Overview of Biomedical Applications of Vibro-acoustography

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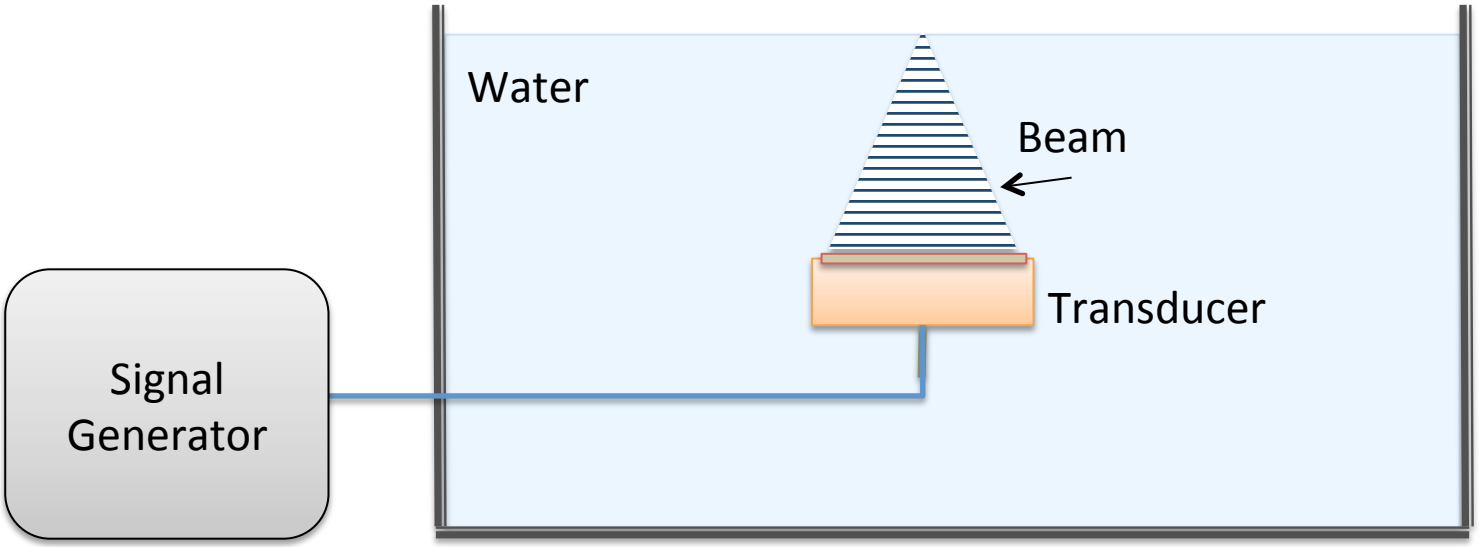
Outline

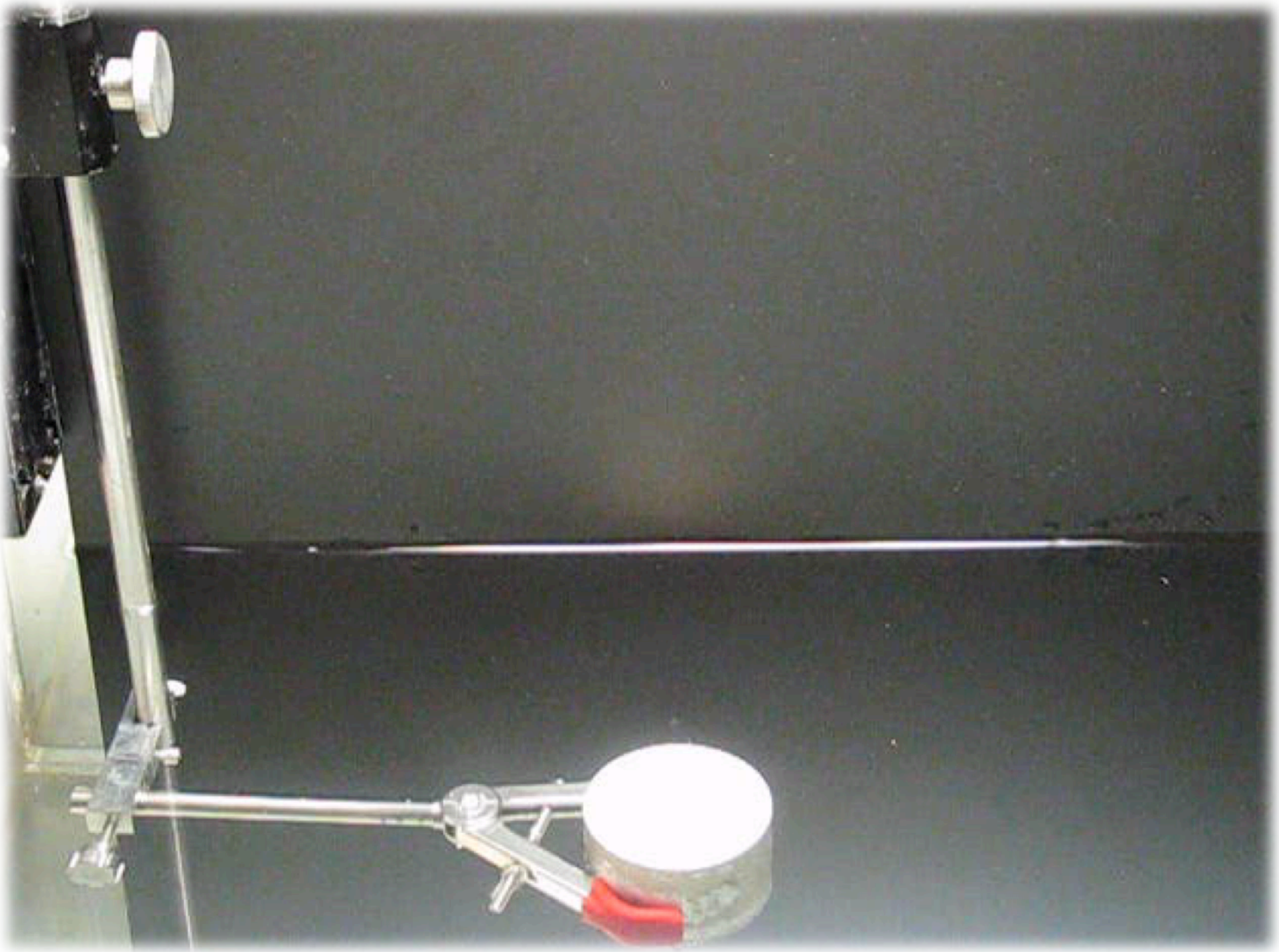
- Ultrasonic (acoustic) radiation force concepts
- Vibro-acoustography:
  - Principles Vibro-acoustography
  - Features
  - Biomedical Applications
- Summary

Ultrasonic (Acoustic) Radiation Force

Demonstration of Ultrasonic "*Radiation Force*"



Acoustic Radiation Force Experiment



Generating different stress fields with URF

- Static force
- Harmonic force
- Localized force
- Transient force

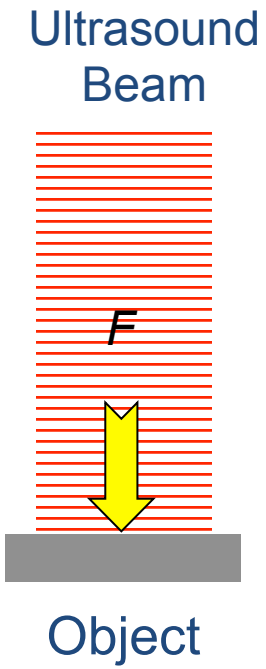
Static Radiation Force

Continuous ultrasound wave:

