

Hypothesis

- High frequency ultrasonic transducers are used to diagnose intravascular diseases.
- Miniaturized transducers that are focused and broadband can be fabricated using MEMS (Micro-electro-mechanical systems) technology to generate high resolution images of the tissue.
- Harmonic imaging can be employed to further improve the resolution, and it provides different (nonlinear) information from the tissue that is not provided by the standard fundamental imaging.

Methodology

- Ultrasonic transducers (Figure 1) are made by applying air pressure to a piezoelectric polymer membrane (PVDF TrFE; Figure 2). They are then integrated with electronics to amplify the detected echoes.
- Pulse inversion technique is used to amplify and generate the first harmonics.
- 360° views of the human coronary arteries are obtained by rotating the transducer inside the vessel (Figure 3).
- The echoes are then processed to create images of the tissue.

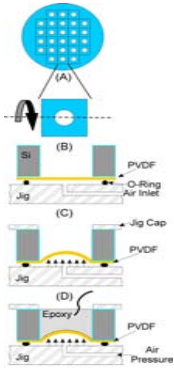


Figure 2. Setup for transducer fabrication. A silicon chip (B) is removed from a tray (A) and is placed with PVDF into a jig (C). Air pressure deflects the PVDF (D), and a lead is attached (E).

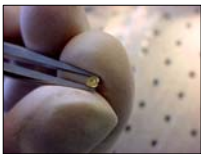


Figure 1. Photograph of a miniaturized transducer.

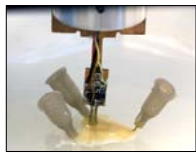


Figure 3. Photograph of the scan setup with transducer imaging human coronary artery.

Results

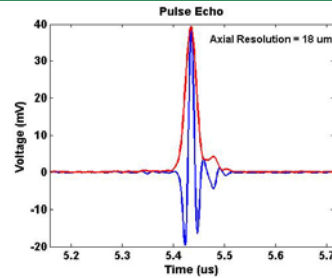


Figure 4. The pulse-echo and its Hilbert transform.

- The transducers fabricated are characterized by using pulse-echo techniques to determine axial and lateral resolution.

Transducer Characteristics	
PARAMETER	VALUE
Aperture	2 mm
F-number	2.04
Center frequency	35 MHz
-6dB Bandwidth % (without electronics)	101%
Axial Resolution	18.75 μm
Lateral Resolution	87.26 μm

Figure 5. Table showing the characteristics of one of the fabricated transducers.

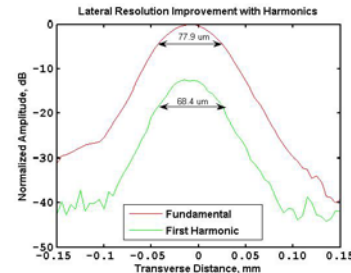


Figure 6. Graph showing the improvement in lateral resolution of the transducer with the use of harmonic imaging.

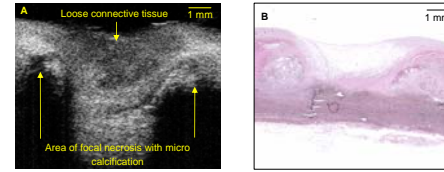


Figure 7. Comparison of 40 MHz standard ultrasonic image (A) of an unfixed human aorta with its histological image (B). The ultrasonic image clearly shows the loose connective tissue. Areas of focal necrosis with micro calcification is cast as typical shadow region in the ultrasonic image.

- Images with near histological resolution can be generated with focused broadband transducers (Figure 7).

Volcano Eagle Eye™ gold Volcano Revolution™ PVDF TrFE Transducer

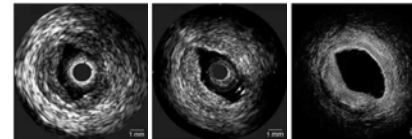


Figure 8. Comparison with commercial IVUS systems, imaging the same area of coronary artery.

- Delineation of coronary artery is seen to be better with focused transducers than compared to commercial IVUS (intravascular ultrasound) systems (Figure 8).
- Transducers fabricated using the MEMS technology exhibit axial resolutions <20 um and lateral resolution <100 um.

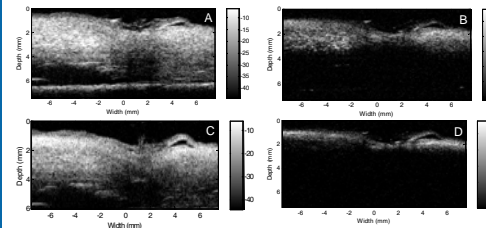


Figure 9. Comparison of images of the same area of human aorta using different frequencies. Fundamental 20MHz (A), Harmonic 40MHz (B), Fundamental 40MHz (C), and Harmonic 80MHz (D).

Conclusions

- A method to fabricate focused broadband transducers capable of imaging the coronary arteries with high resolution has been developed.
- Harmonic imaging can be utilized to further improve the resolution to aid the diagnosis of cardiovascular diseases.
- Since harmonic imaging offers different information about the tissue, it could help in better characterization of tissue, and it could provide enhanced diagnostic accuracy.

Recommendations

- Non-linearity of the tissue can be explored to better differentiate the tissue composition.
- The speed of acquisition of the scan lines needs to be increased to near real time.

References

- Chaitanya Chandrana, Nikolay A. Kharin, Geoff Vince, Shuvo Roy, and Aaron J. Fleischman, "Micro-Electro-Mechanical Systems (MEMS) based focused ultrasound transducers for high resolution second harmonic imaging applications," IEEE Trans of Ultrason., Ferroelect., Freq.Contr., FC, pp. 693-697, 2006.