EMERGING TECHNOLOGIES

Futures in Ultrasonic Diagnosis

Michigan Sonographers' Society - 2016
Novi, MI

Presented by: Jim Baun, BS, RDMS RVT, FSDMS
Mindray ZONARE

Course Outline

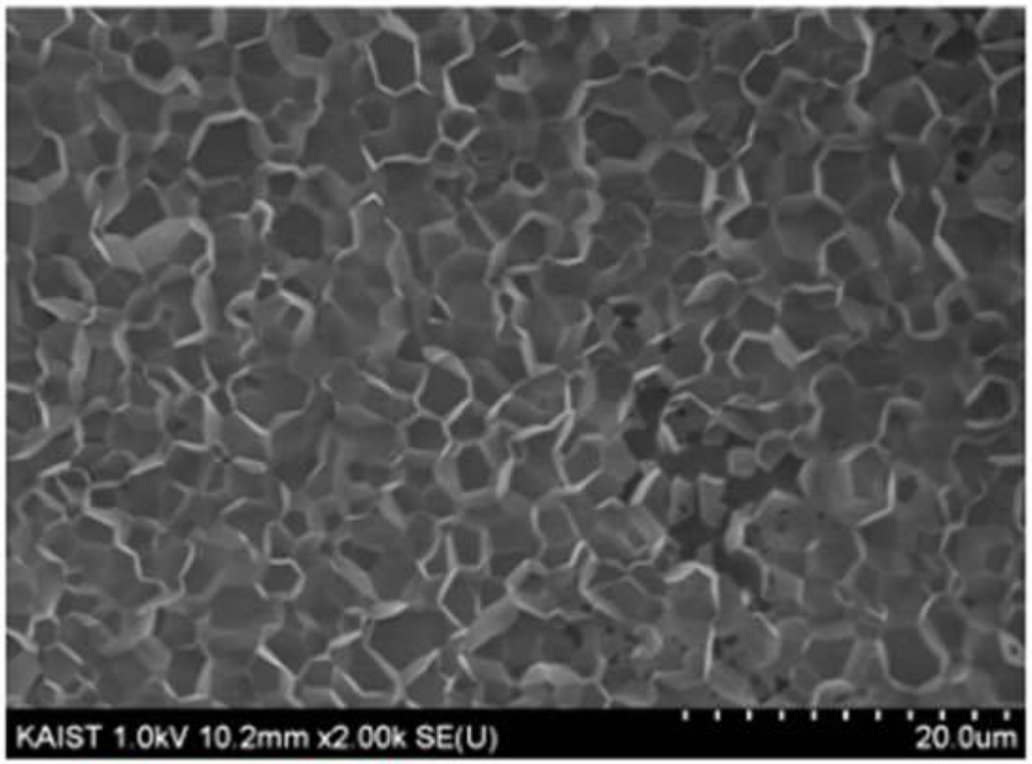
- Single crystal transducer technology
- ZONE Sonography Technology (ZST) - ZONARE
- Elastographic methods:
  - Acoustic radiation force impulse (ARFI)
  - Shear wave elastography (SWE)
- Virtual histology - IVUS
- Photoacoustic imaging
- Vector Flow Imaging (VFI)

Single Crystal Technology

- PZT has dominated transducer technology for decades
- Ceramic PZT consists of random micro crystal dipoles
- New “recipes” for growing piezoelectric crystals yield oriented dipoles
  - Less voltage required
  - Broader transmit and receive bandwidths
  - Better sensitivity
  - Improved S/N ratio