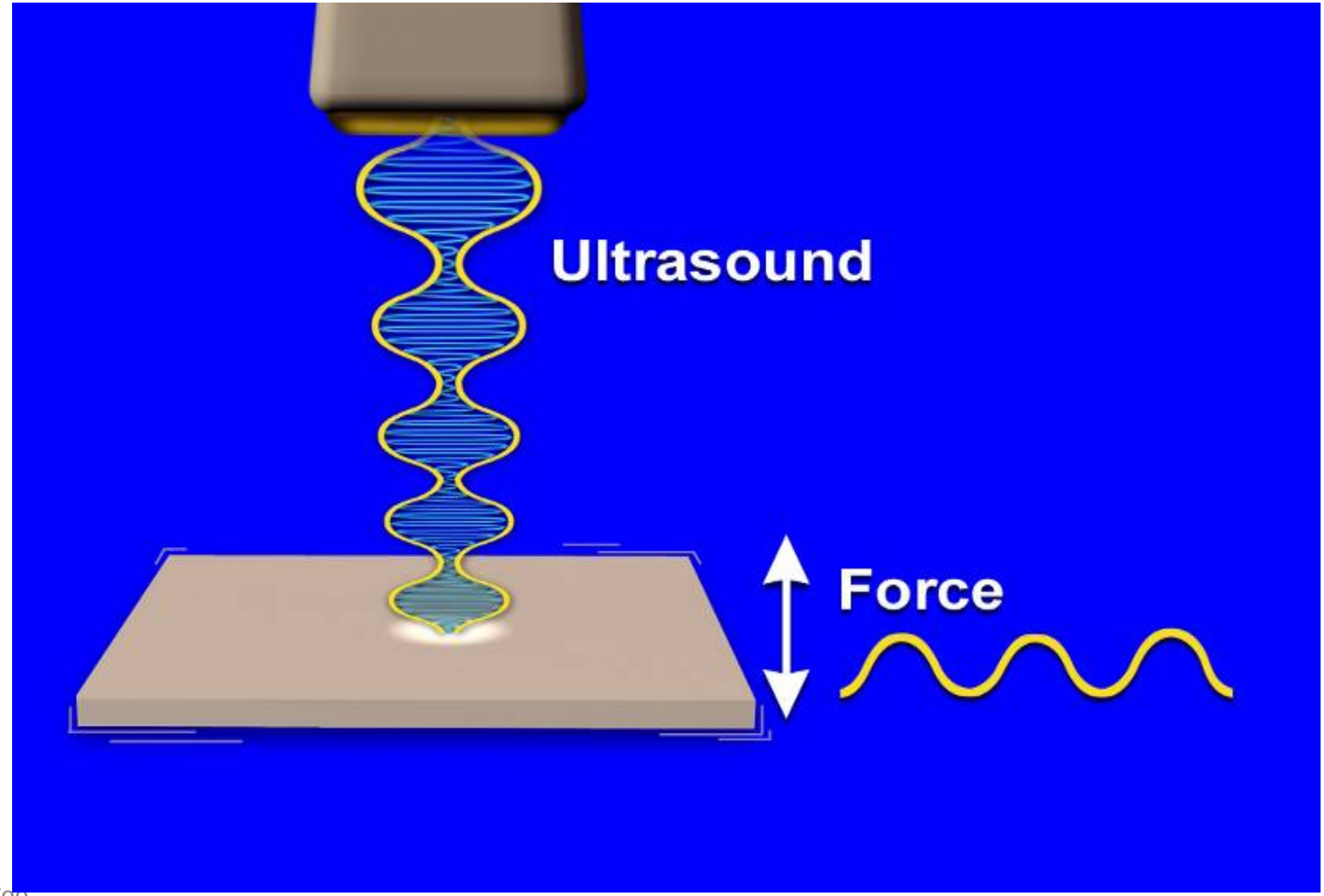
Radiation Force = (Total Power) / Speed: $F = P/c$

Ultrasound Radiation Force in Biological Tissues:

c = 1.5 km/s,
F=0.66 mN/W



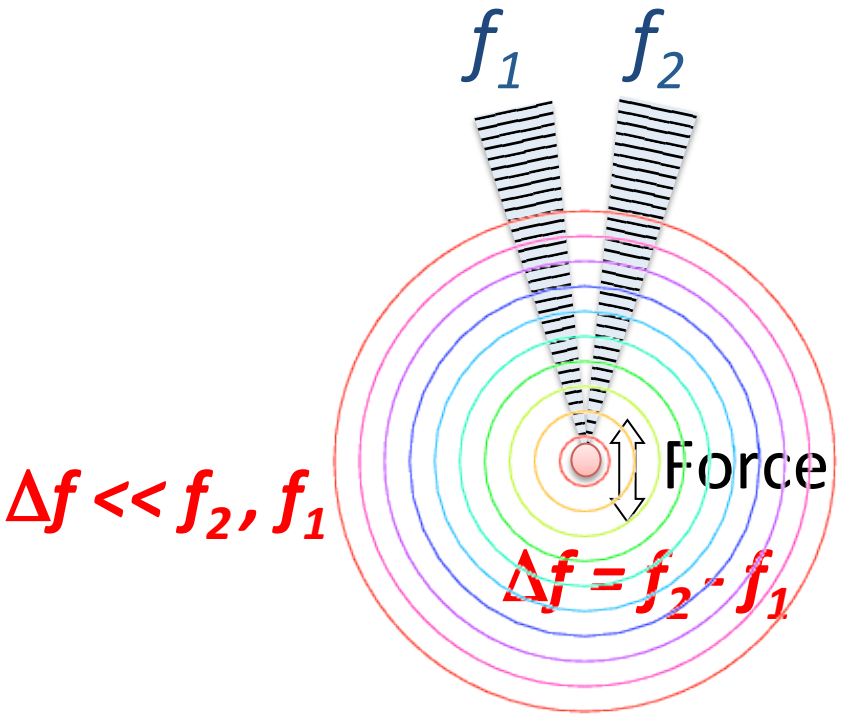
Harmonic Radiation of Force: Amplitude Modulated Ultrasound



Localized Radiation Force

Key Concepts:

- **Harmonic stress confined to a small region**
- **Conversion of ultrasound to audio range sound**



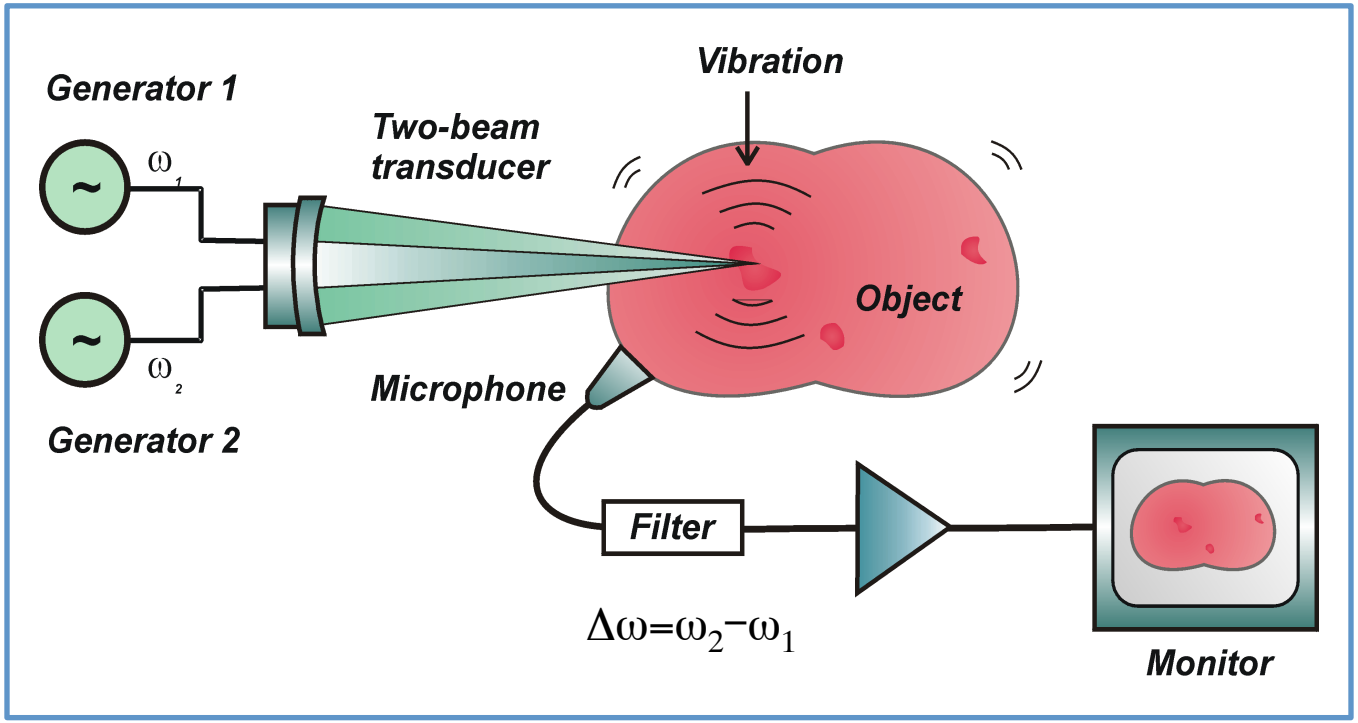
Advantages of using Ultrasonic Radiation Force

