Ultrasound Instrumentation

BME 4401 Medical Imaging

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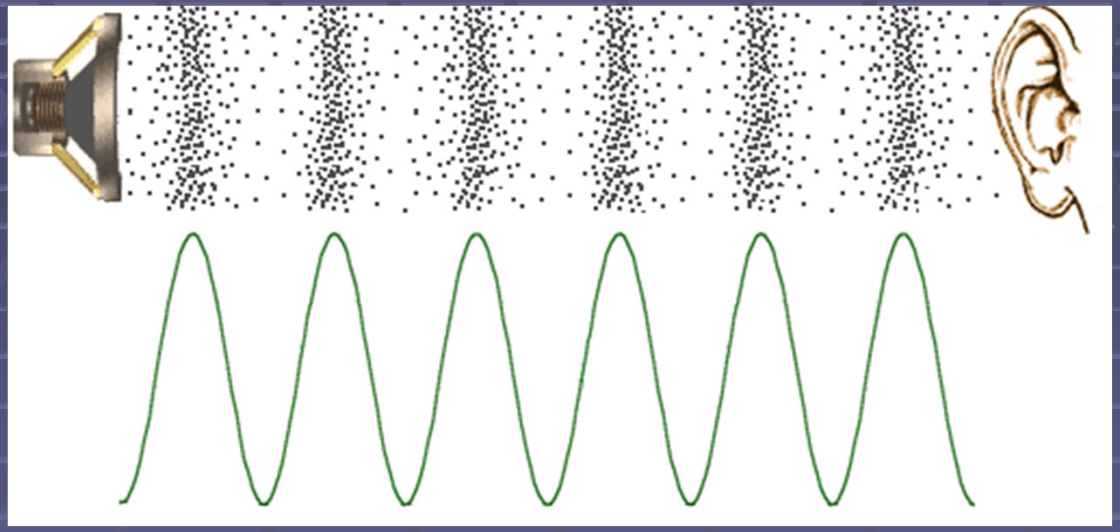
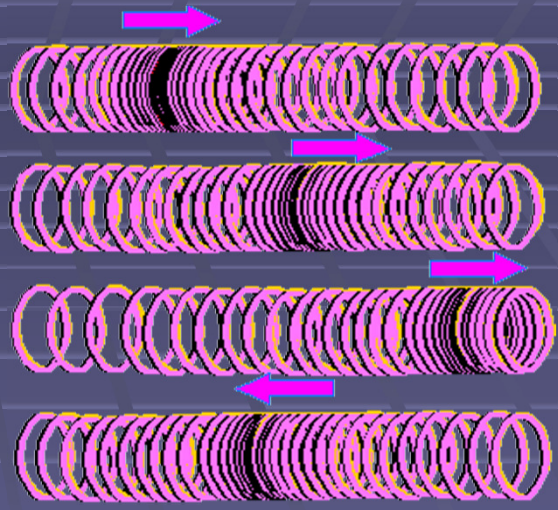
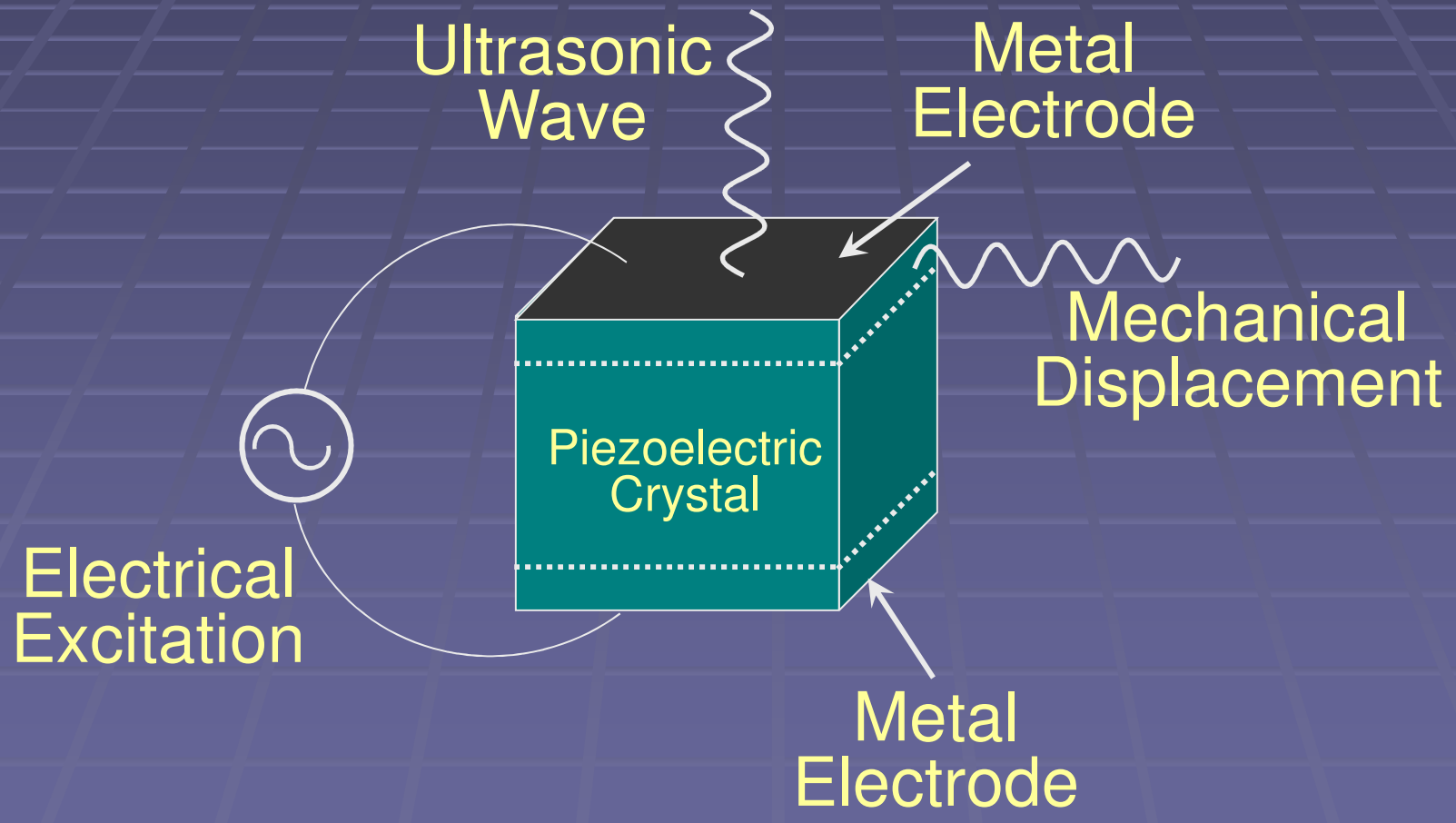
Sound Waves



