinguish shunts, tissues and fluids

  ▶ Demonstrate PA imaging of shunts with different levels of occlusion

Deliverables

▸ **Maximum**

 ▸ Demonstrate realtime PA imaging through the skull of shunts with different levels of occlusion

 ▸ Monitor clearing of the shunt

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Original Timeline

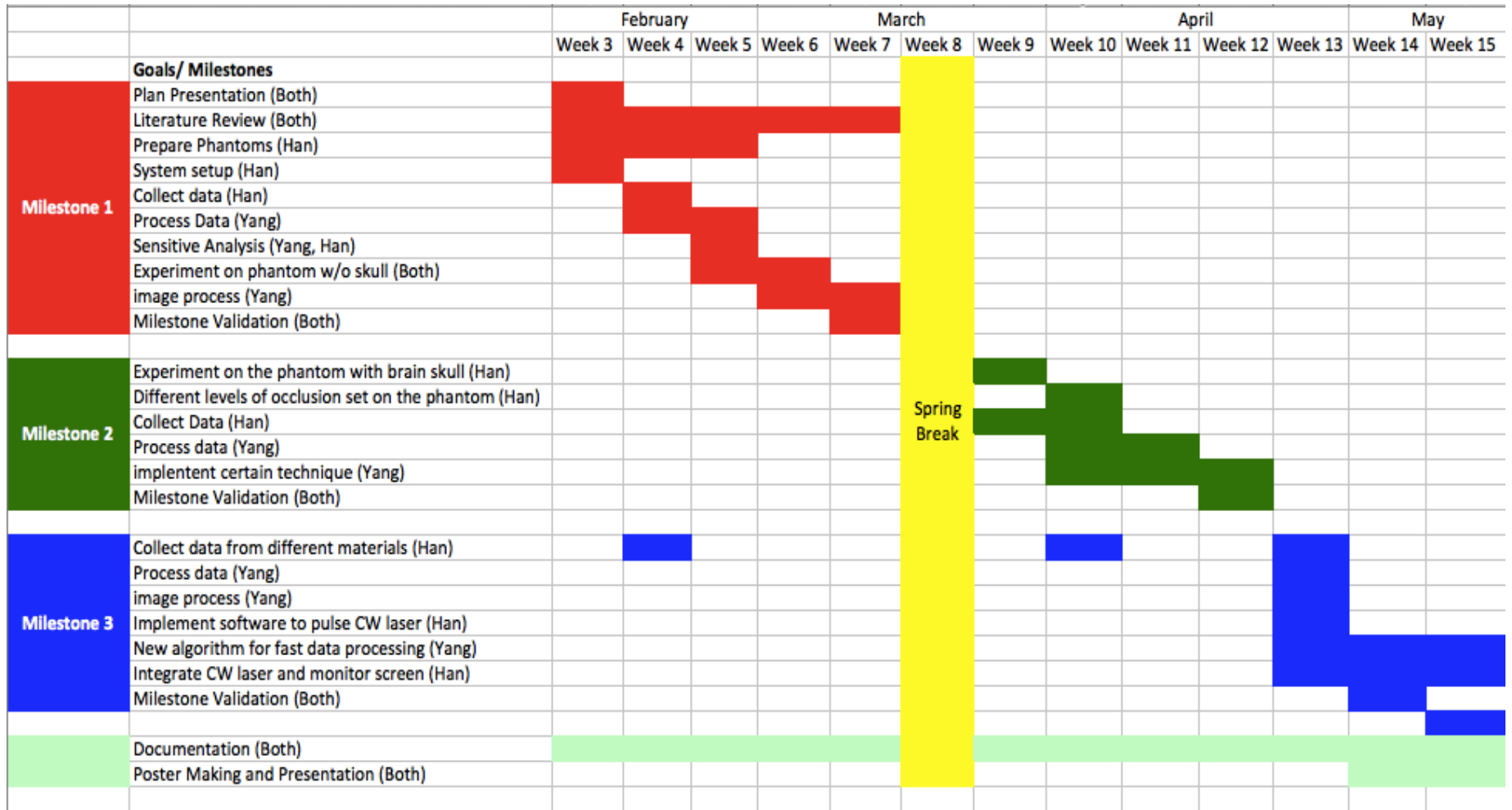|	Goals/ Milestones	February					March		April				May	
		Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15
Milestone 1	Plan Presentation (Both)	■												
	Literature Review (Both)	■	■	■	■	■								
	Prepare Phantoms (Han)	■	■											
	System setup (Han)	■												
	Collect data (Han)		■	■										
	Process Data (Yang)		■	■										
	Sensitive Analysis (Yang, Han)			■	■									
	Experiment on phantom w/o skull (Both)			■	■									
	image process (Yang)				■	■								
	Milestone Validation (Both)					■								
Milestone 2	Experiment on the phantom with brain skull (Han)							■						
	Different levels of occlusion set on the phantom (Han)							■	■					
	Collect Data (Han)								■					
	Process data (Yang)								■	■				
	implentent certain technique (Yang)									■				
	Milestone Validation (Both)													
Milestone 3	Collect data from different materials (Han)		■						■			■		
	Process data (Yang)											■		
	image process (Yang)											■		
	Implement software to pulse CW laser (Han)											■		
	New algorithm for fast data processing (Yang)											■		
	Integrate CW laser and monitor screen (Han)											■		
	Milestone Validation (Both)													■
	Documentation (Both)	■	■	■	■	■		■	■	■	■	■	■	■
	Poster Making and Presentation (Both)												■	■