☑ **Remote** ……. *target internal organs*

☑ **Noninvasive** …. *non-ionizing*

☑ **Localized** …….. *focused point-force*

Vibro-acoustography



Comparison with B-mode ultrasound imaging:

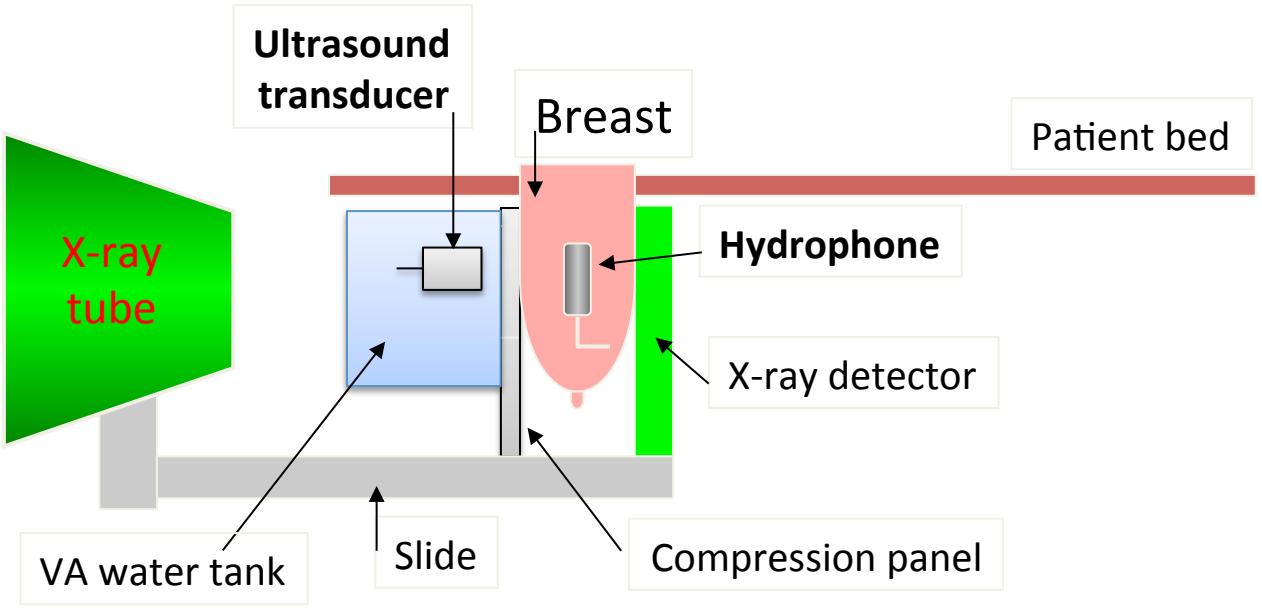
- Transmit and receive signals at *significantly* different frequencies
- Transmit and receive paths are different

Features of Vibro-acoustography

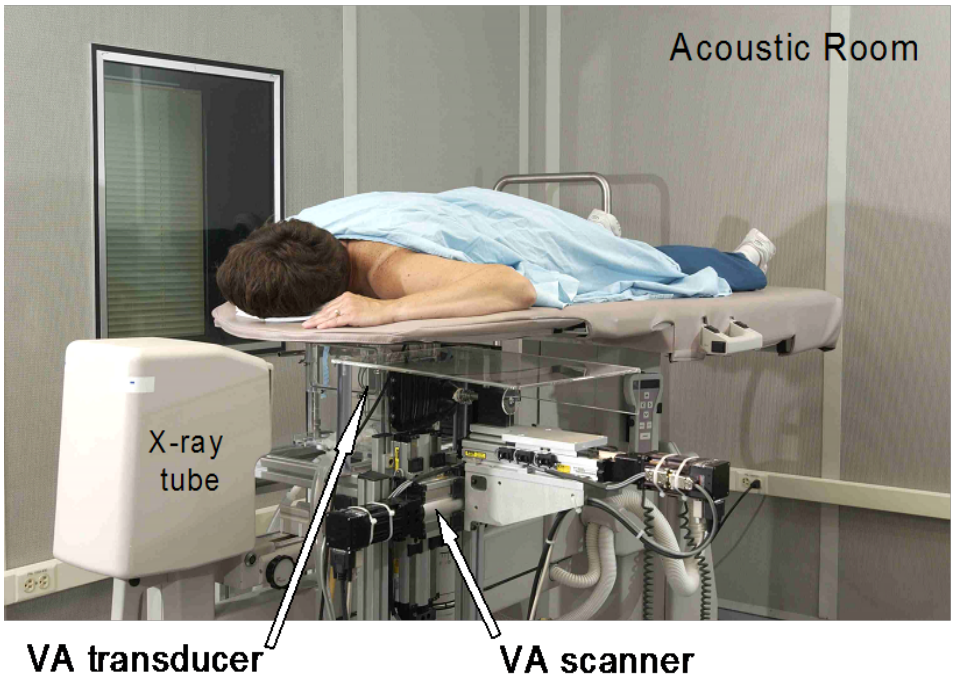
- Ultrasound resolution, acoustic image
- Speckle free
- Angle-independent: Specular surface
- Resonance mode imaging