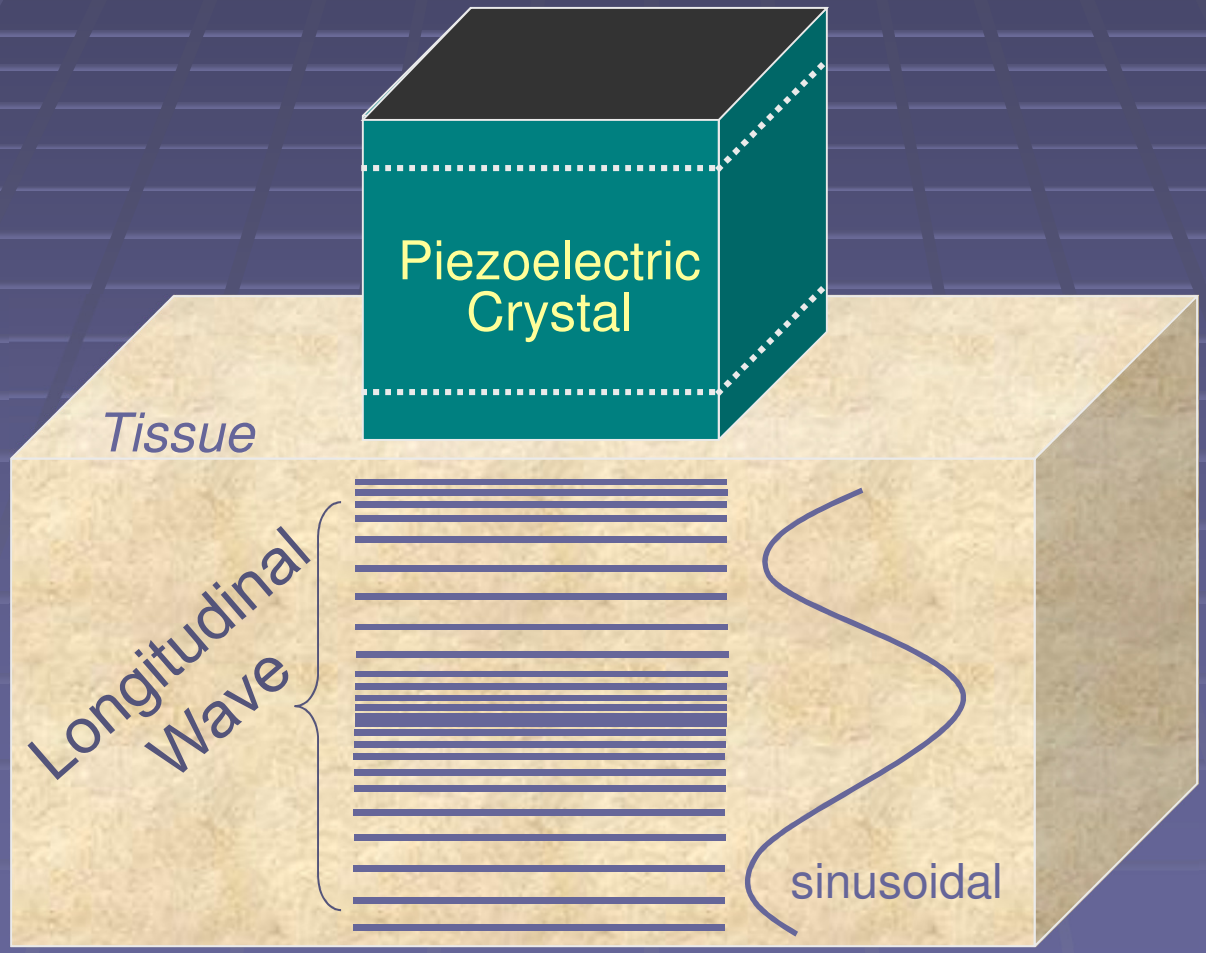


http://www.youtube.com/watch?v=aguCWnbRETU

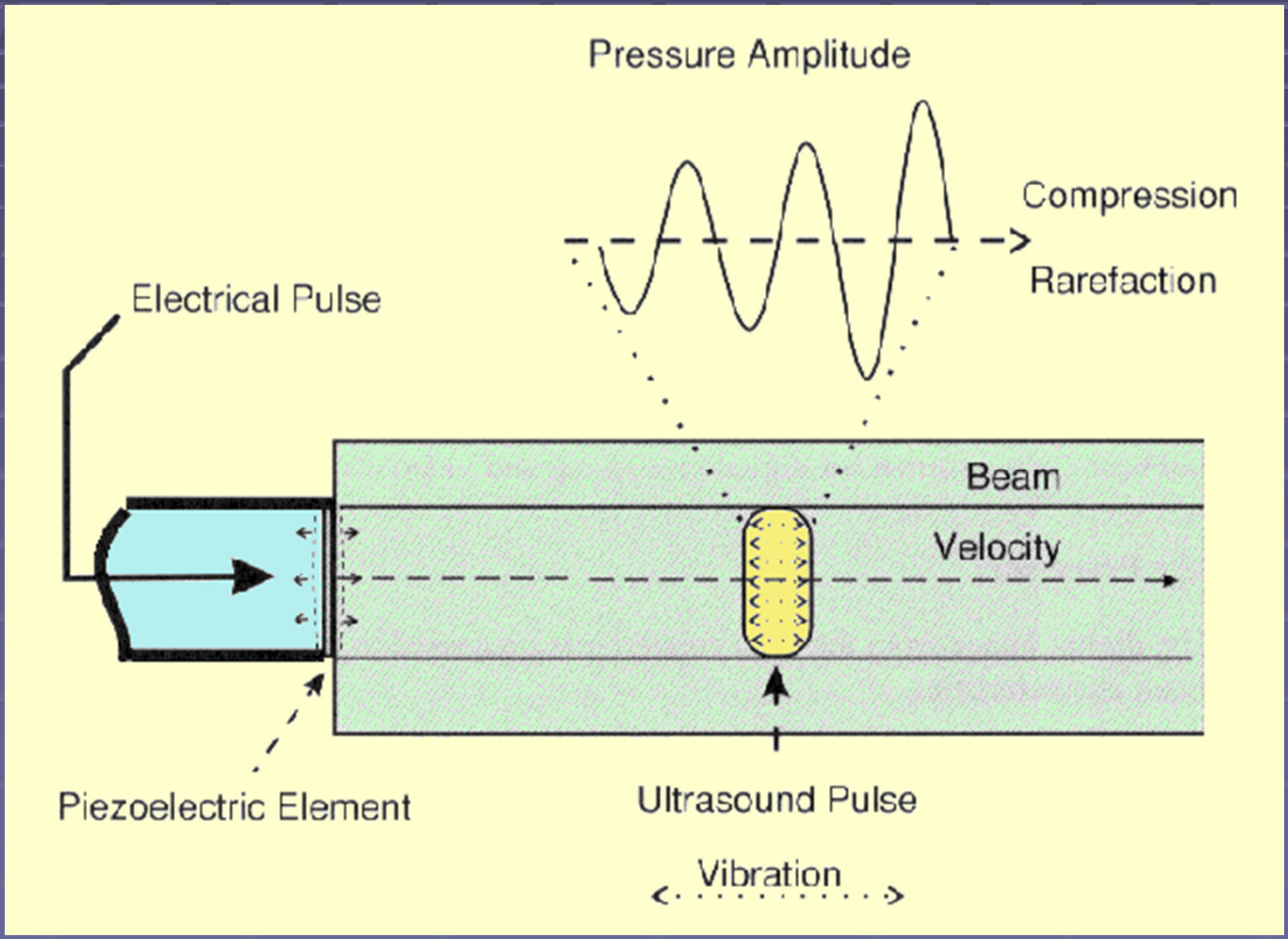
Ultrasonic Transducers



Ultrasonic Transducers



Ultrasonic Transducers



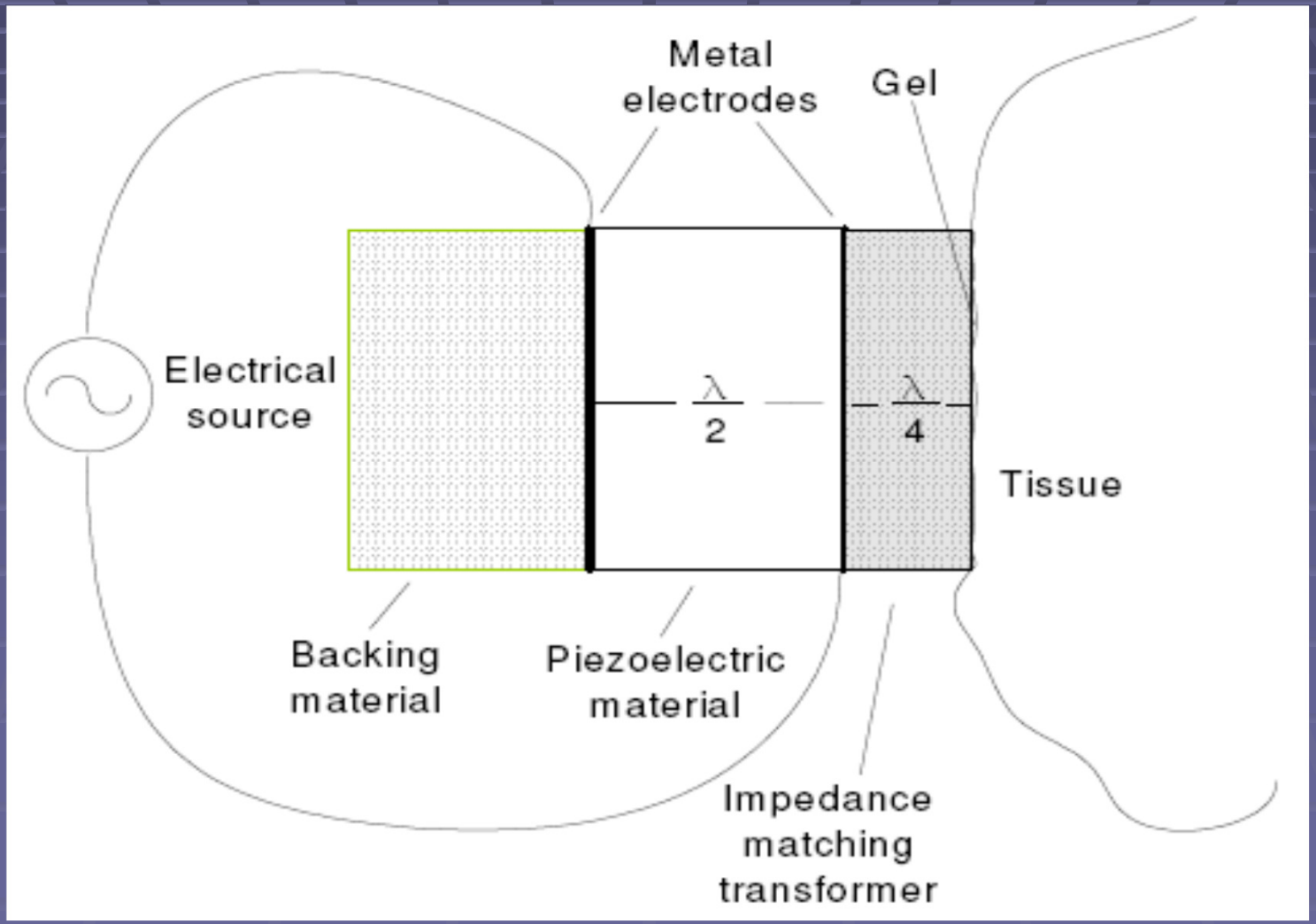
Impedance Matching

Maximum energy transfer:
optimum oscillation &
impedance matching

Transducer =
½ sinusoidal wavelength

Coupled to tissue through ¼
wavelength transformer

Impedance Matching



Impedance Matching

$$Z_T = \text{sqrt}\,[\, Z_{IN} * Z_{OUT}\,]$$

$Z_T \rightarrow$ characteristic impedance of transformer

$Z_{IN} \rightarrow$ characteristic impedance of material at input of transformer (transducer)

$Z_{OUT} \rightarrow$ characteristic impedance of material at output of transformer (tissue)

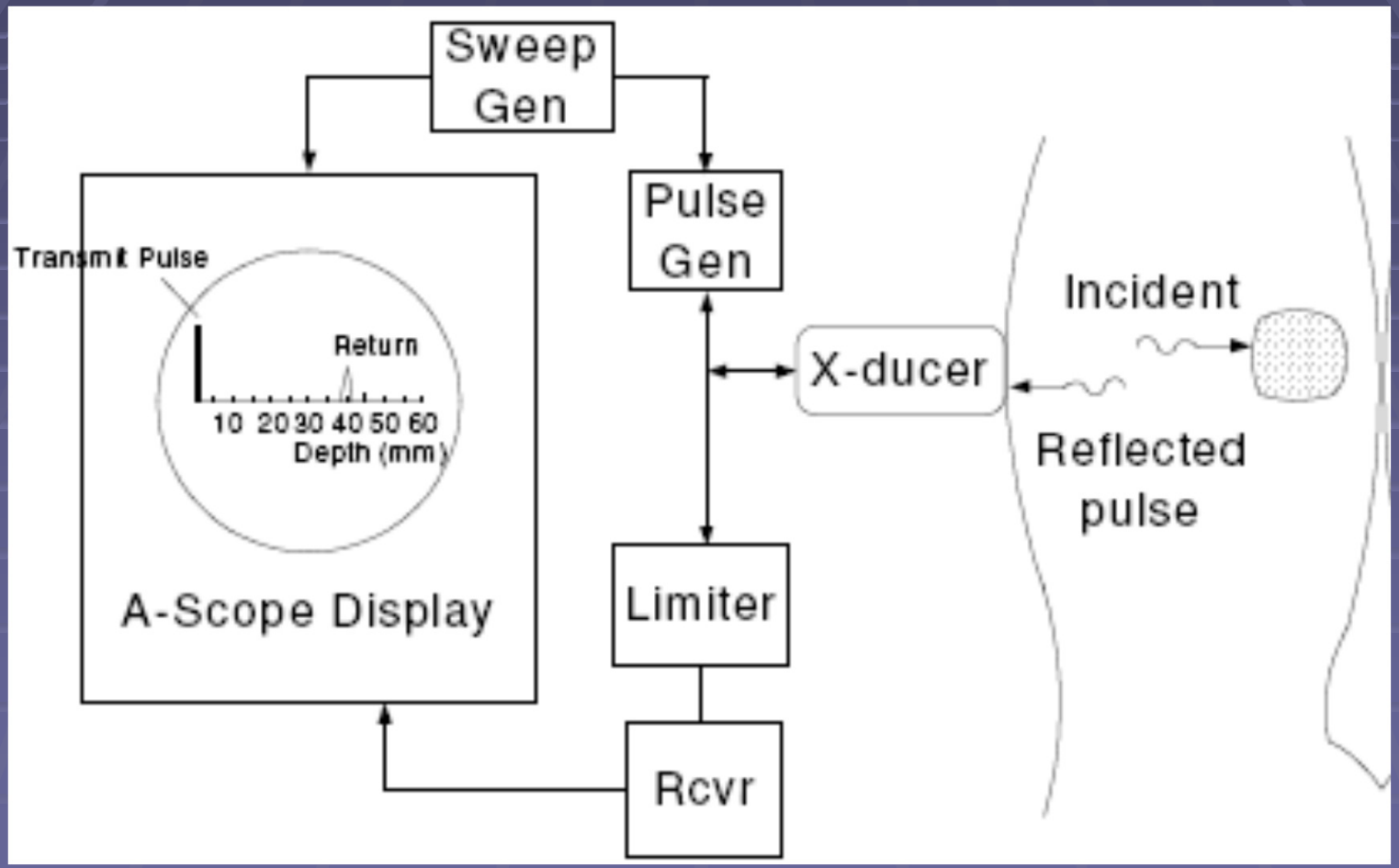
Table 6.1. Typical ultrasonic parameters

