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Molecular Imaging…Clearly™

3D photoacoustic and ultrasonic imaging of the breast using a spherical detector array

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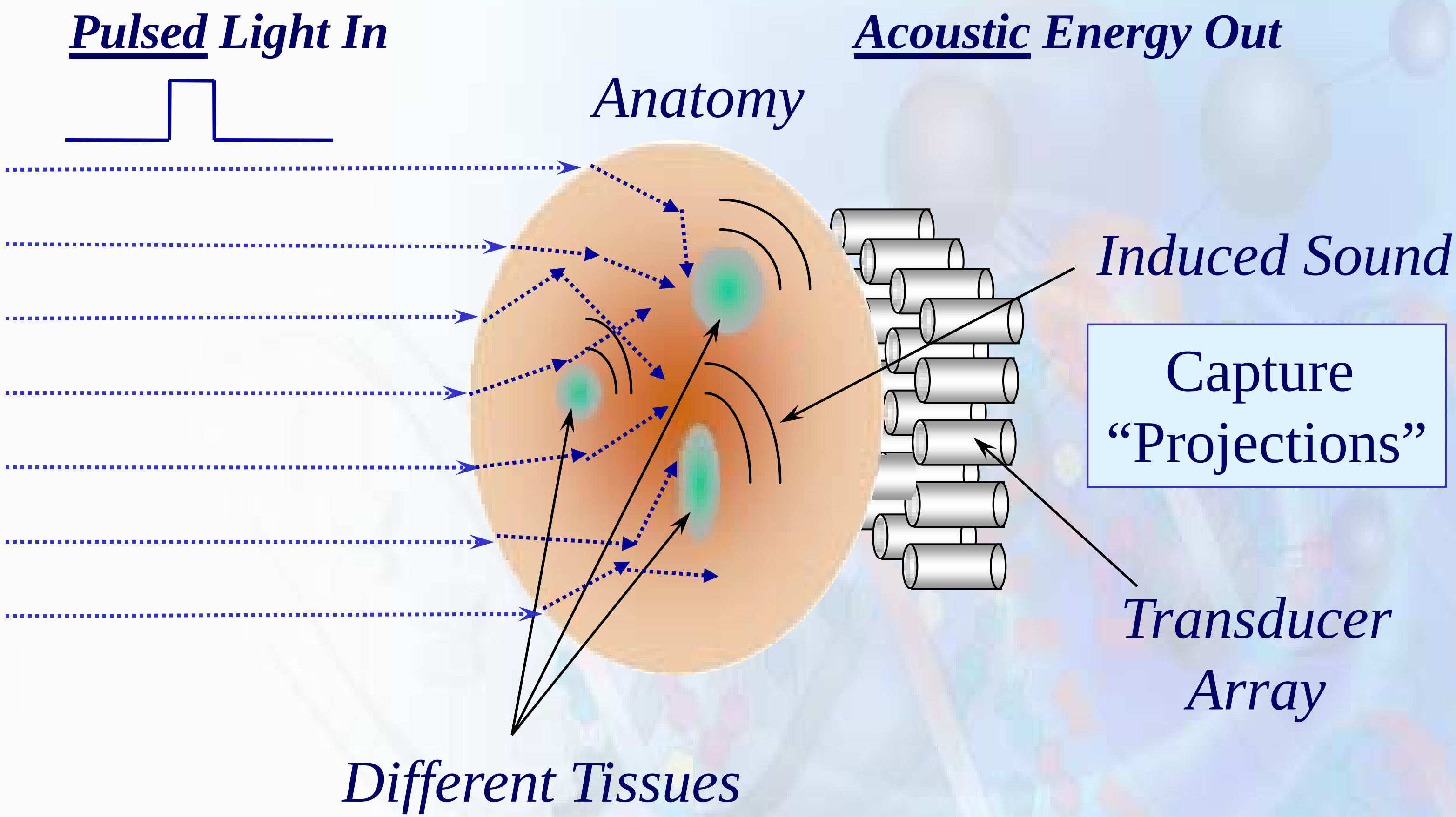
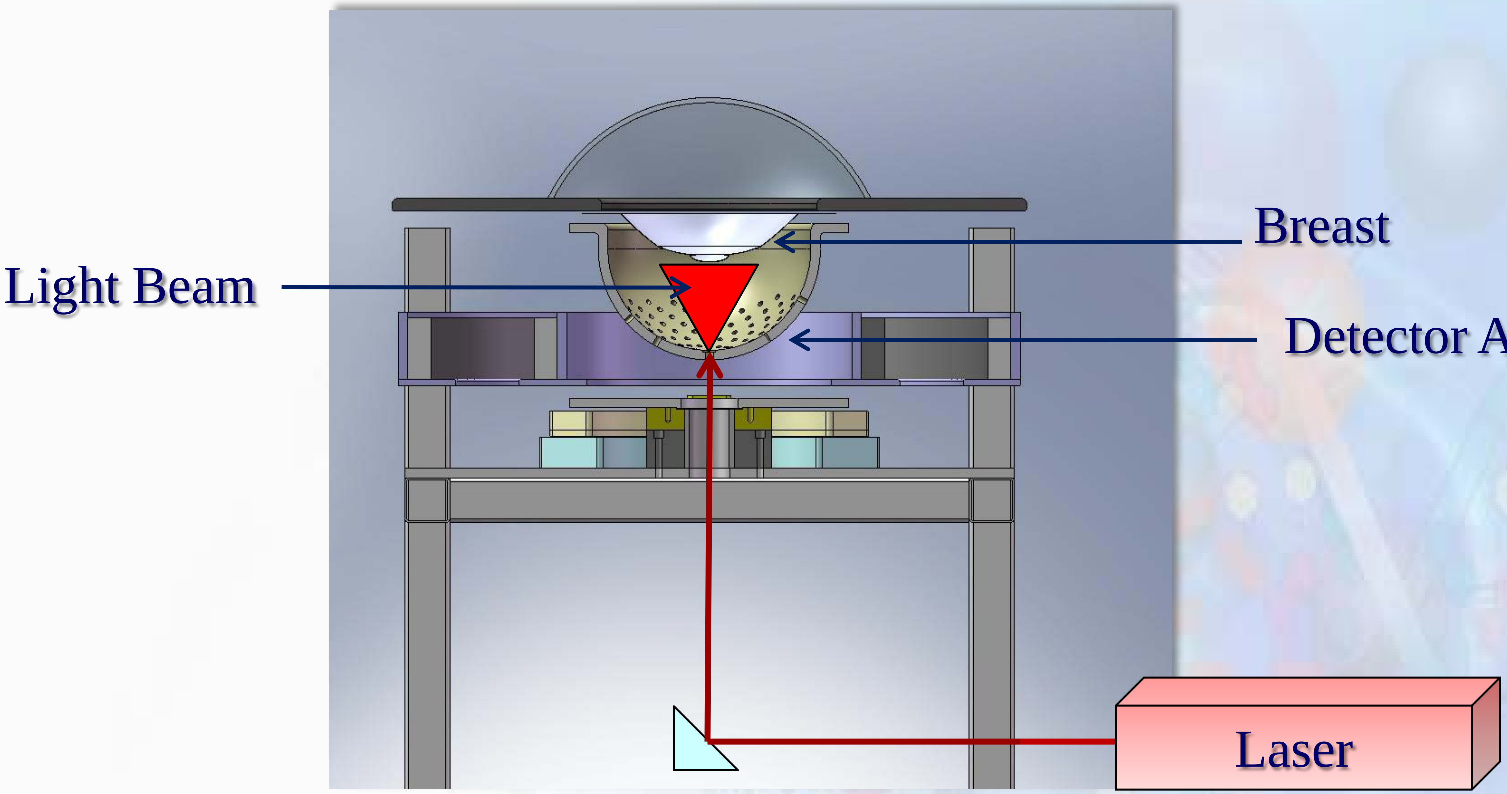
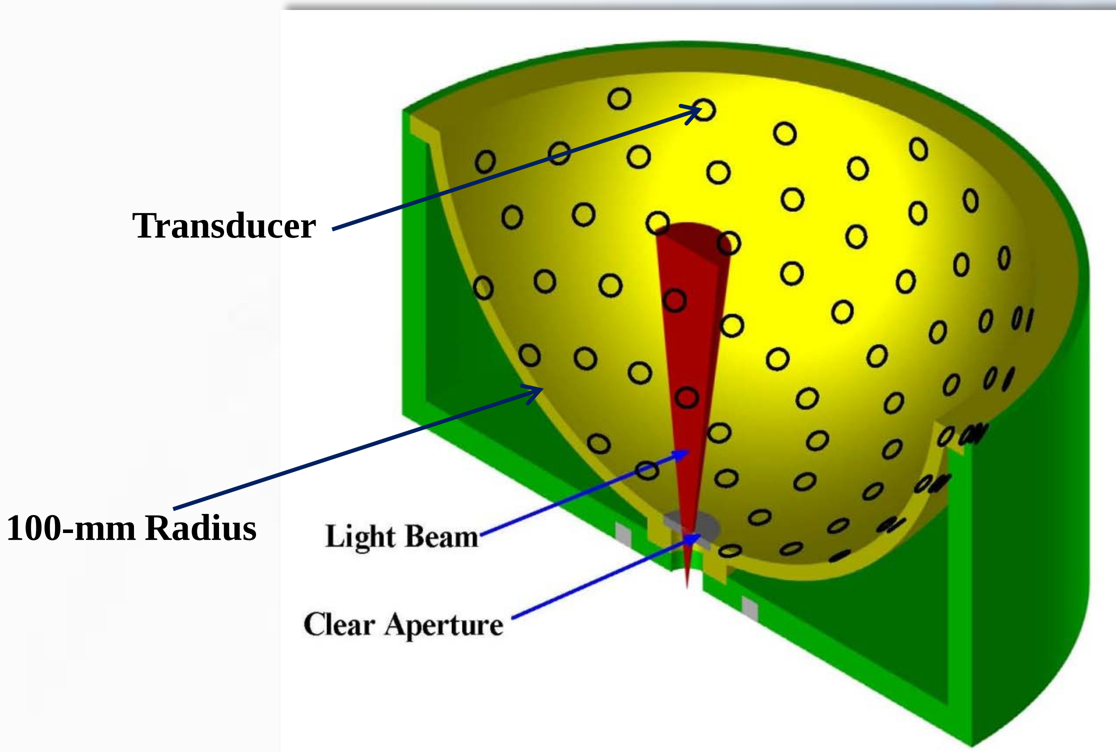
Photoacoustic Approach