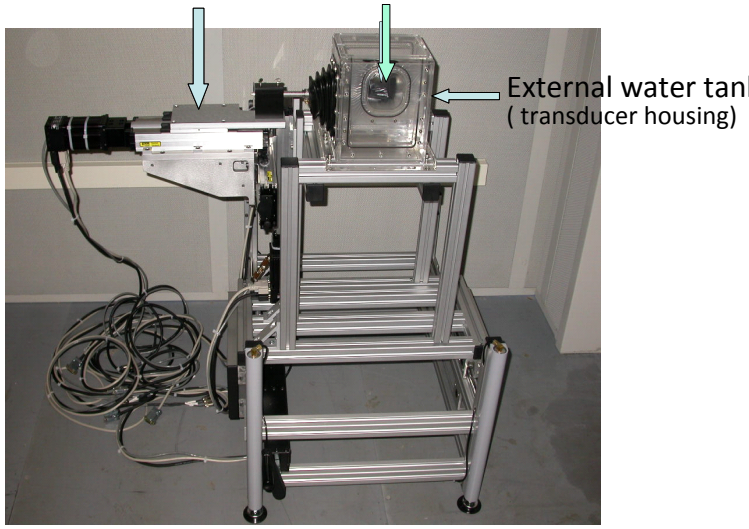
In vivo Breast Vibro-acoustography

Combined Vibro-acoustography-Mammography System



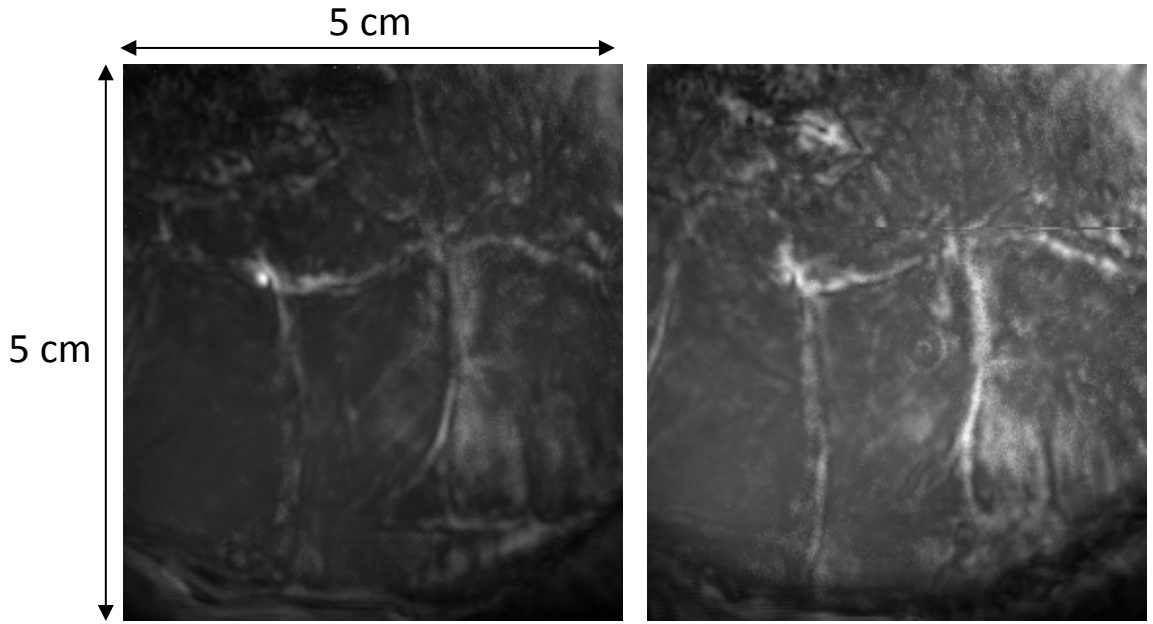
Combined Vibro-acoustography-Mammography System





In vivo Breast Vibro-acoustography

Normal Breast with Calcification



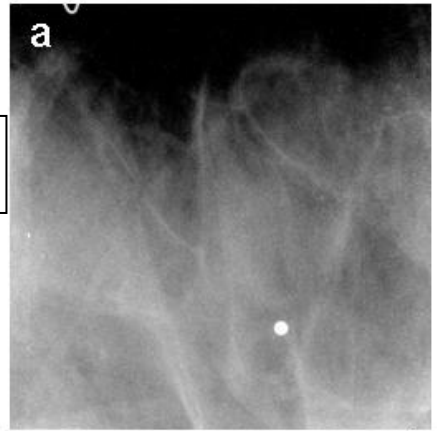
Δf = 50 kHz

Speckle free Imaging – Easier to see calcification

In Vivo Breast Vibro-acoustography

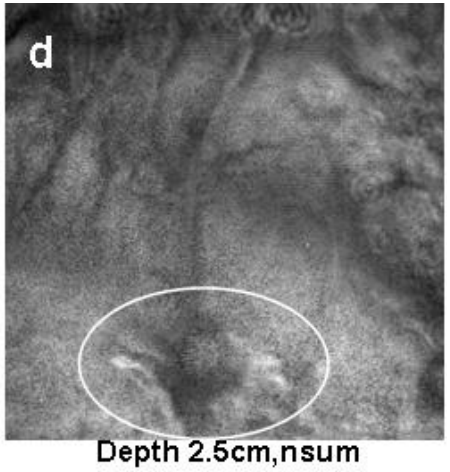
Papilloma

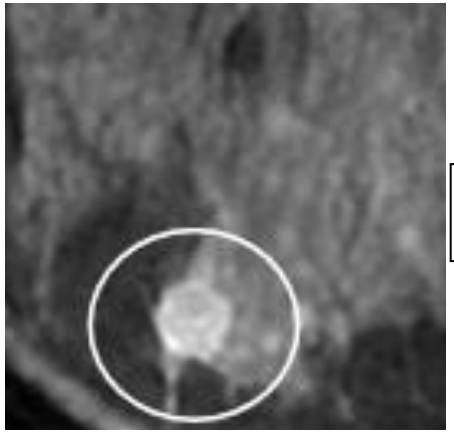
Mammo



US

VA





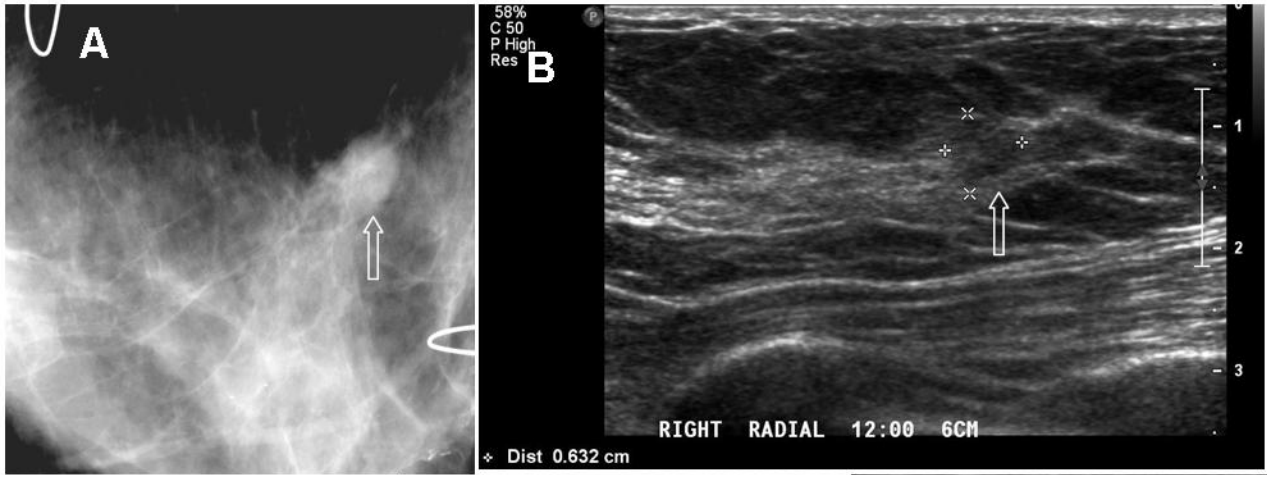
MRI

Lesion not seen in x-ray. In US it looks like a cyst, and ductal extensions not seen. VA is similar to MRI.