Material	Propagation Speed (m/s)	Density (g/mL)	Characteristic Impedance (kg/m^2-s)
Air	330	0.0012	0.000396×10^6
Blood	1530	1.06	1.622×10^6
Bone	2700-4100	1.38-1.81	$3.726\text{-}7.421 \times 10^6$
Fat	1460-1470	0.92	$1.343\text{-}1.352 \times 10^6$
Lung	650	0.40	0.260×10^6
Muscle	1540-1630	1.07	$1.648 - 1.744 \times 10^6$
Water	1520	1.000	1.520×10^6

Impedance Matching

- Characteristic impedance can be adjusted using different viscosities of oil in rubber in the λ/4 transformer
- Different consistency used for skull bone and muscle for maximum power transfer
- Backing material: reflects energy of piezoelectric material back toward λ/4 transformer (amount chosen appropriately)

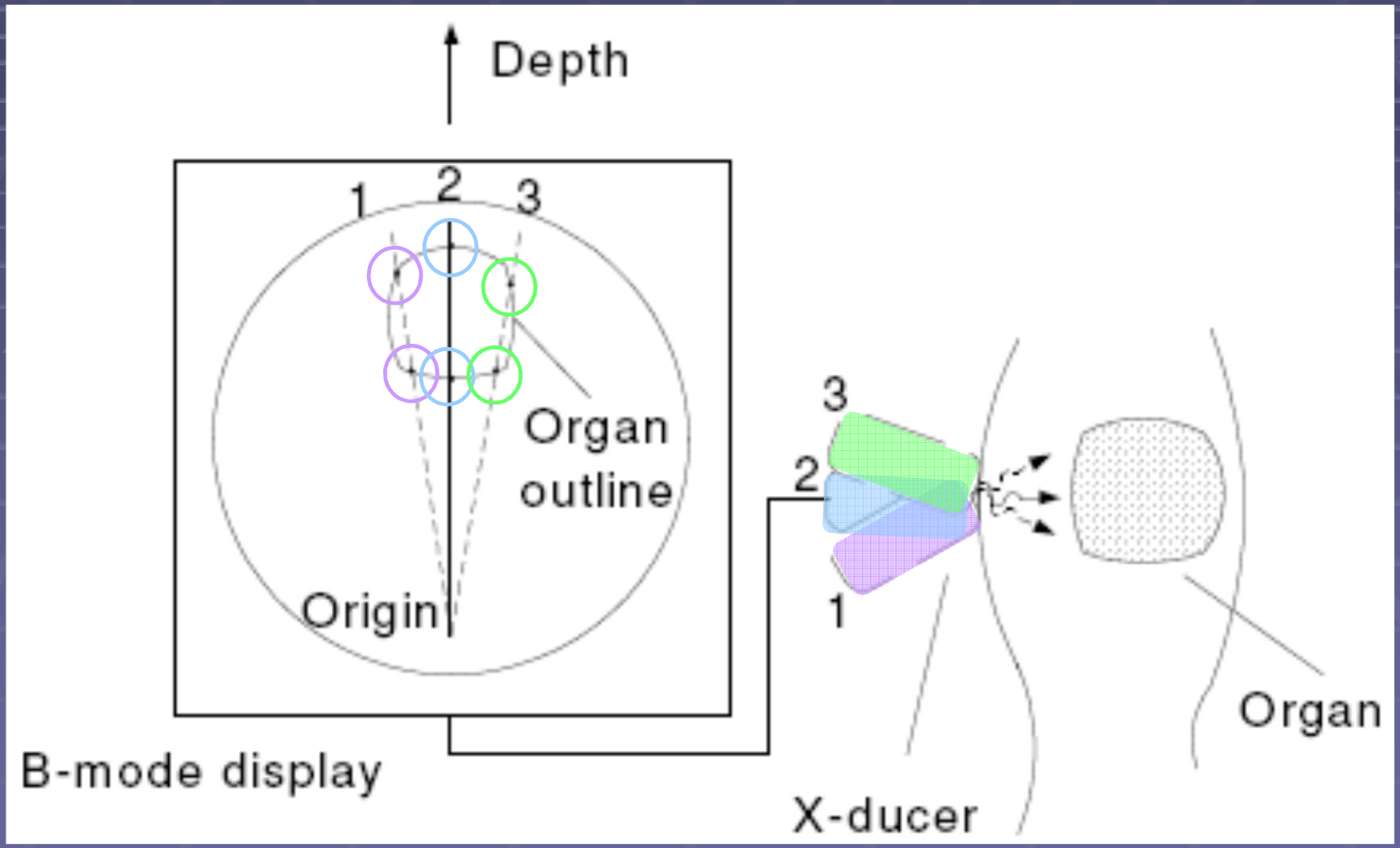
A-Scope Ultrasound Imaging



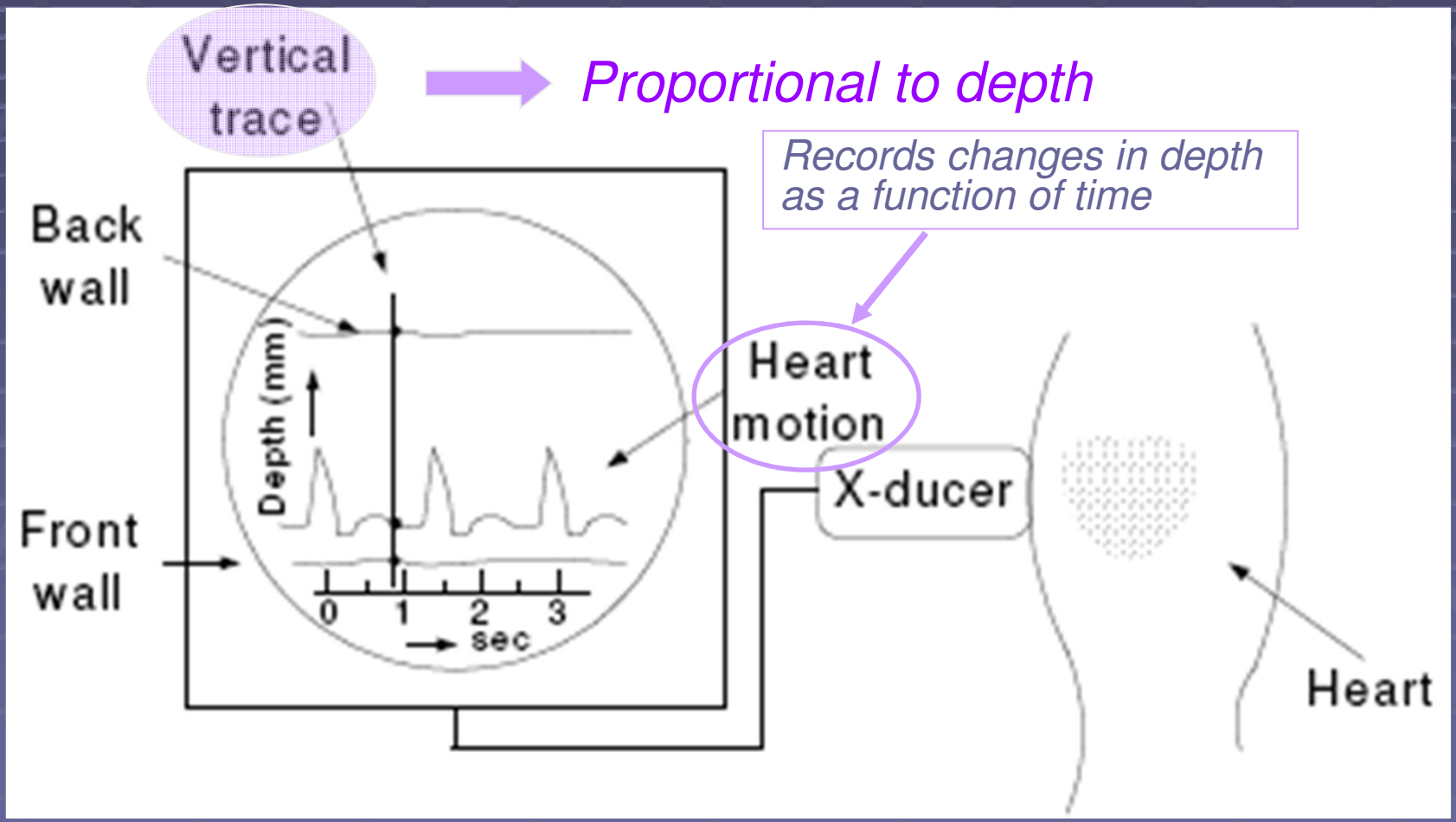
A-Scope Ultrasound Imaging

- Trace measures time elapsed from transmit pulse to return (time of travel)
- Time of round trip travel is converted to distance to determine depth of object imaged
- Planar view (depth and breadth) acquired using B-scope.