Overview of Photoacoustic Scanner



Detector Array Geometry



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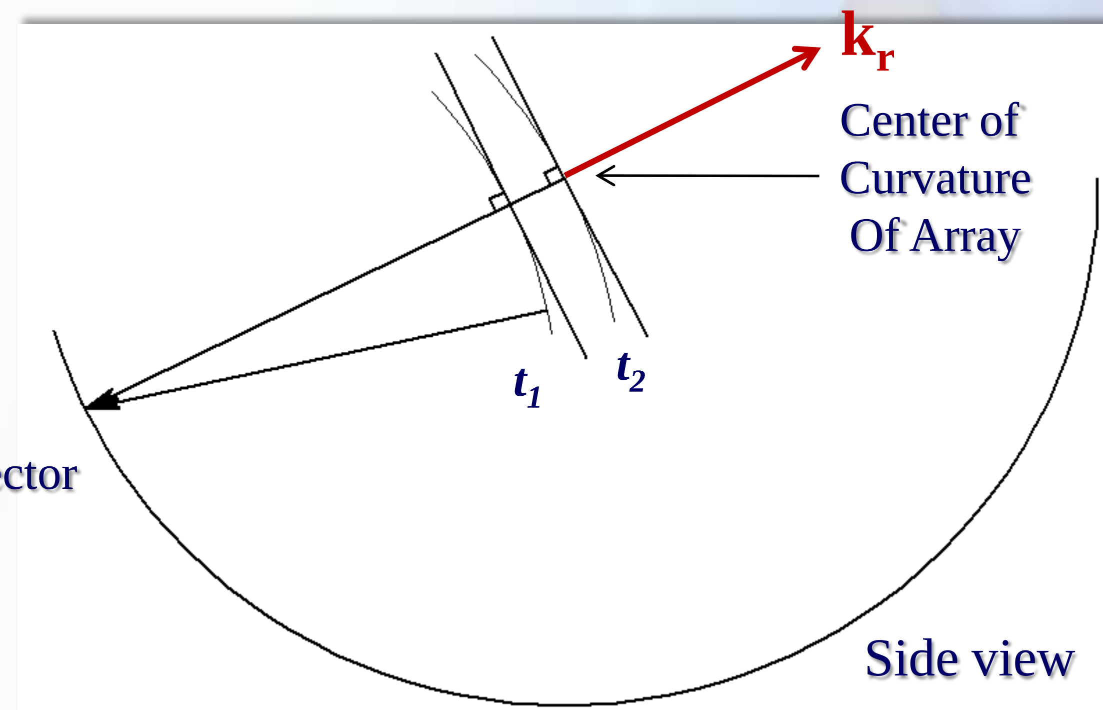
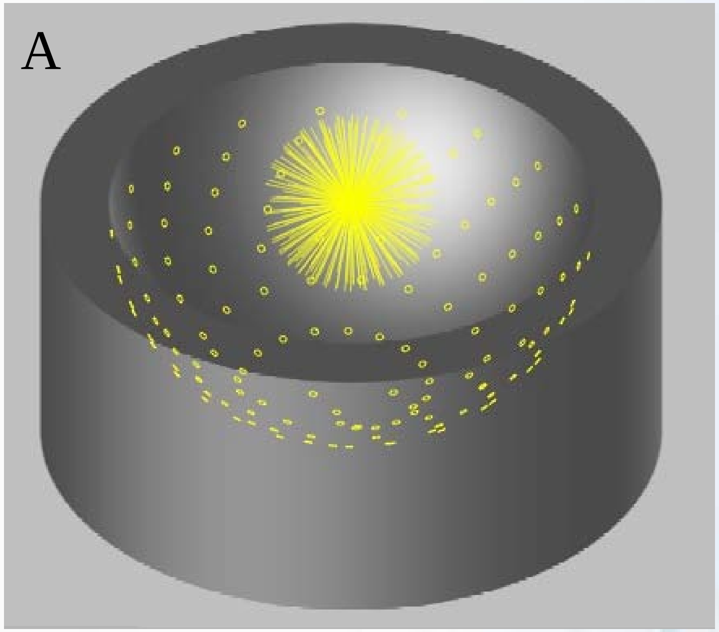
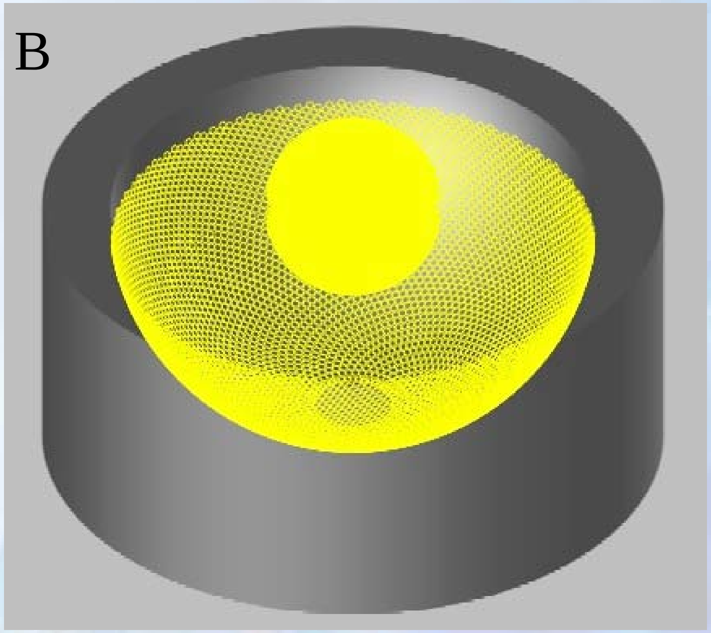
PAT: Iso-temporal surfaces are spherical, centered at receive transducer