Spring Break (Week 8)

Project Summary → Progress: Phantom → Progress: Imaging → Deliverables → **Milestones** → Dependencies → Reading list

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Revised Timeline

	Goals/Milestones	March Week4	April Week1	Week2	Week3	Week4	May Week1	Week2
Milestone 1	Brain Phantom Construction (Han)	▓						
	System setup(Yang) Done							
	Preliminary tests(Yang) Done							
	Experiment on phantom w/o skull(Both)	▓						
	Visualization of occlusion(Yang)							
	Milestone Validation(Both)							
Milestone 2	Skull Construction(Han)	▓	▓					
	Experiment on phantom with skull(Both)			▓	▓			
	Different levels of occlusions set in the shunts(Han)				▓			
	Visualization of occlusion(Yang)							
	Add occlusion material at the end of the fiber(Han)				▓			
	Visualization of shunts(Yang)							
	Milestone Validation(Both)							
Milestone 3	Collect data from different materials(Han)					▓		
	Integrate MUSiiCToolkit(Both)						▓	
	Integrate clearing stem(Han)						▓	
	Visualiztion of clearing stem end point(Yang)						▓	
	Milestone Validation(Both)						▓	
	Documentation(Both)	▓	▓	▓	▓	▓	▓	▓
	Poster Making and Presentation(Both)							▓

Project Summary → Progress: Phantom → Progress: Imaging → Deliverables → **Milestones** → Dependencies → Reading list

Milestone Validations

Milestone	Original plan	Revised plan	Status
Phantom construction	2/28	4/8	In progress
Preliminary test	2/28	3/27	Done
Visualization of occlusion w/o skull	3/18	3/29	In progress
Visualization of occlusion and shunts with skull	4/15	4/22	Not started
Real-time imaging of occlusion and shunts with skull	5/10	5/10	Not started

Project Summary → Progress: Phantom → Progress: Imaging → Deliverables → Milestones → Dependencies → Reading list

Dependencies

Dependency	Resolved by	Resolved	Fallback plan	Influences
Access to Dr. Boctor's lab	3/11	Yes		All the milestones
Laser system back	3/18	Yes		All the milestones
Jello phantoms	3/26	Yes		Milestone I
PVA phantoms	3/31	No		
Skull construction	4/8	No	Borrow a piece of skull	Milestone II
Data collection training	2/27	Yes		Milestone I
Training of laser	3/27	Yes		Milestone I
MUSiiCToolkit	4/22	No	Code by ourselves	Maximum deliverable