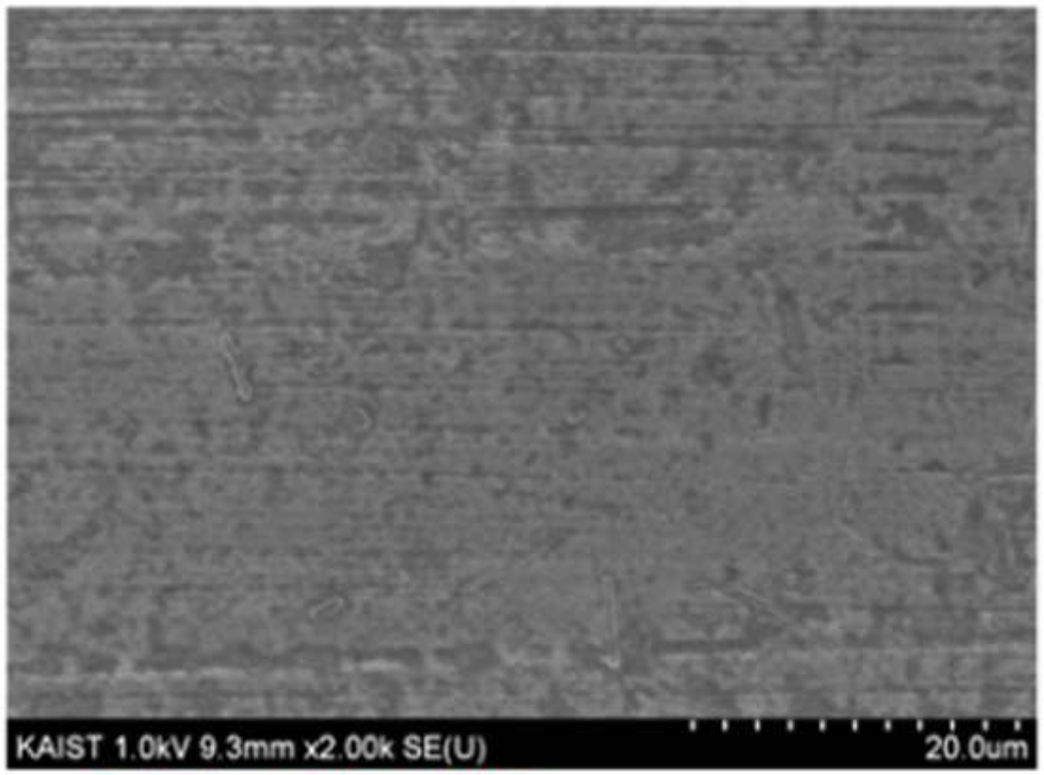
SINGLE CRYSTAL TECHNOLOGY

Photomicrographs



1-a. Polycrystalline PZT

PZT



1-b. Single crystalline PMN-PT

PMN - PT

Advantages

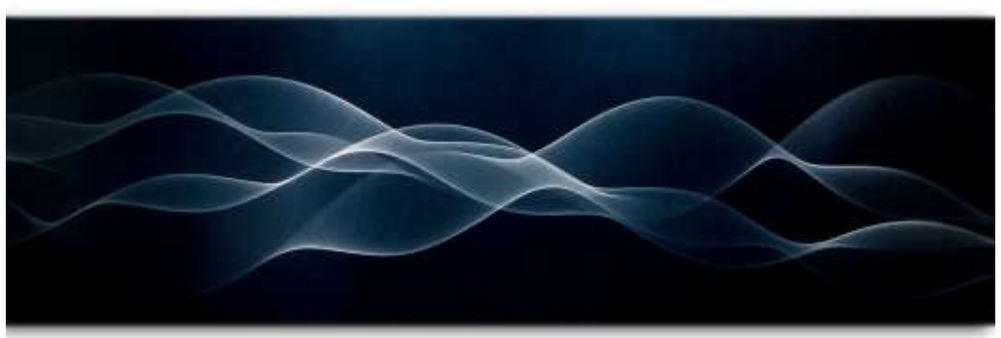
- More powerful, pure and efficient acoustic beam
- 85% more efficient than PZT crystals
- Improved spatial and contrast resolution at depth
- Minimal signal loss in harmonic imaging
- Particularly beneficial in cardiology applications

Disadvantages

- Impractical to use with center frequencies >6 MHz
  - Exceptional fragility
  - Low sound velocity
  - Low coercive force
- Impractical to use with low center frequencies <3 MHz with small elements
  - Very high electrical impedance
  - Causes severe mismatch to cable and system
  - Underperforms PZT

ZONE Sonography Technology

- New core imaging technology – 1998
- Software-based vs. hardware-based
- Data acquired in large ZONES vs. line-by-line
- High speed, high-capacity digital signal processing
- Image created pixel-by-pixel
- Automatic sound speed compensation