Detector Geometry: Radial Projections

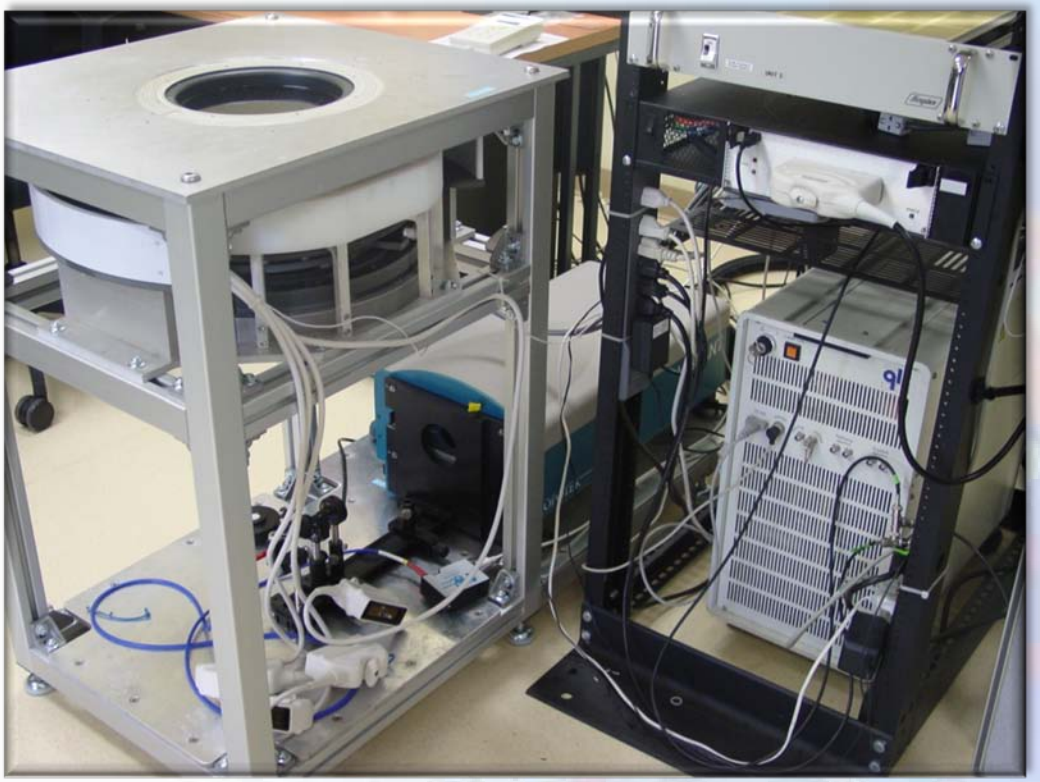


1-angle *K-space* sampling



30-angle *K-space* sampling

Photoacoustic Scanner



PAT Scanner Parameters

- Hemispherical Bowl: R = 100 mm
- 128 Detectors
  - 3-mm diameter
  - 5 MHz center frequency
  - 70% bandwidth
- OPO Tunable Laser (680 – 950 nm), ~20 mJ/pulse

Acquisition Protocol

- Water-filled bowl rotates
- Breast immobilized in 5” D. plastic “cup”
- Wavelength = 750-800 nm
- 240 Angles = 24 sec

Reconstruction using filtered backprojection

$s*_i(t) \equiv IFFT[Fil(\omega)S_i(\omega)]$ - **filtered** *temporal signal recorded at transducer i.*

$$I(\mathbf{r}) = \sum_i s*_i\left(\left|\mathbf{r} - \mathbf{r}_i\right| / c\right)$$

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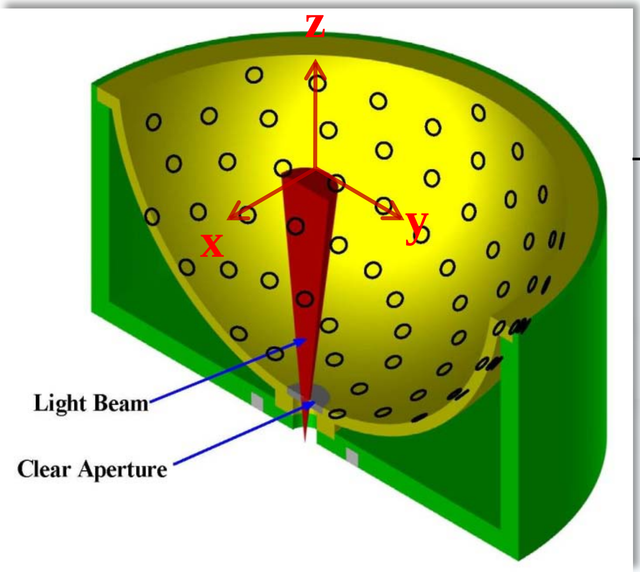
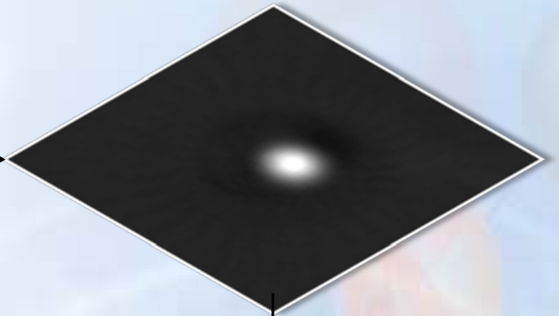
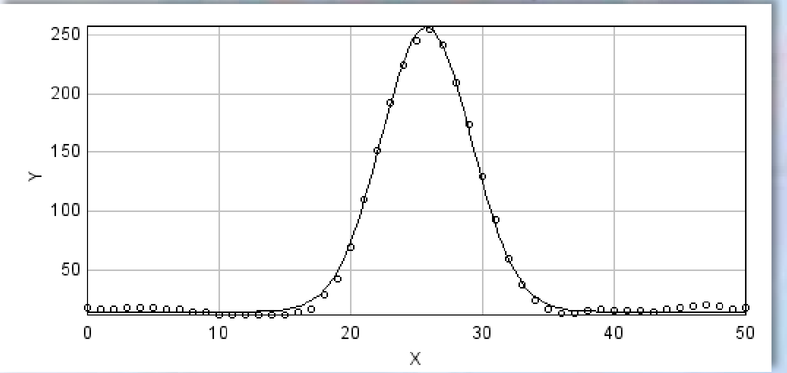
Spatial resolution