Reading list

- ## Phantom Construction

- Parastoo Farnia, Alireza Ahmadian, Alireza Khoshnevisan, AmirHossein Jaberzadeh, Nasim Dadashi Serej, Anahita F. Kazerooni: An efficient Point Based Registration of Intra-operative Ultrasound images with MR images for computation of brain shift; a Phantom Study. 33rd Annual International Conference of the IEEE EMBS Boston, Massachusetts USA, August 30 - September 3, 2011

- Sean Jy-Shyang Chen1, Pierre Hellier2, Jean-Yves Gauvrit4,5,6, Maud Marchal3, Xavier Morandi4,5,6, and D. Louis Collins: An Anthropomorphic Polyvinyl Alcohol Triple-Modality Brain Phantom based on Colin27. McConnell Brain Imaging Centre, Montreal Neurological Institute, McGill University, Montreal, Canada

- Ronald O. Bude, Ronald S. Adler: An Easily Made, Low-Cost, Tissue-Like Ultrasound Phantom Material. J Clin Ultrasound 23:271 – 273, May 1995.

- Frederic Bevilacqua, Dominique Piguet, Pierre Marquet, Jeffrey D. Gross, Bruce J. Tromberg, and Christian Depeursinge: In vivo local determination of tissue optical properties: applications to human brain. 1 August 1999/Vol.38, No.22/ Applied Optics.

- Brian W. Pogue, Michael S. Patterson: Review of tissue simulating phantoms for optical spectroscopy, imaging and dosimetry. Journal of Biomedical Optics 11(4), 041102 (July/August 2006).

- A N Yaroslavsky, P C Schulze, I V Yaroslavsky, R Schober, F Ulrich and H-J Schwarzmaier: Optical properties of selected native and coagulated human brain tissues in vitro in the visible and near infrared spectral range. Phys. Med. Biol. 47(2002) 2059-2073.

- K J M Surry, H J B Austin, A Fenster and T M Peters: Poly(vinyl alcohol) cryogel phantoms for use in ultrasound and MR imaging. Phys. Med. Biol. 49(2004) 5529-5546.

- Matteo Gatto, Gianluca Memoli, Adam Shaw, Neelaksh Sadhoo, Pierre Gelat, Russell A. Harris: Three-Dimensional Printing (3DP) of neonatal head phantom for ultrasound: Thermocouple embedding and simulation of bone. Medical Engineering & Physics 34(2012) 929-937.

Reading list

- ## Photoacoustic and Ultrasound imaging

- Limng Nie, Xin Cai, Konstantin Maslov, Alejandro Garcia-Uribe, Mark A. Anastasio, Lihong V. Wang, "Photoacoustic tomography through a whole adult human skull with a photon recycler", Washington University, Department of Biomedical Engineering, St. Louis, Missouri 63130.

- H. J. Kang et al., "Software framework of a real-time pre-beam-formed RF data acquisition of an ultrasound research scanner," Proc. SPIE 8320, 83201F (2012).

- N. Kuo, H.J. Kang, D.Y. Song, J.U. Kang, E.M. Boctor, "Real-time Photoacoustic Imaging of Prostate Brachytherapy Seeds Using a Clinical Ultrasound System", *Journal of Biomedical Optics, 17(6)*, June 2012.

- P. J. Stolka, H.-J. Kang, and M. B. Emad, "The MUSiiC toolkit: Modular Real-Time Toolkit for Advanced Ultrasound Research," MIDAS Journal, (2010)

- H.-J. Kang, P. J. Stolka, and M.B.Emad, "OpenITGLinkMUSiiC toolkit: A Standard Communications Protocol for Advanced Ultrasound Research," MIDAS Journal, (2010)

- M. Fink, "Time reversal of ultrasonic fields-Part I: Basic principles". *IEEE Trans. Sonics Ultrason. 39(5), 555–566 (1992).*

- J.-L. Robert, M. Burcher, C. Cohen-Bacrie, and M.Fink, "Time reversal operator decomposition with focused transmission and robustness to speckle noise: Application to microcalcification detection". *J. Acoust. Soc. Am., 119:3848-3859 (2006).*

Thank you !

Questions ?