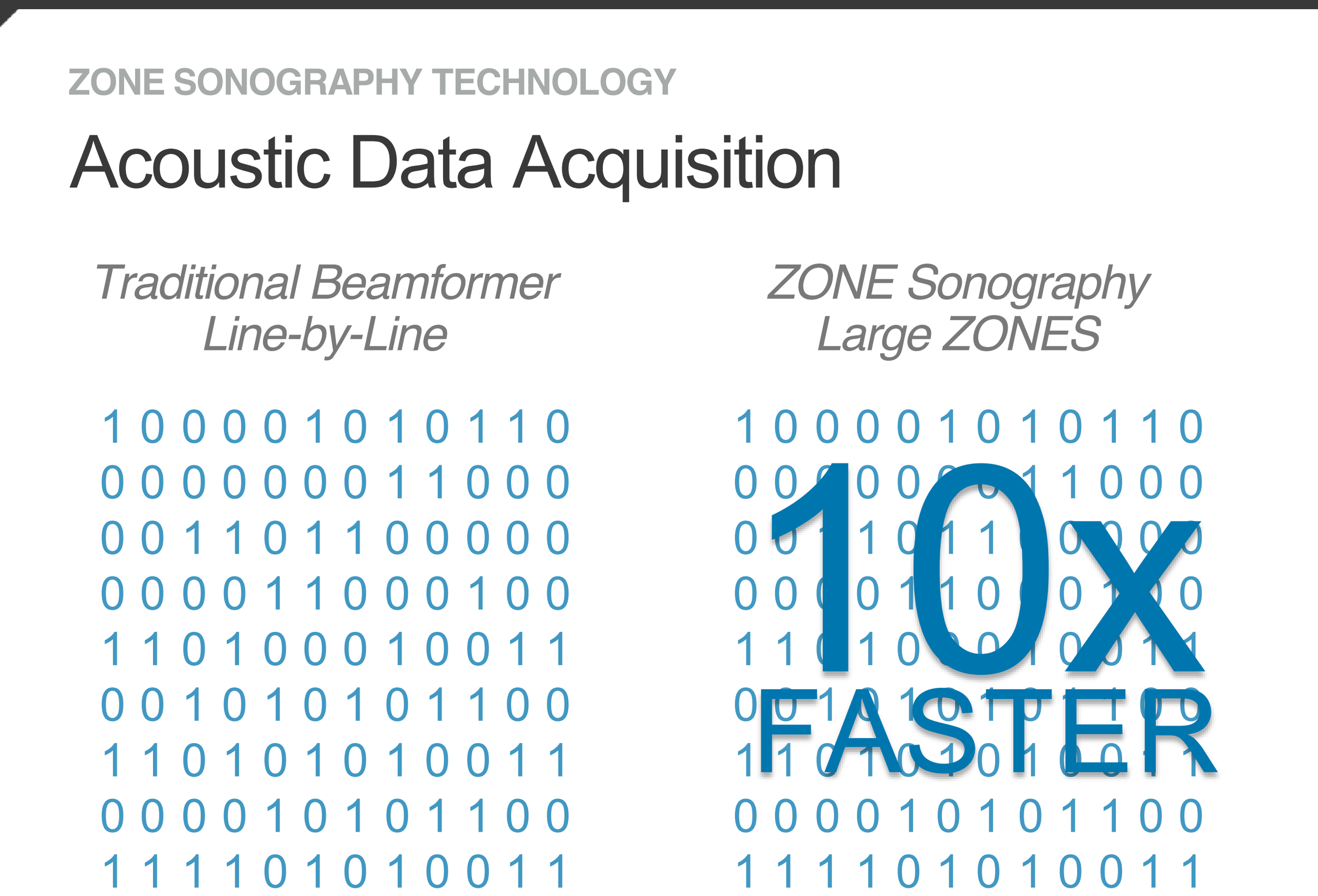


ZONE SONOGRAPHY TECHNOLOGY

Acoustic Data Acquisition

Traditional Beamformer
Line-by-Line

ZONE Sonography
Large ZONES



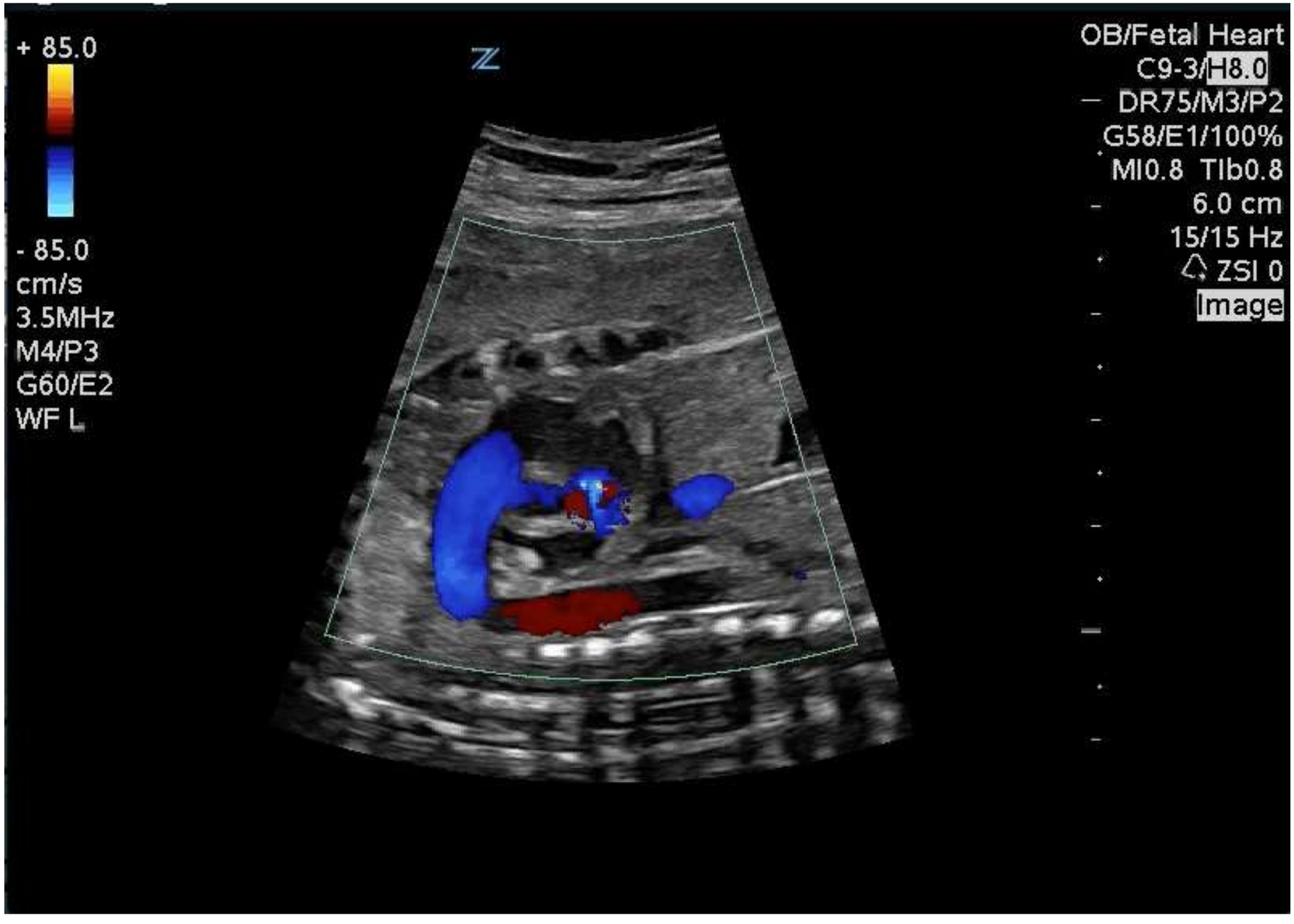
Acoustic Data Acquisition

Clinical benefits:

- Extremely fast and accurate display of anatomical motions and hemodynamic states
- Reduces tissue motion artifacts