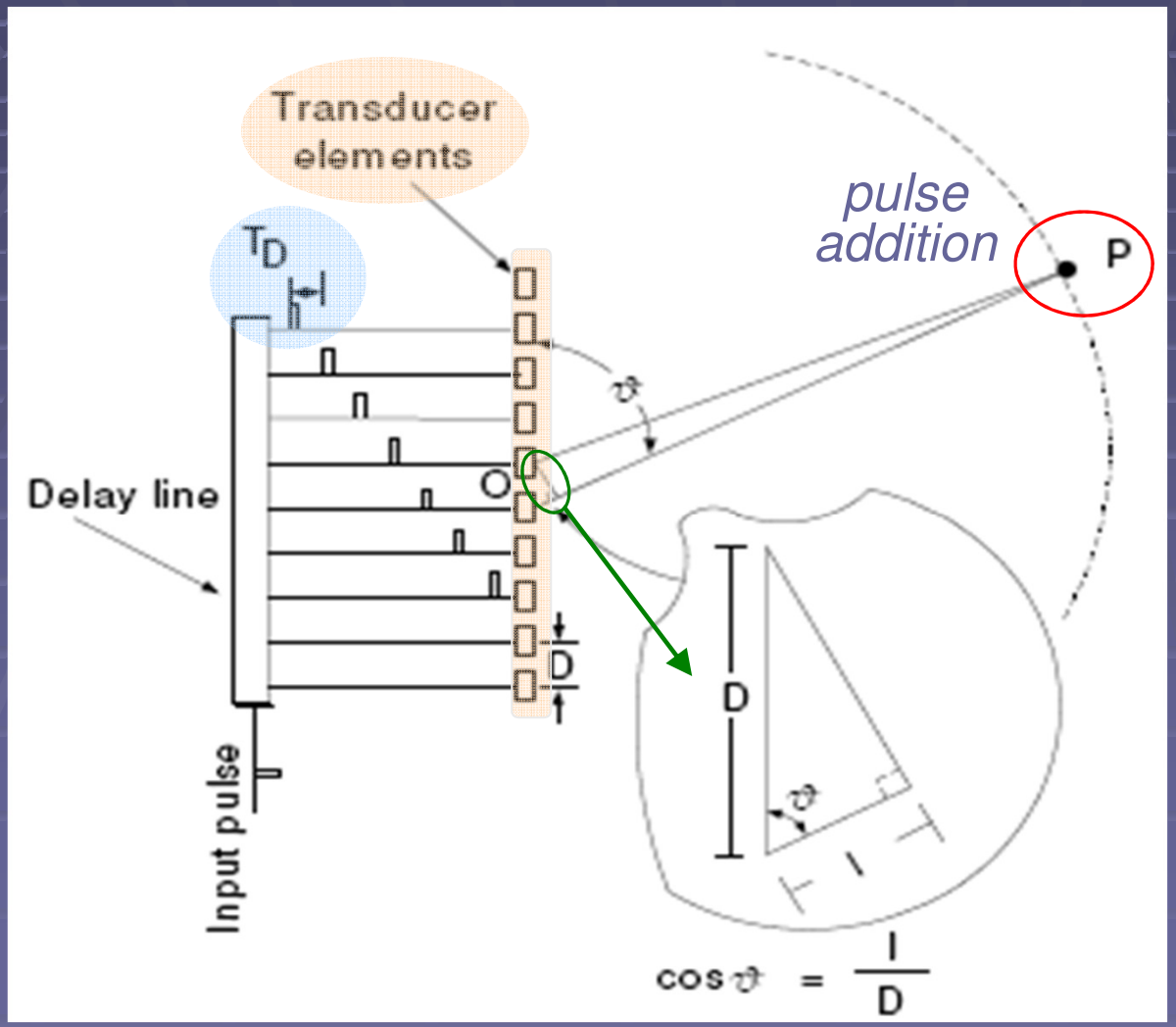
B-Scope Ultrasound Imaging



M-Mode Display



Phased Array

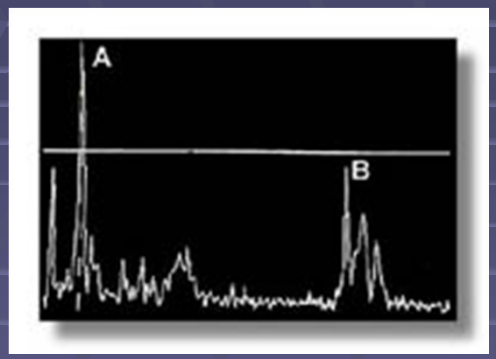


$$\cos \vartheta = \frac{l}{D}$$

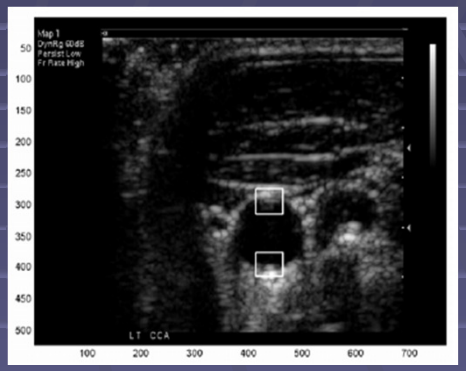
$$l = c\,T_D$$

$$\cos \vartheta = \frac{c\,T_D}{D}$$

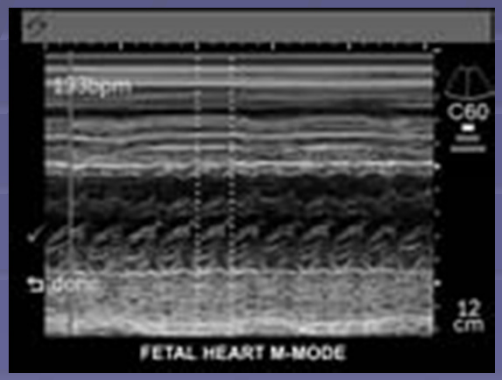
Ultrasound Imaging Modes



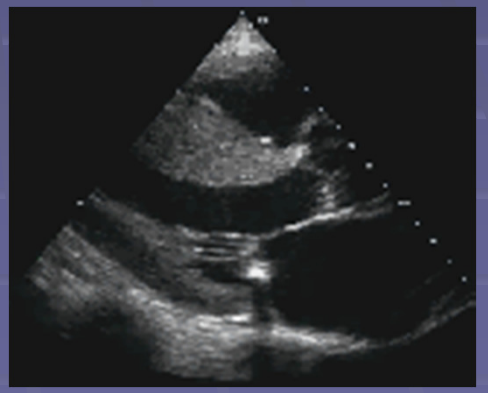
A-mode
(no longer used)



B-mode
"Brightness"