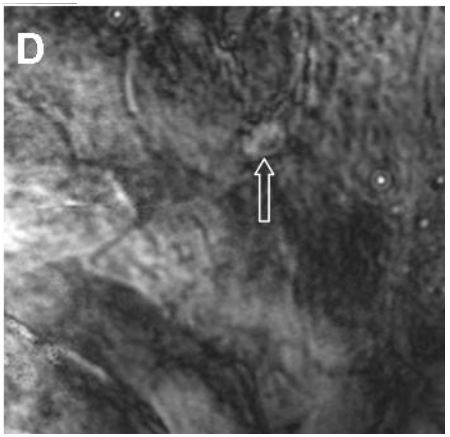
In Vivo Breast Vibro-acoustography

Mammo

US



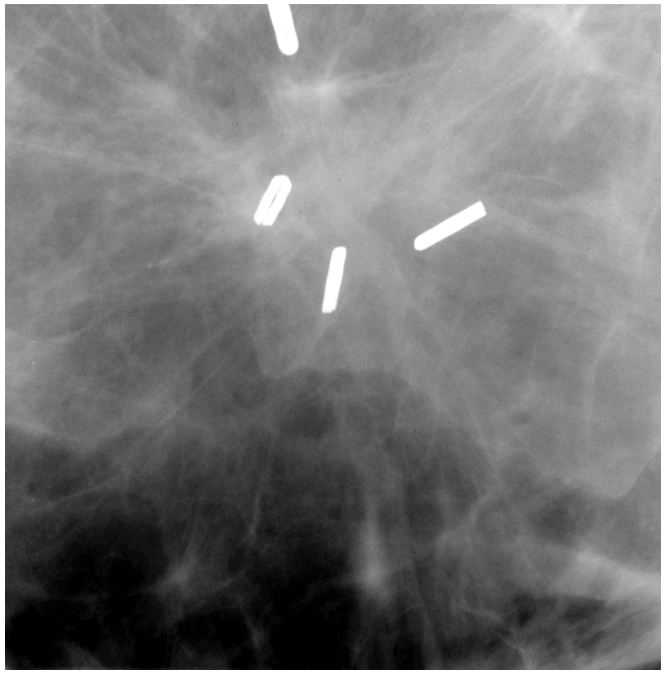
VA



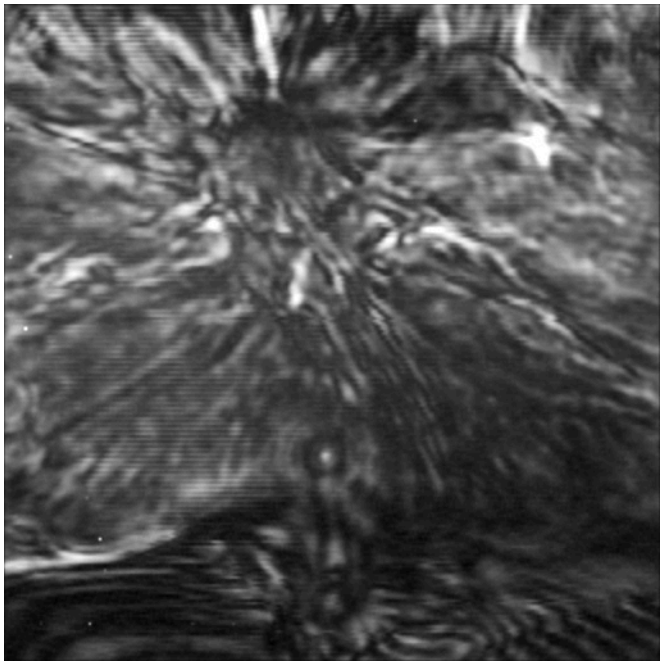
Invasive mammary carcinoma, Nottingham grade I (of III), with mucinous features (VAP037)

The x-ray shows a hint of a cancer lesion. Ultrasound shows a dark region about (arrow) 6 mm in diameter, however it is not easy to distinguish that from other regions. Vibro-acoustography clearly shows the lesion with clear boundary

Tissue Structure, Surgical Scar and Clips



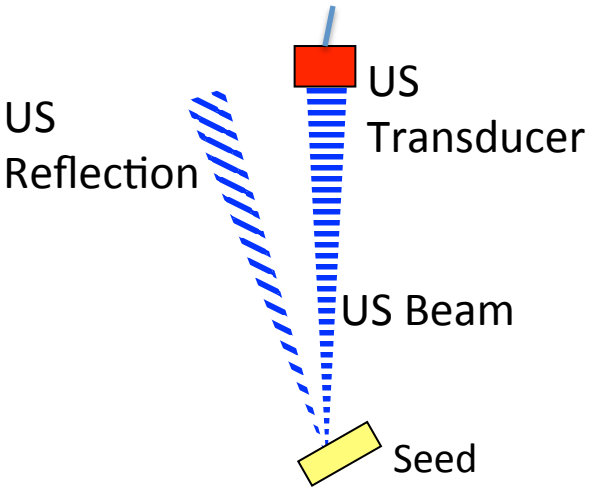
Mammogram



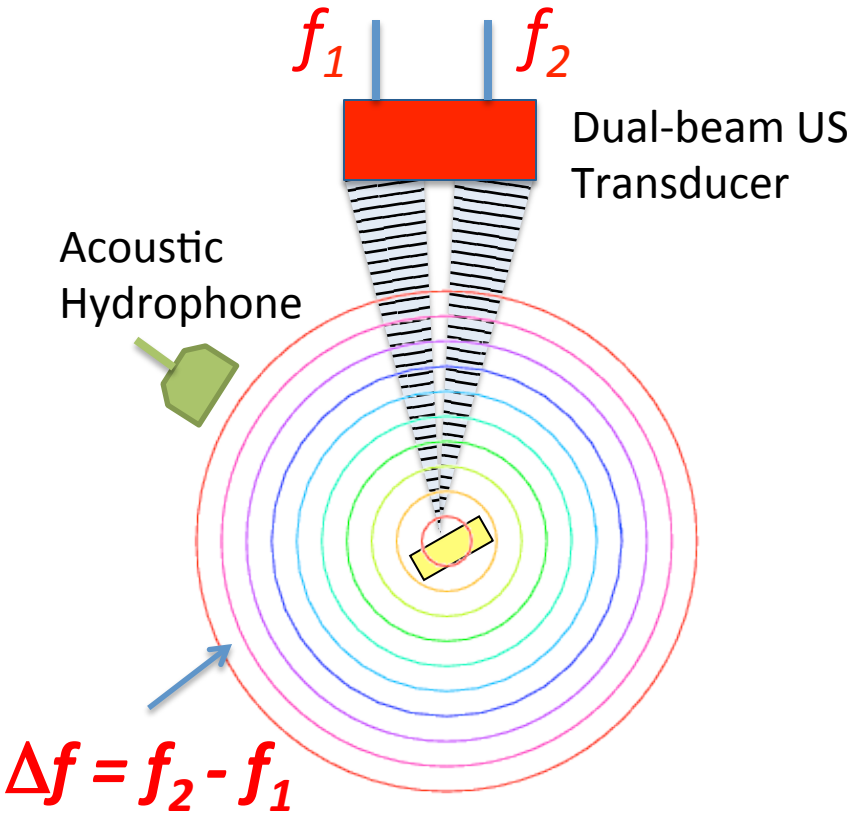
VA (1.5 cm depth, 50 kHz)