- Superior image quality across all US modes

ZONE SONOGRAPHY TECHNOLOGY

ZONE SONOGRAPHY TECHNOLOGY



ZONE SONOGRAPHY TECHNOLOGY

Acoustic Data Processing

Traditional Beamformer 100%

ZONE Sonography 190%

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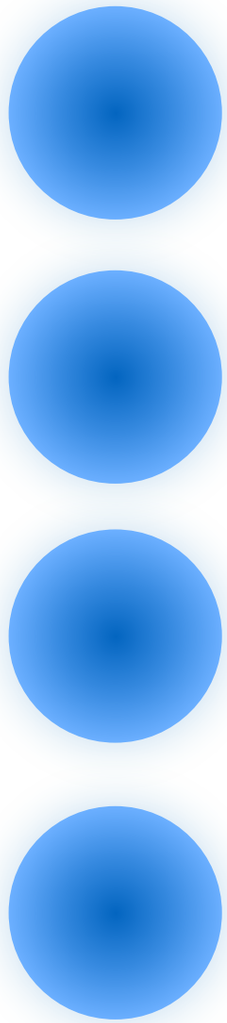
ZONE SONOGRAPHY TECHNOLOGY

Dynamic Pixel Focusing ™

Pixel-by-pixel focusing on transmit AND receive:

- Every Frame
- Every Depth
- Every Time



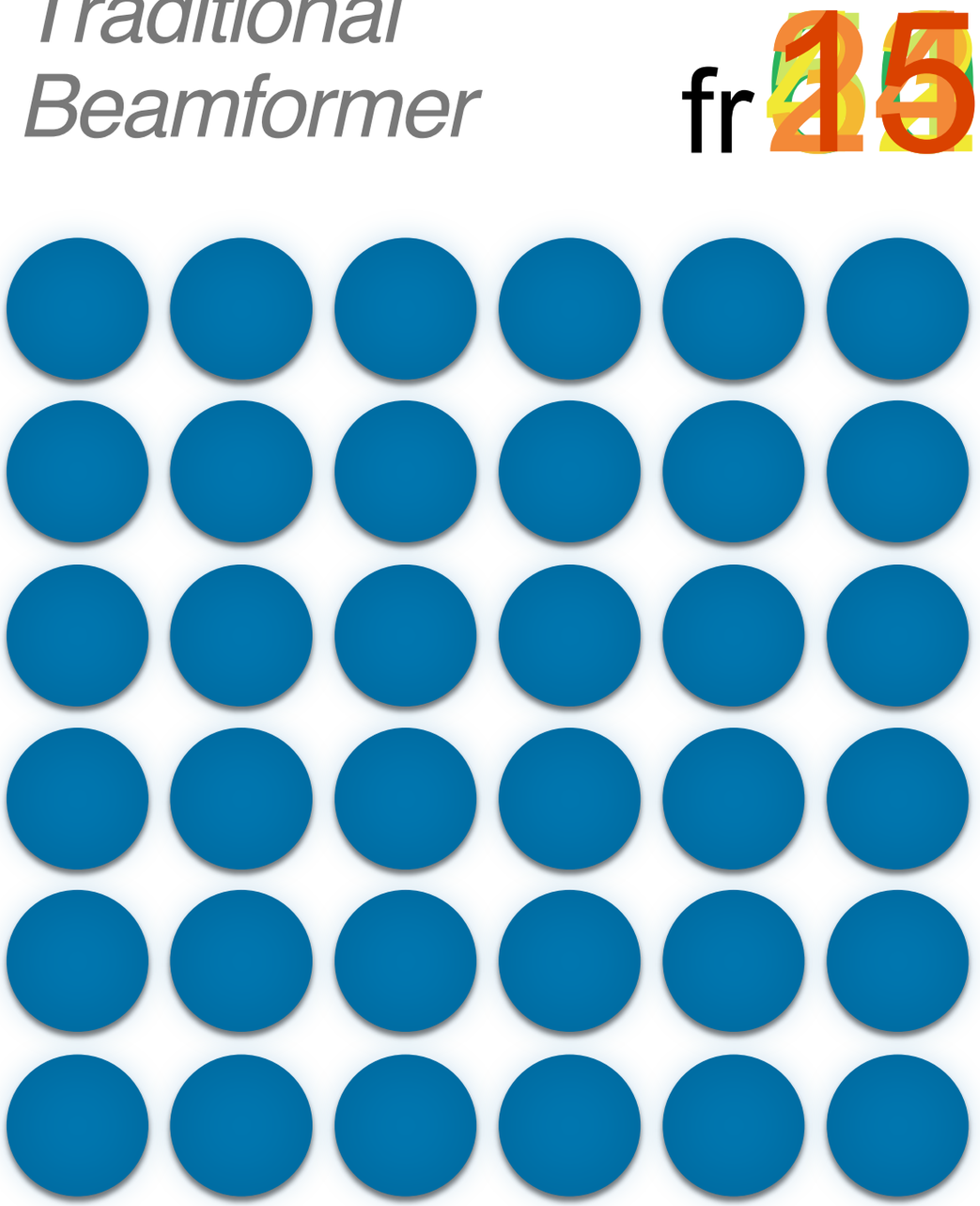
Enhanced spatial resolution:

- Axial
- Lateral
- Elevational

ZONE SONOGRAPHY TECHNOLOGY

Dynamic Pixel Focusing ™

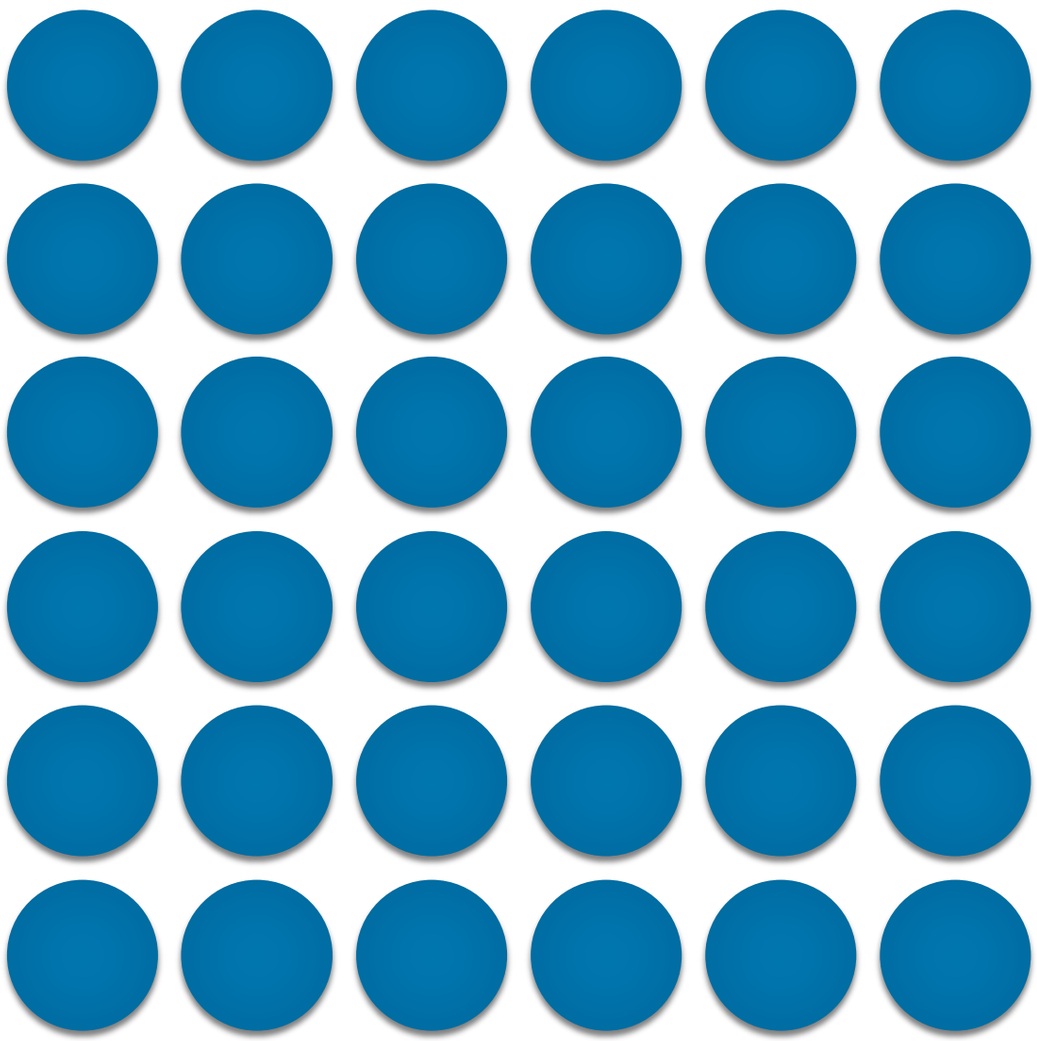
Traditional Beamformer



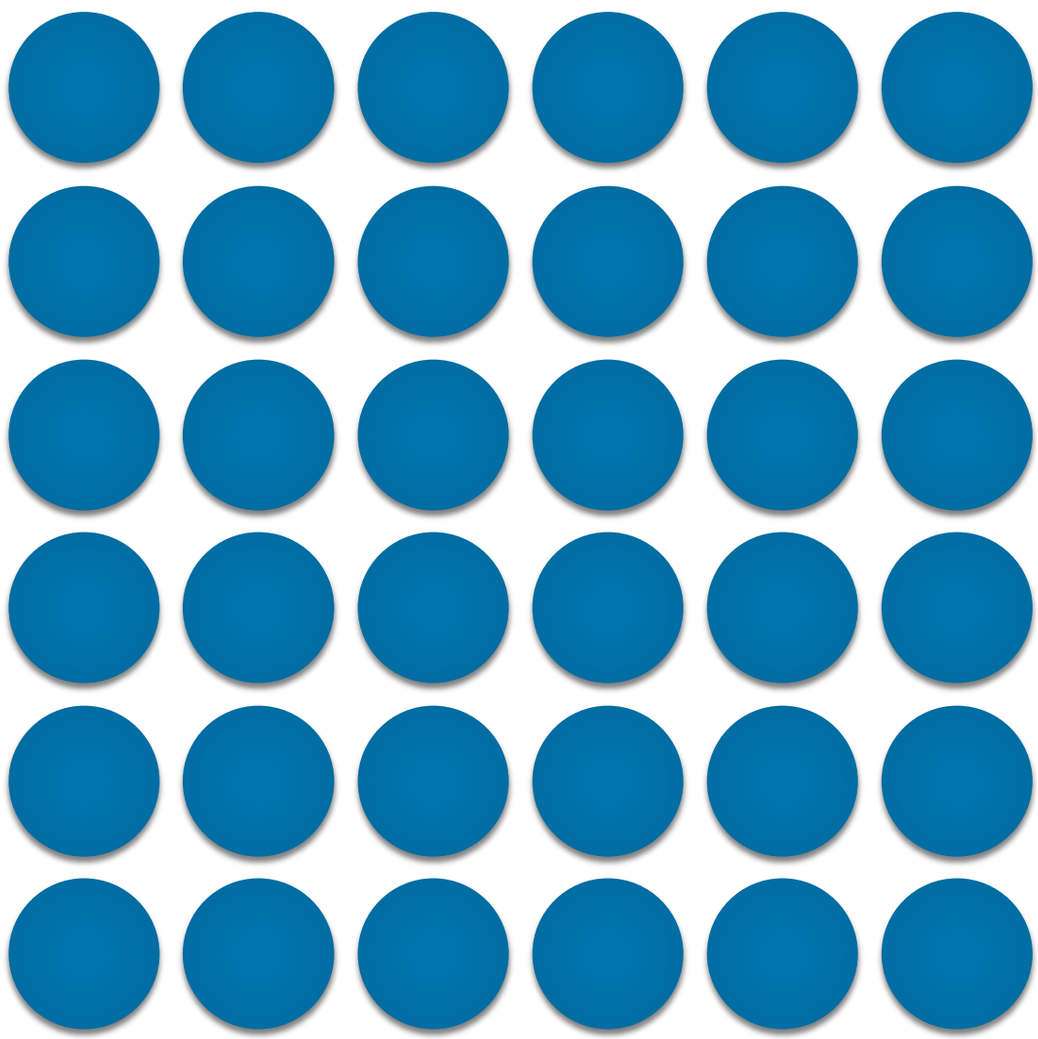
ZONE SONOGRAPHY TECHNOLOGY

Dynamic Pixel Focusing ™