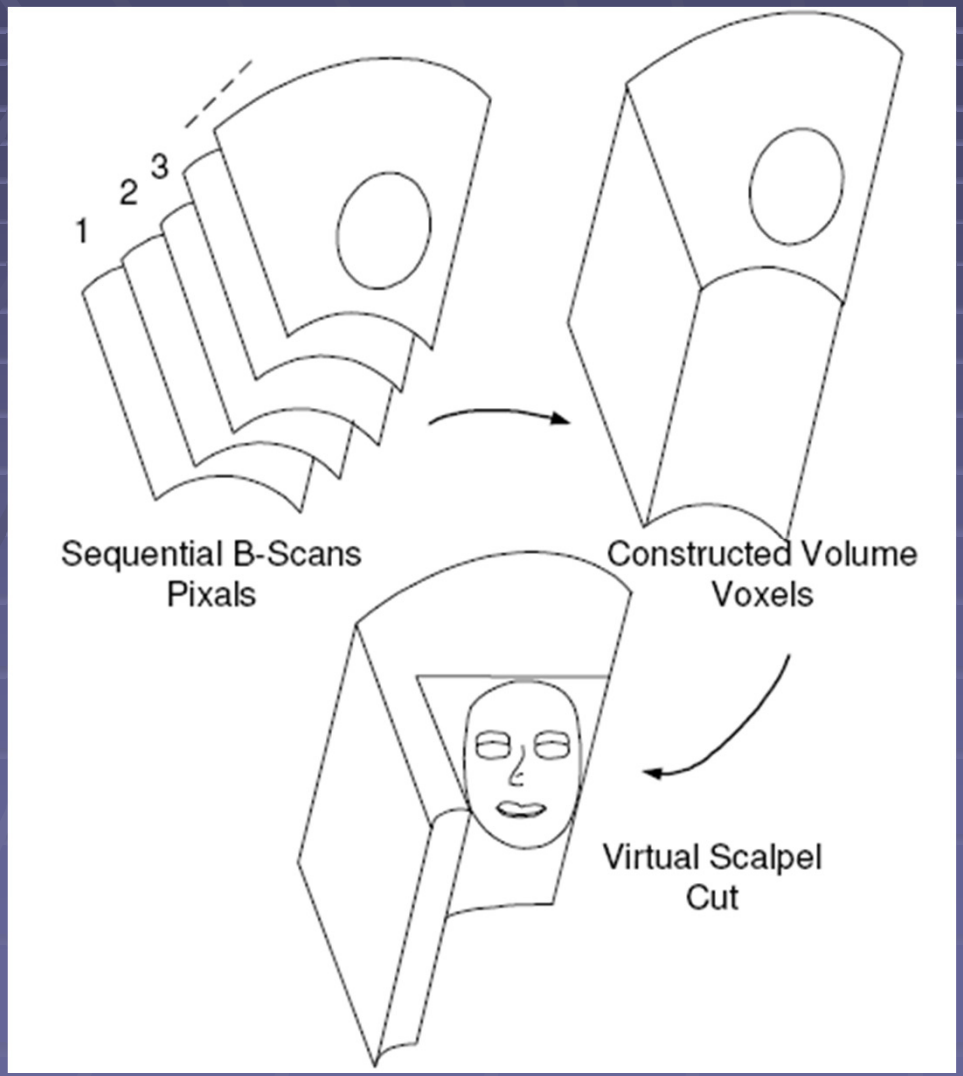


M-mode
"Motion"



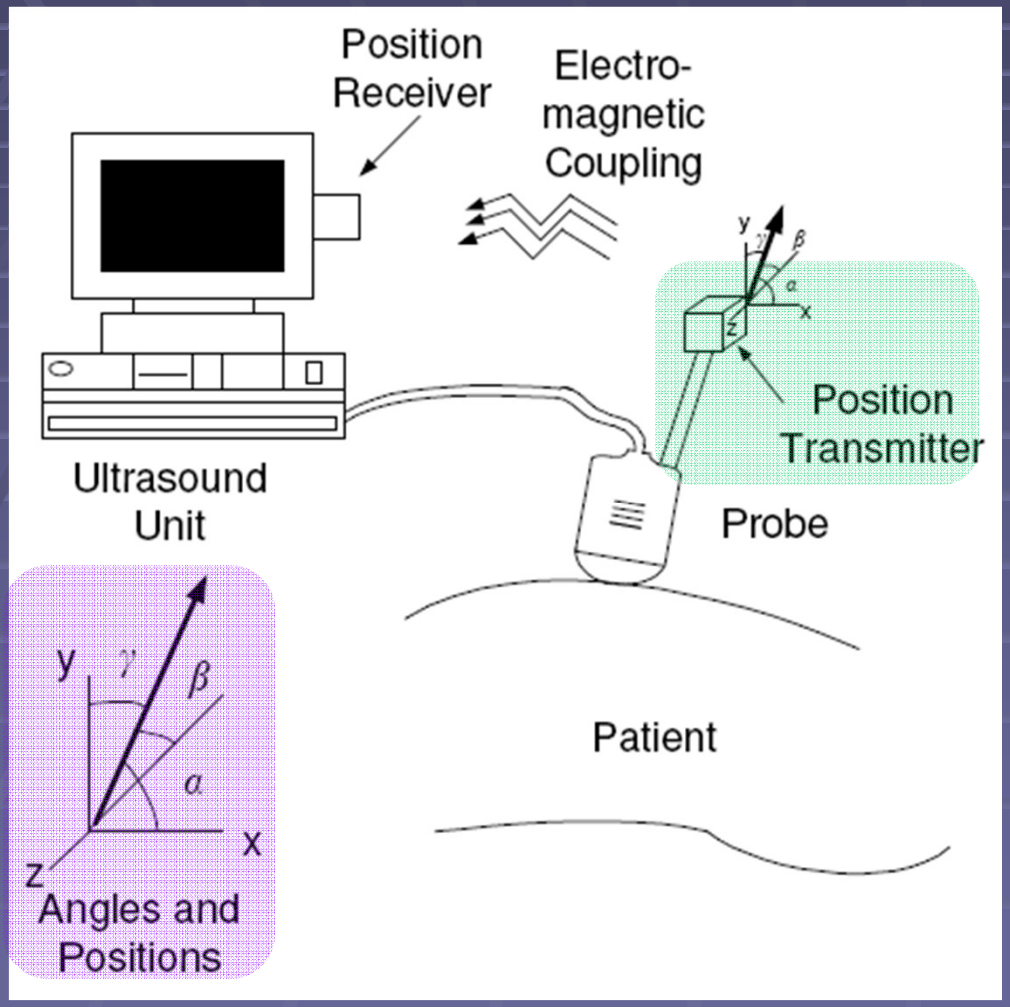
2D real time
(phased array)

3D and 4D Ultrasound Imaging



- B-mode images acquired at electronic speeds (10 to 60 per second) using phased array transducers.
- Successive x-y planes along z-direction stored in computer memory.
- Pixels converted to voxels of constant color or grey scale.
- Set of images used to construct a volume.

3D and 4D Ultrasound Imaging



- Position transmitter senses x,y,z position and relative angle.
- Position info. is used to accurately color the position voxels.
- 4D Ultrasound: 3D images processed in real time (30 frames/s).
- 2D array of transducers.

Harmonic Imaging

- Microbubbles – ultrasound contrast agent
- Used to image smaller and deeper vessels
- Bubbles in blood must be smaller than the smallest capillaries in the lungs (~10 µm)
- Bubble creates air-blood boundary, reflects ultrasound
- Bubble can resonate at frequencies of diagnostic ultrasound

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Harmonic Imaging

- Bubble can resonate at frequencies of diagnostic ultrasound
- Improves reflection properties and introduces harmonics of incident US freq.
- Bubbles burst → enhance second harmonic

Ultrasound Resolution

&

Doppler Effect