Imaging Specular Object

B/C-mode US

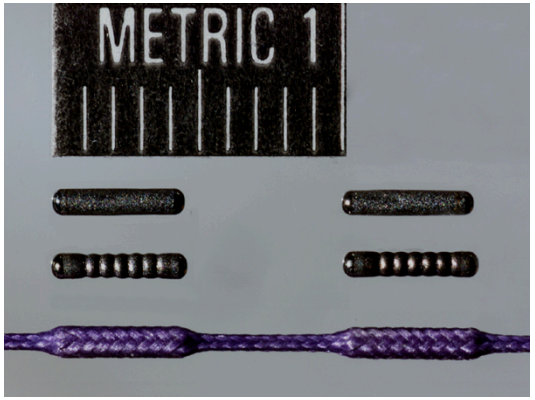


Vibro-acoustography

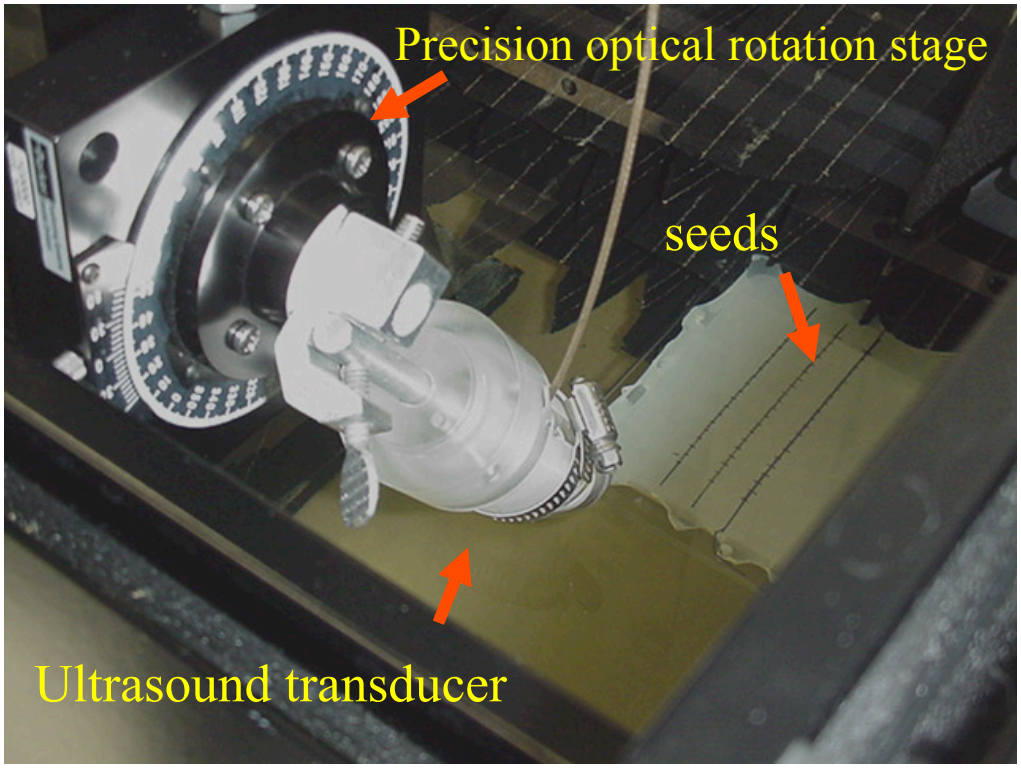


Vibro-acoustography of Brachytherapy seeds & comparison with Ultrasound

Brachytherapy Seeds

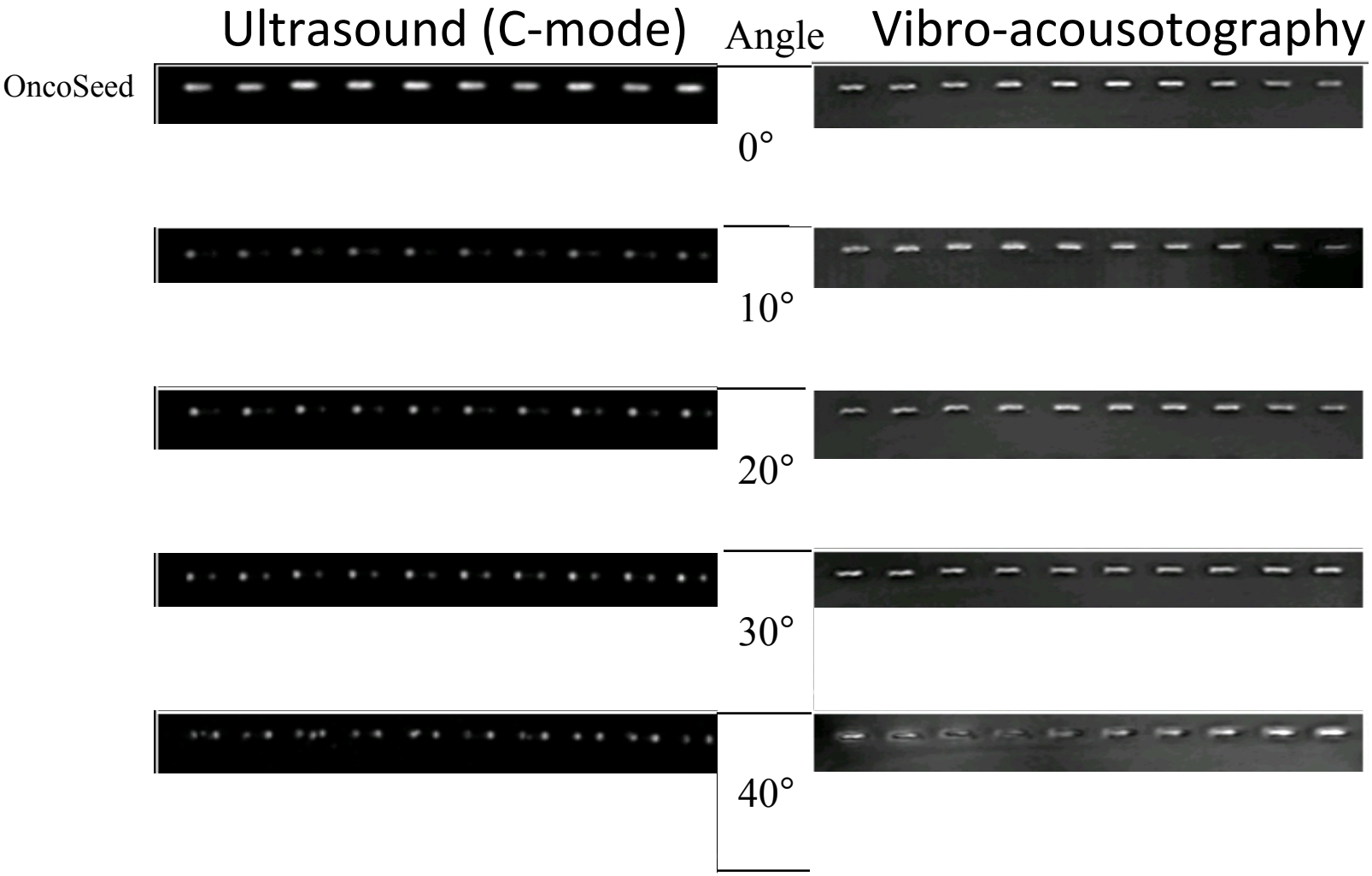


Experimental Setup



Experiments: (1) Pulse echo ultrasound, (2) Vibro-acoustography

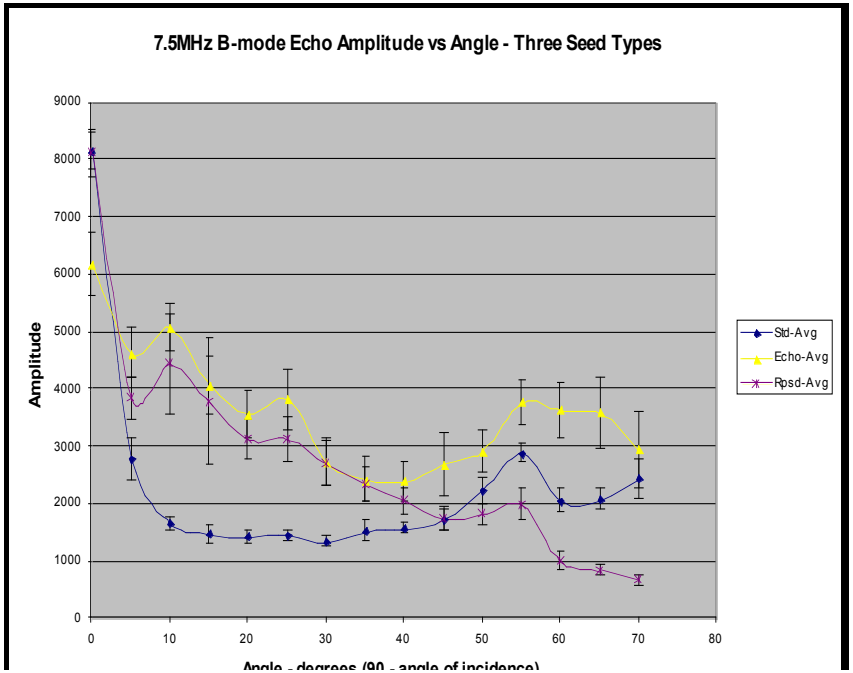
Vibro-acoustography and Ultrasound Imaging of Seeds as a Function of Angle