Traditional Beamformer fr 15



ZONE Sonography fr 60

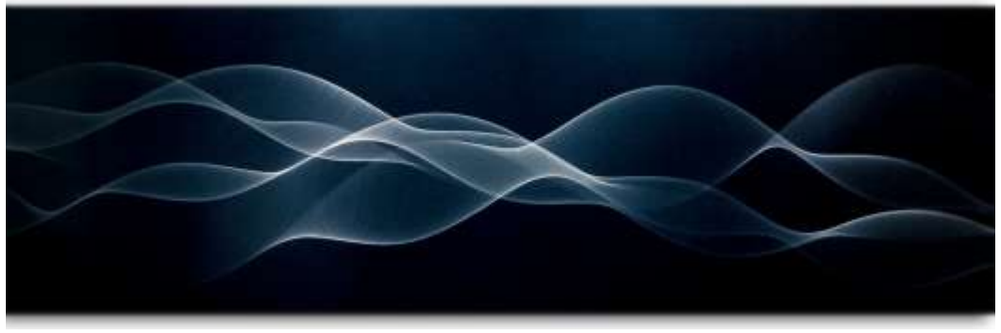


ZONE SONOGRAPHY TECHNOLOGY

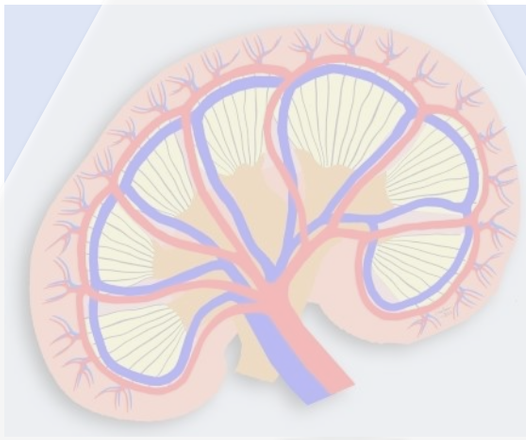
Sound Speed Compensation ™

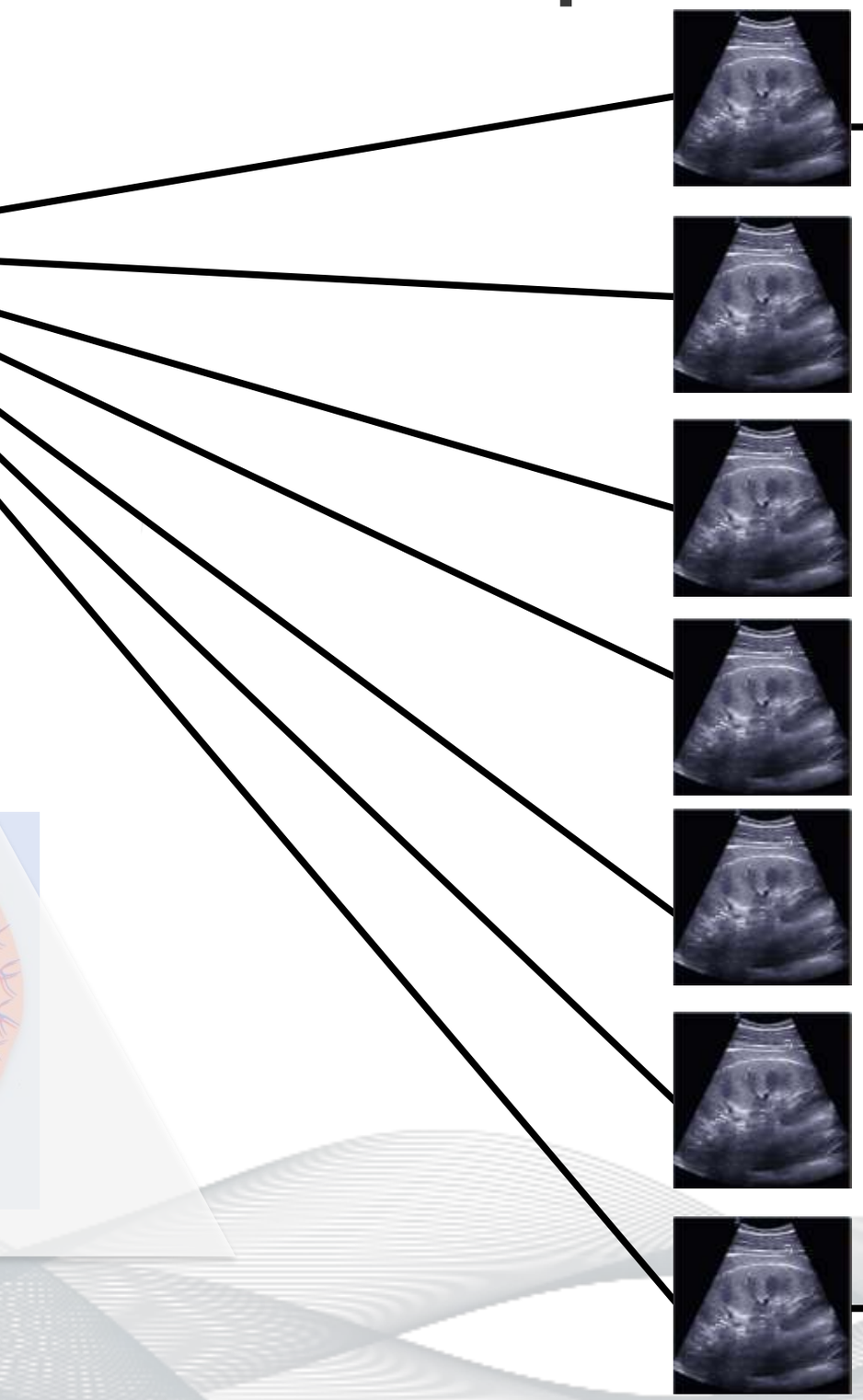
- Conventional SS calibration - 1540 m/sec