PSF_{xy}



FWHM = 280 μm



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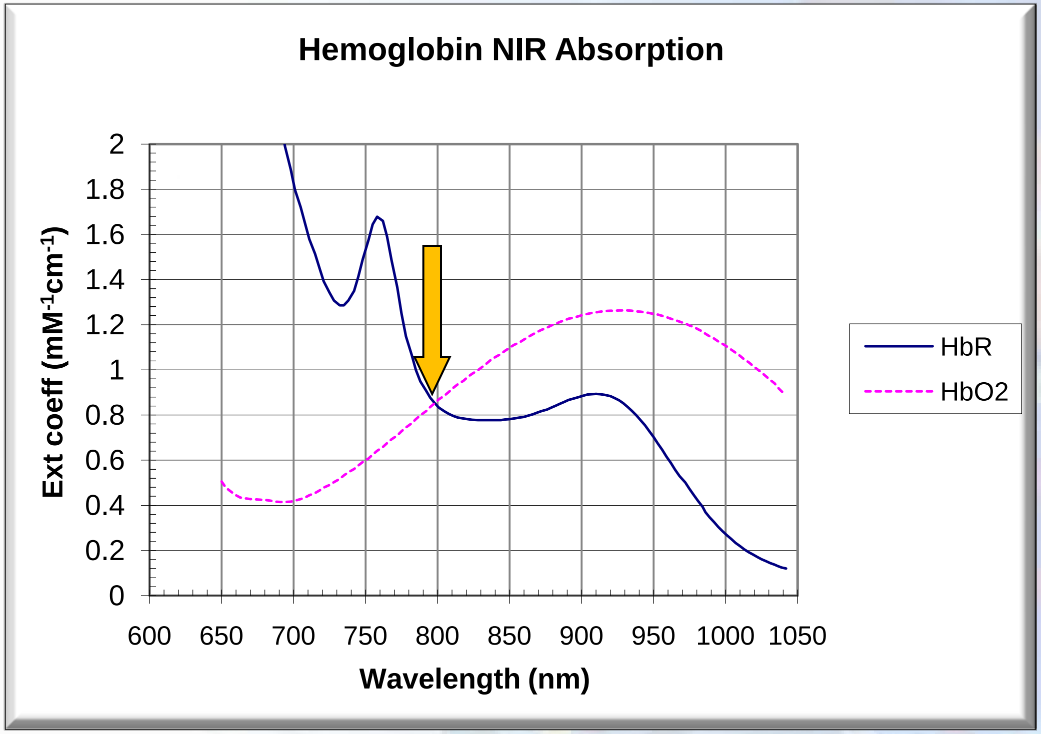
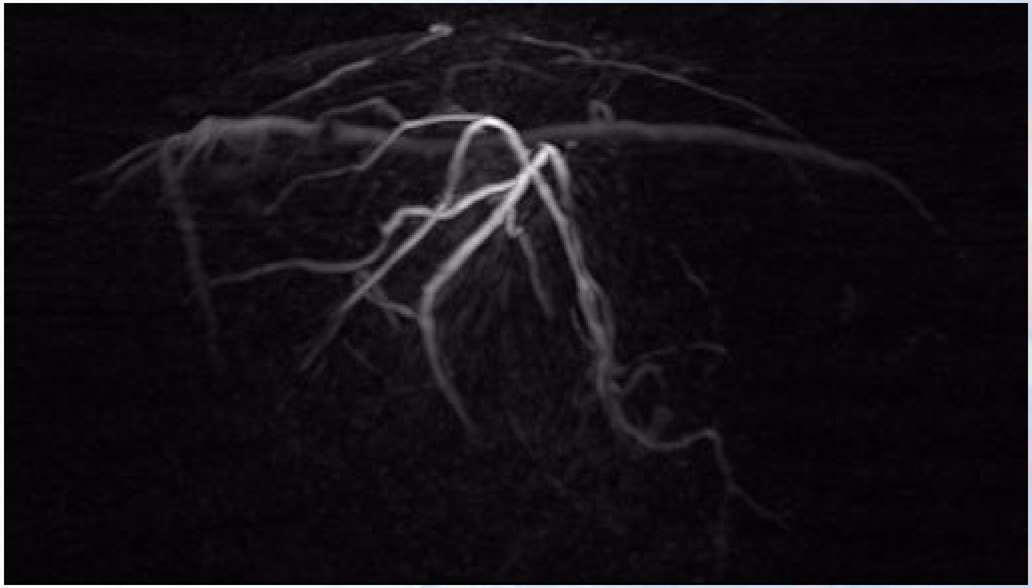
Hemoglobin in the blood absorbs twenty times more light than adipose or glandular breast tissue.