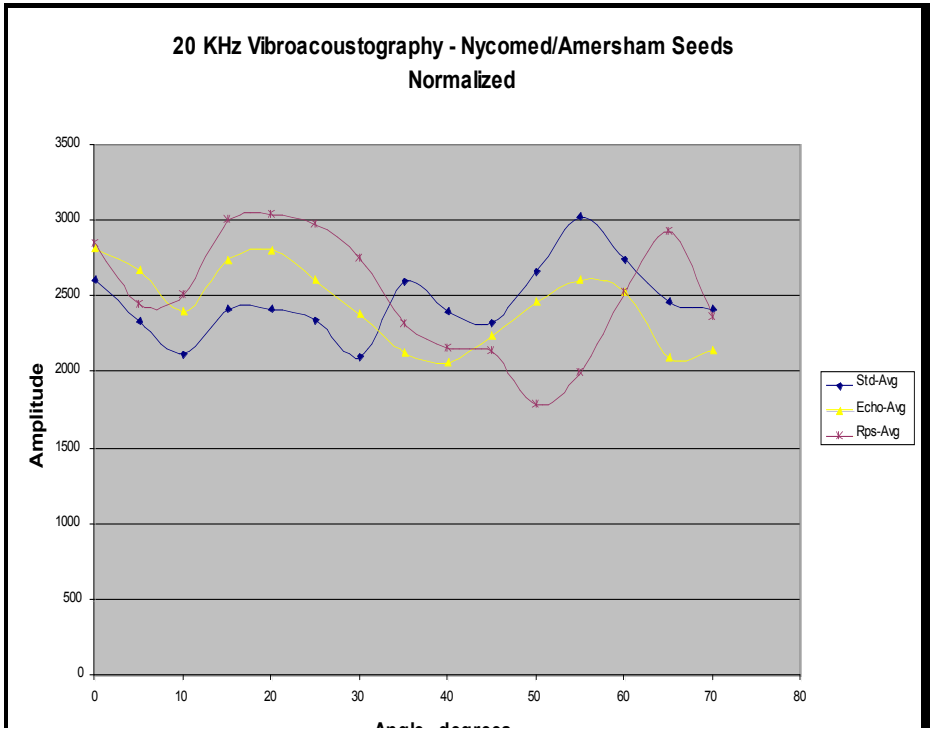
Mitri, et al, *Ultrasonics* 49 (2009) 31–38

Sensitivity to Orientation

Ultrasound (C-mode)



Vibro-acoustography



Mitri, et al, *Ultrasonics* 49 (2009) 31–38

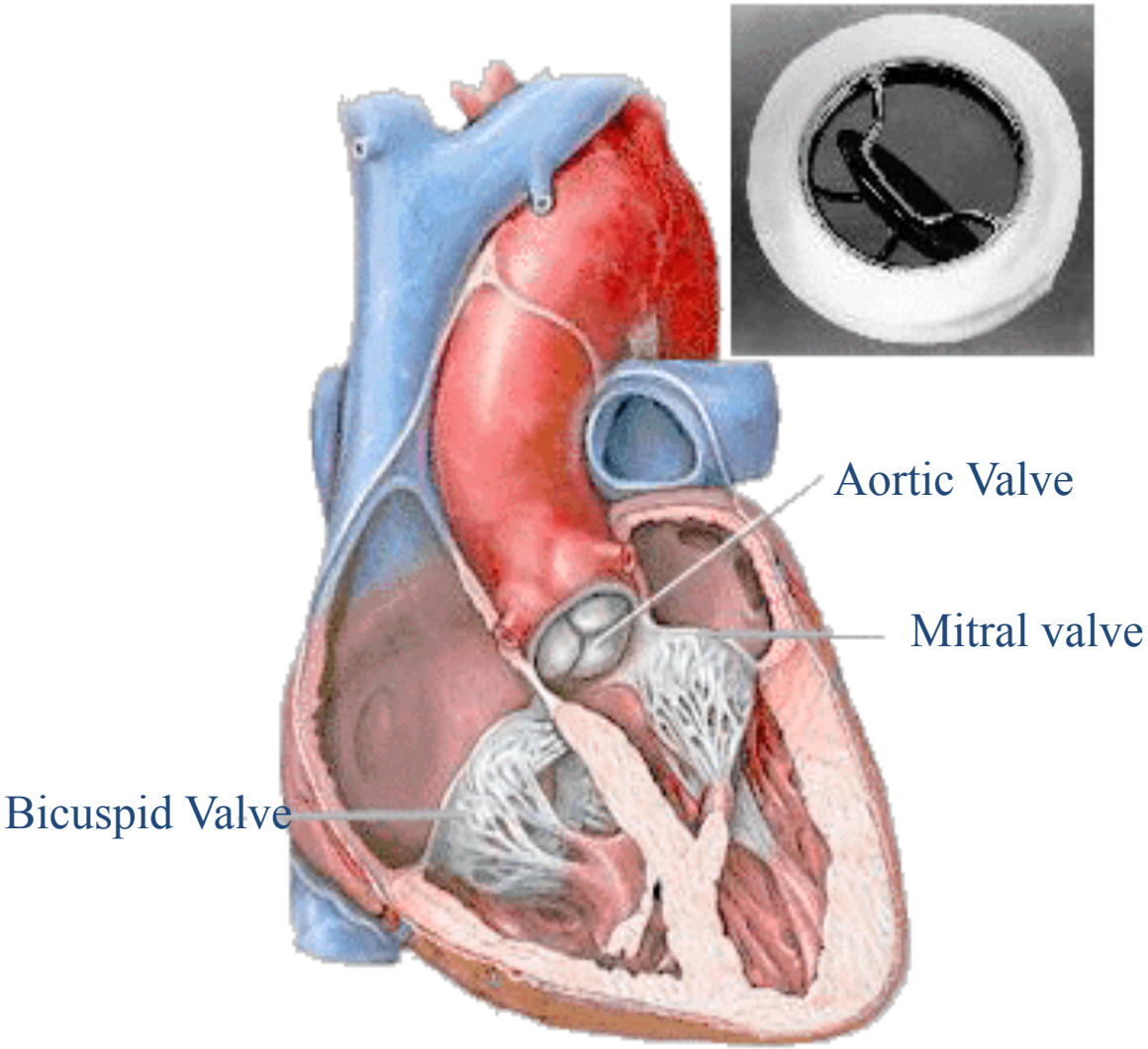
Resonance Mode Imaging
(Vibroacoustic Spetrography)

Key concept:

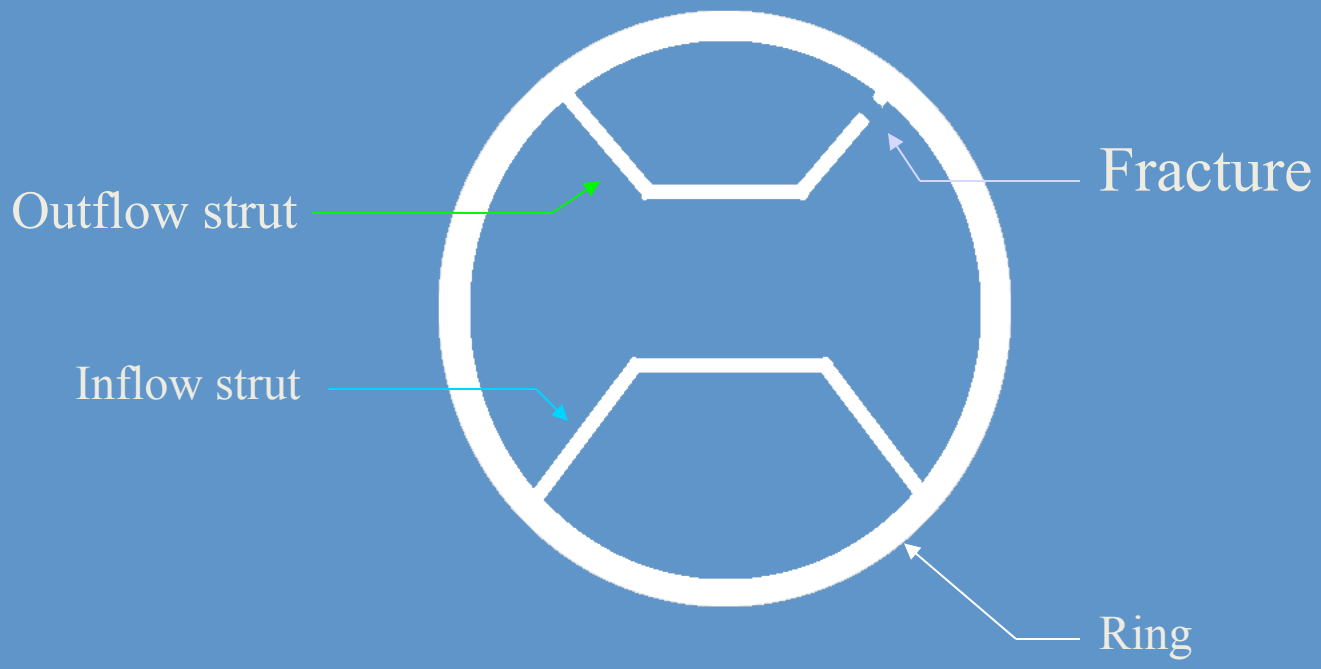
Testing the Integrity of Object Using Resonance Frequency