Photoacoustic Breast Image Displays Blood Vessels in **3D**



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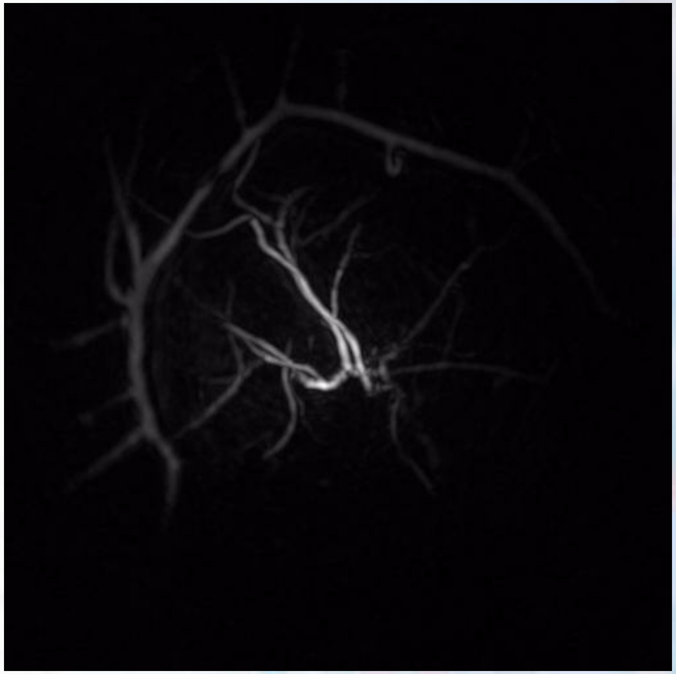
Photoacoustic Breast Image Displays Blood Vessels in **3D**



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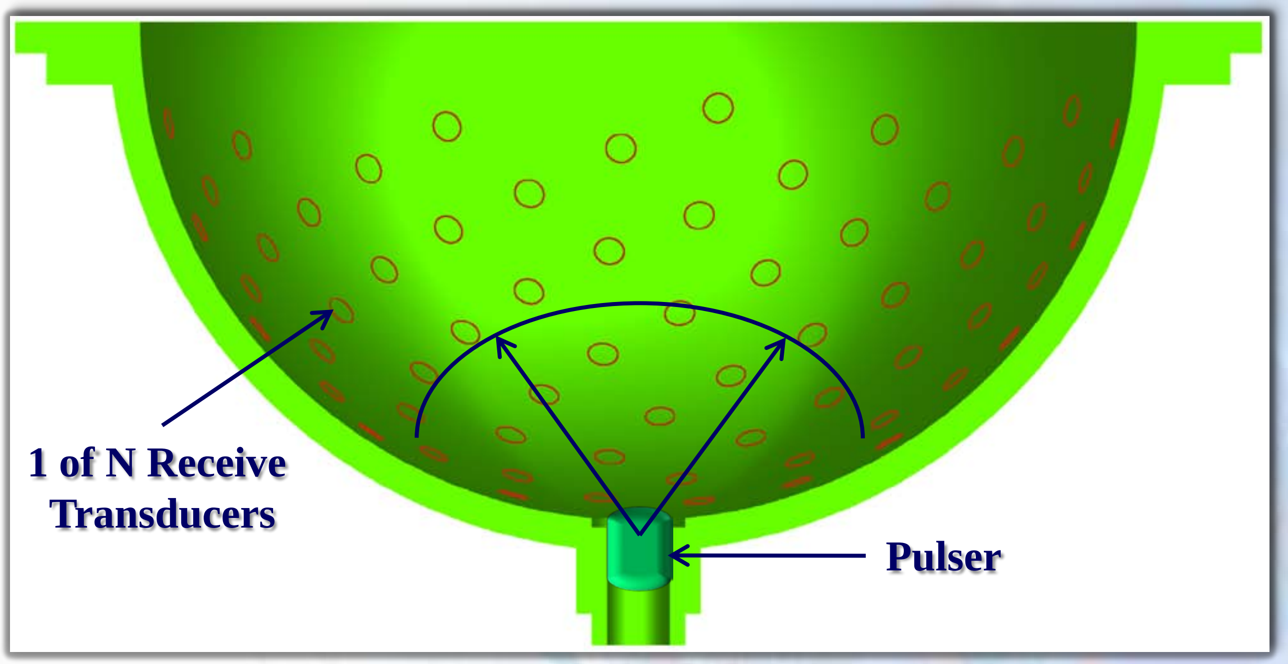
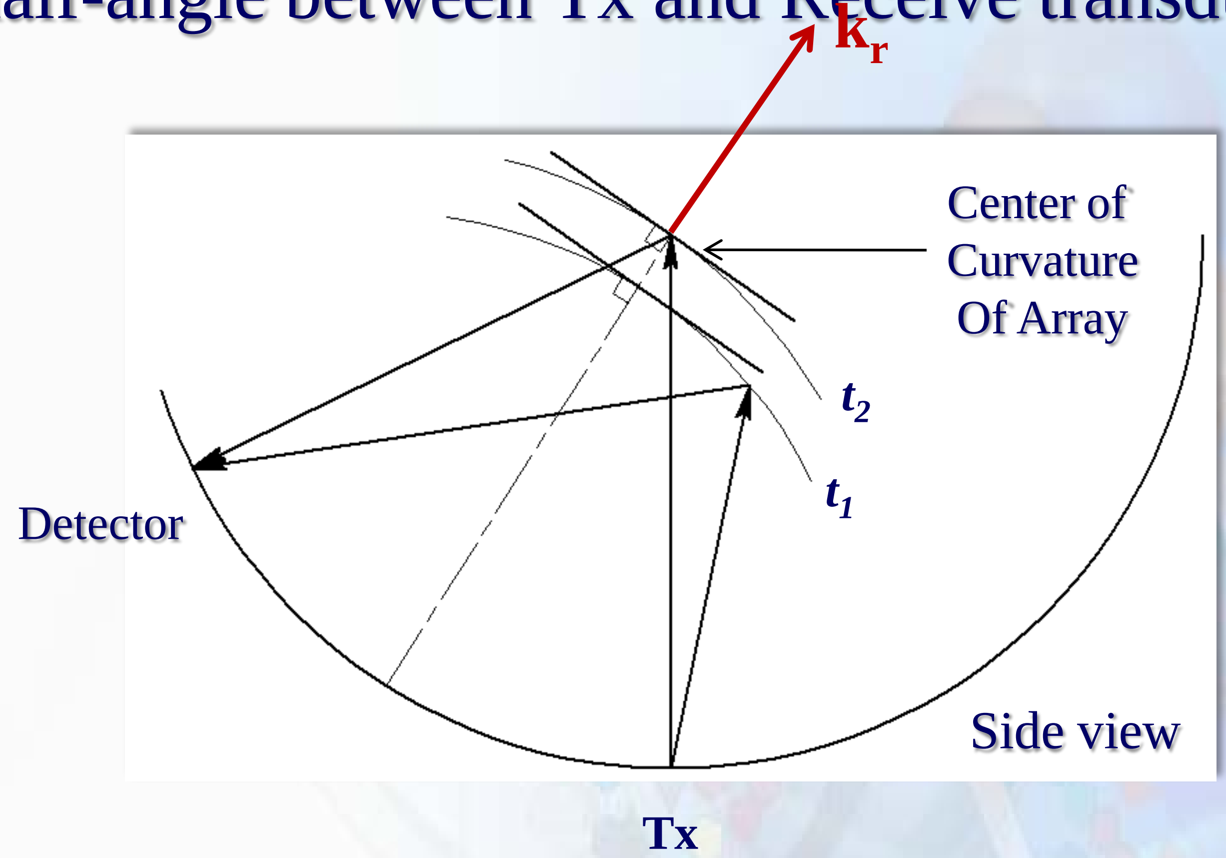
Integrated Backscatter Ultrasound (IBUS)



Single Tx + Receive Array (N elements)

IBUS: Iso-temporal surfaces are elliptical, centered at half-angle between Tx and Receive transducers



Reconstruction using Filtered Backprojection

$s^*_i(t) \equiv IFFT[Fil(\omega)S_{ij}(\omega)]$ - **filtered** *temporal signal recorded at transducer i following pulse from location* $\mathbf{r}_0$.

$$I(\mathbf{r}) = \sum_{ij} s^*_{ij}\left(\frac{|\mathbf{r}-\mathbf{r}_i| + |\mathbf{r}-\mathbf{r}_0|}{c}\right)$$

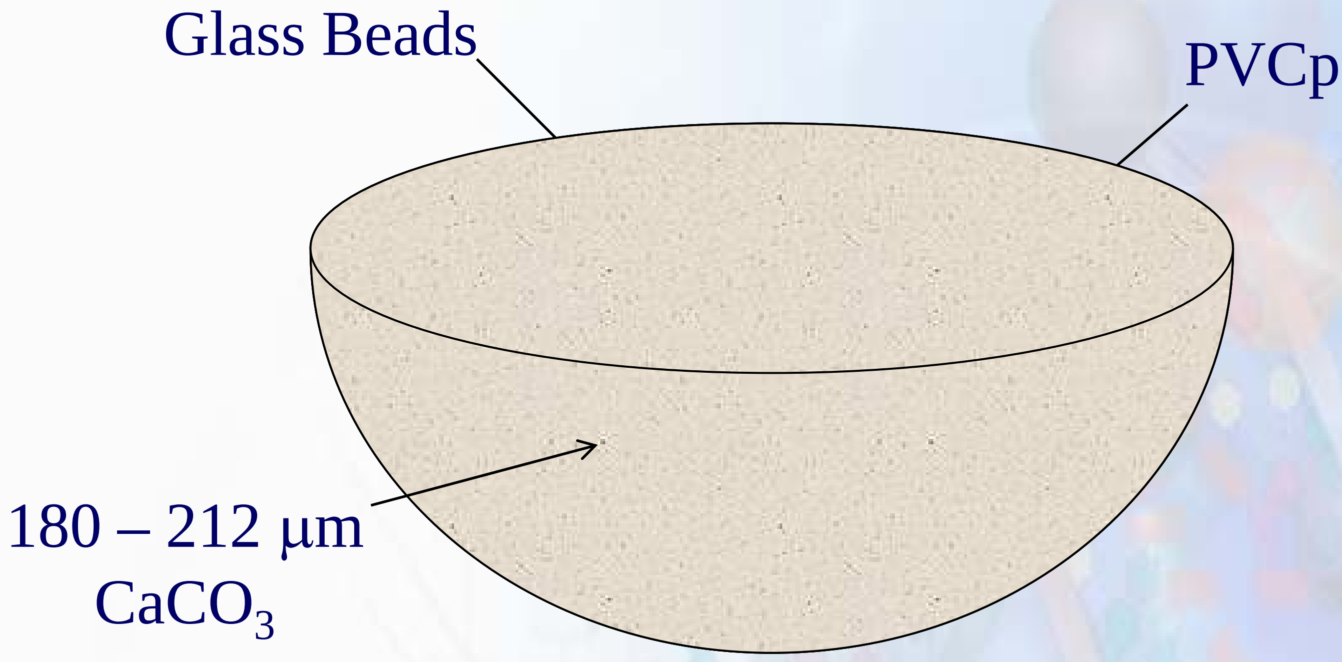
IBUS Phantom Imaging

Backscatter Phantom

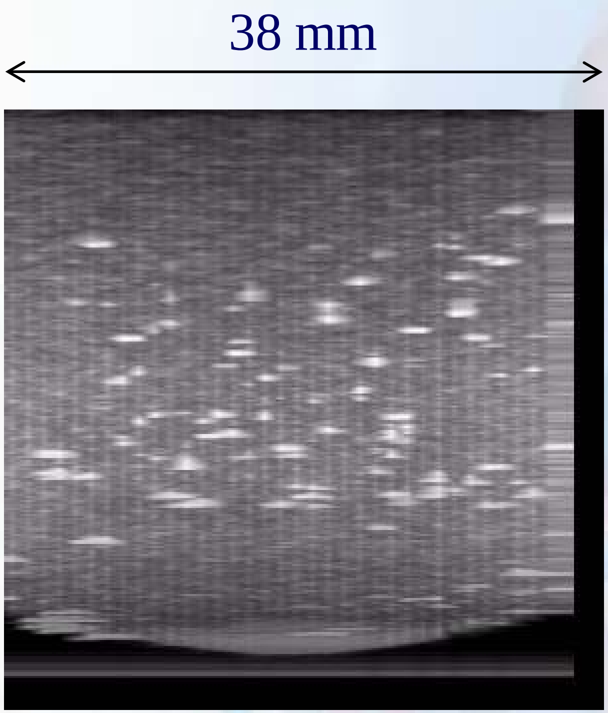
IBUS Image

38 mm

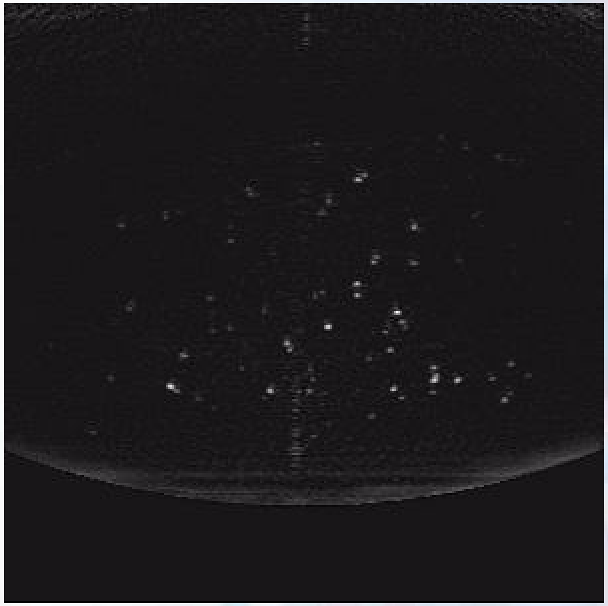
Microcalcification Phantom



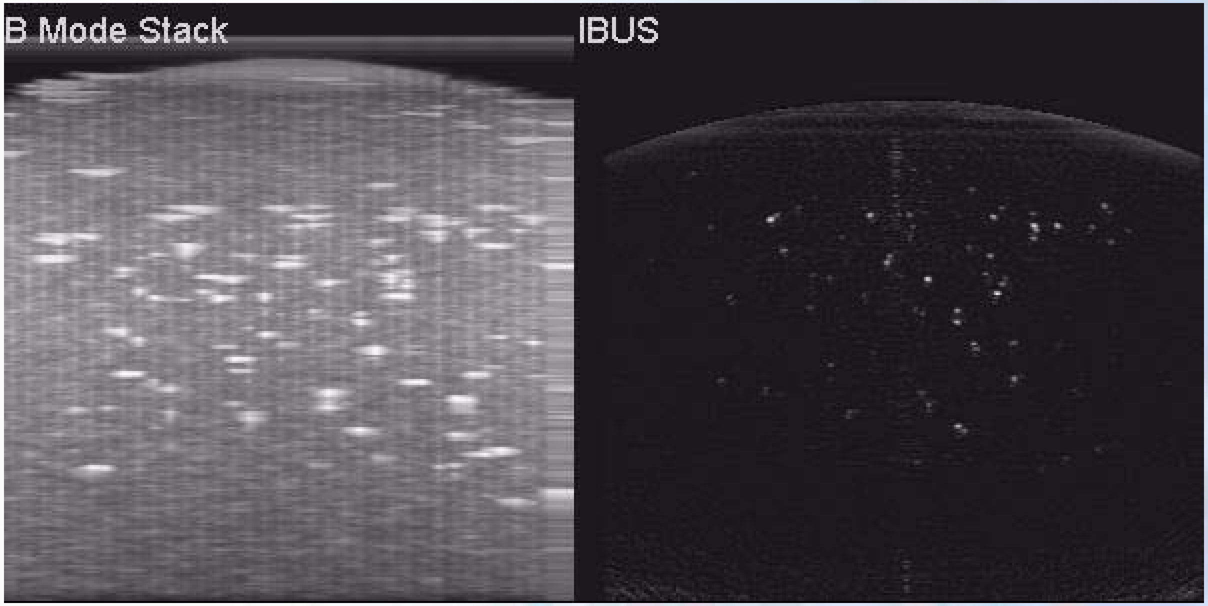
MIP of 3D Stack of B-Mode (5 MHz)



MIP of 3D IBUS (5 MHz)



3D B-Mode v. IBUS



Conclusions

1. We can visualize hemoglobin in the breast with submillimeter spatial resolution in 3D using a pulsed laser operating in the near infrared.
2. Breast neoplasms that contain hemoglobin should be detectable.
3. Dynamic contrast-enhanced PAT imaging is possible using organic dyes, e.g., indocyanine green.

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Conclusions

1. 3D- integrated backscatter ultrasound (IBUS) images can be formed using a PAT detector array.
2. Spatial resolution is improved 3-5-fold over B-mode US.
3. Microcalcifications as small as 100 - 200 microns are detectable with high CNR.

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Future

1. Increase field of view.
2. Implement dynamic scanning.
3. Integrate PAT and IBUS into a single platform.

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