Potential Application: Imaging implants

Resonance Mode Imaging: Mechanical Heart Valve

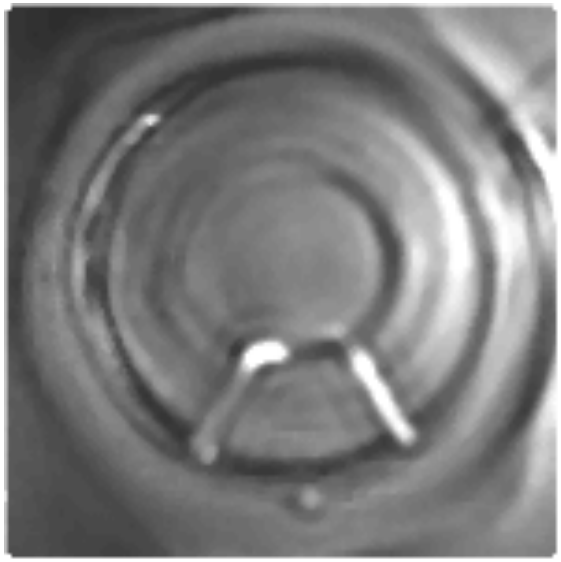


Fracture in the Heart Valve

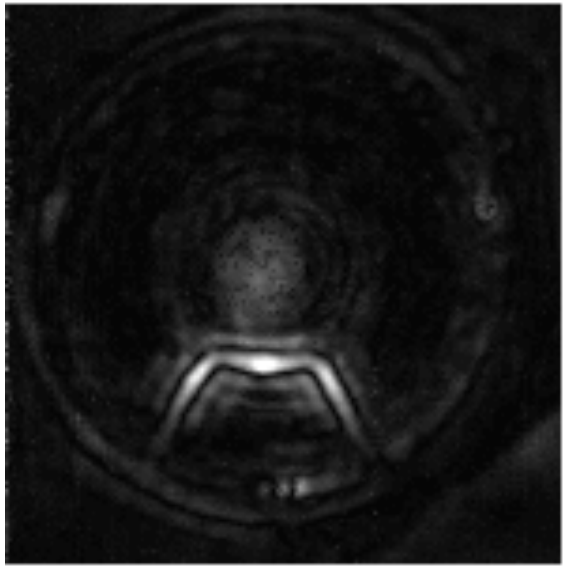


Goal: Image to detect fracture

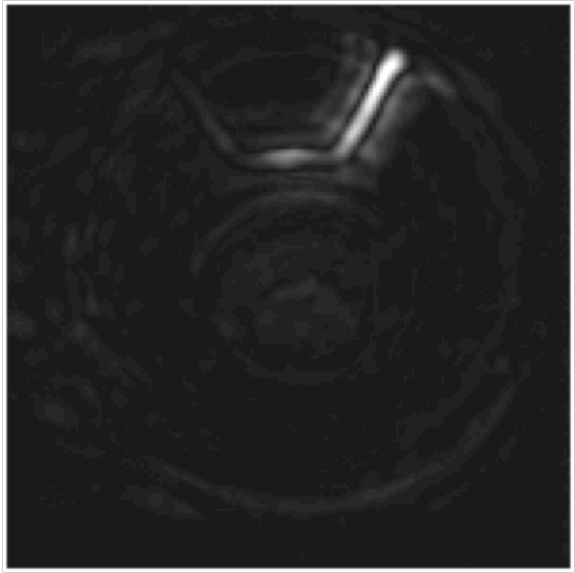
Resonance Mode Imaging
(Vibroacoustic Spectrography)



48 kHz
Whole valve



7.4 kHz
Intact strut



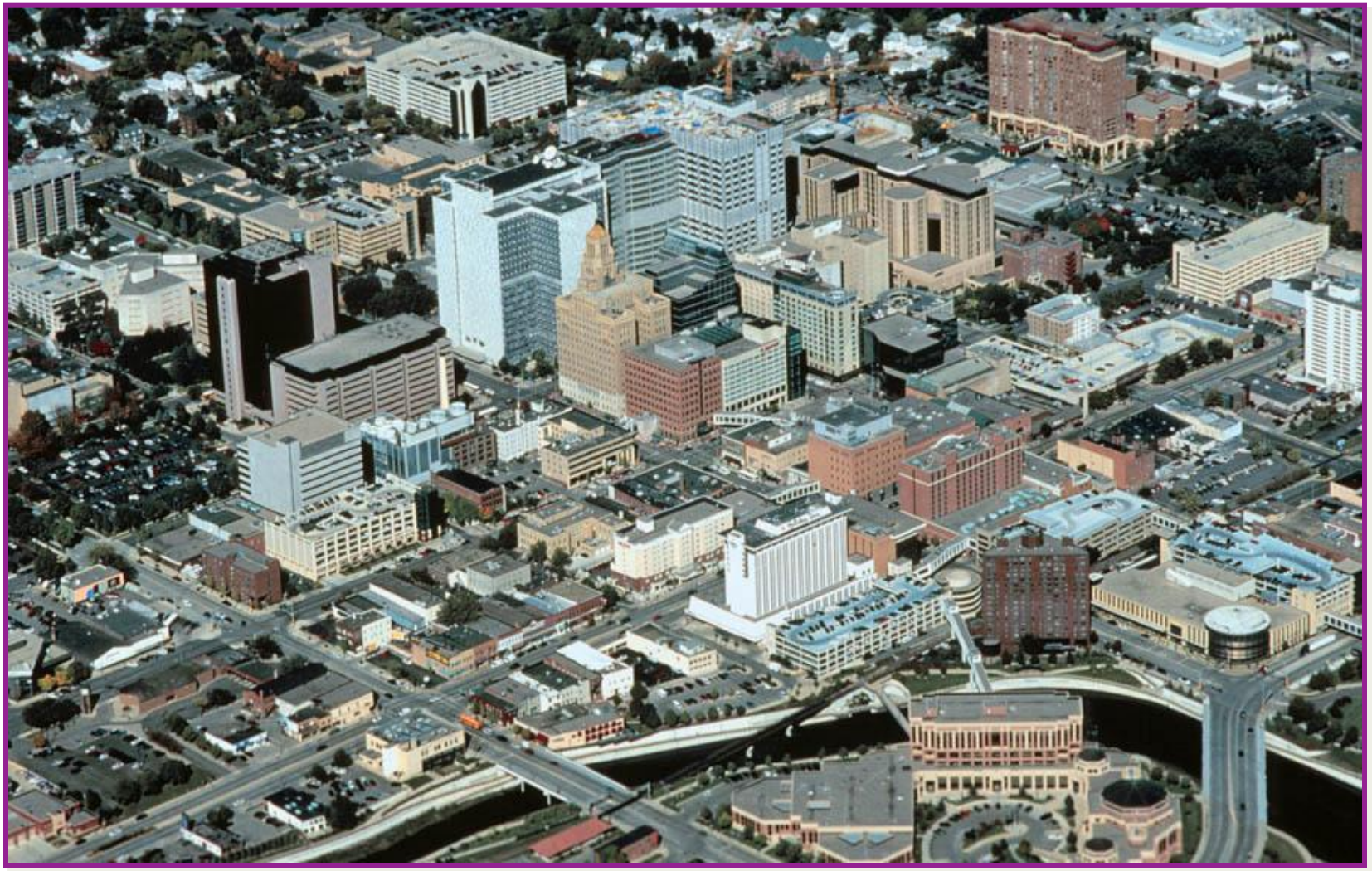
2.04 kHz
Broken strut

$\Delta f = f_2 - f_1$

Summary

- Overview of vibro-acoustography
- Radiation force of ultrasound
- Generate localized harmonic radiation force
- Conversion of ultrasound to low frequency sound
- Vibro-acoustography principles
- Features of Vibro-acoustography:
  - ✓ Speckle free – Detecting calcifications
  - ✓ Independent of angle – Specular reflectors
  - ✓ Resonance mode imaging – Testing integrity

Thank you!



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Thank You!