- Sound speed varies in human soft tissue 1,450-1,650 m/sec



Sound Speed Compensation ™





Trial Frames
Different *V*

SW
Decision

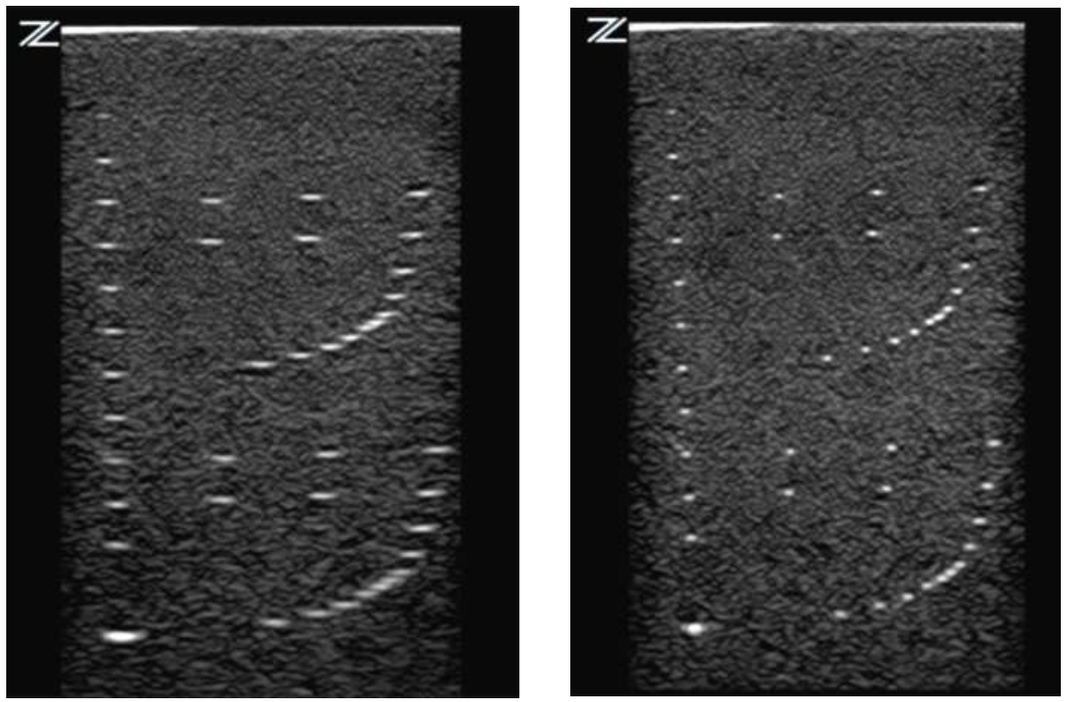
ZONE SONOGRAPHY TECHNOLOGY

Sound Speed Compensation ™

Clinical benefits:

Clinical benefits:

- Improved spatial and contrast resolution
- Improved imaging at depth
- Improved imaging of dense organs
- Improved imaging in diffusely diseased organs



ZONE SONOGRAPHY TECHNOLOGY

Elastographic Methods

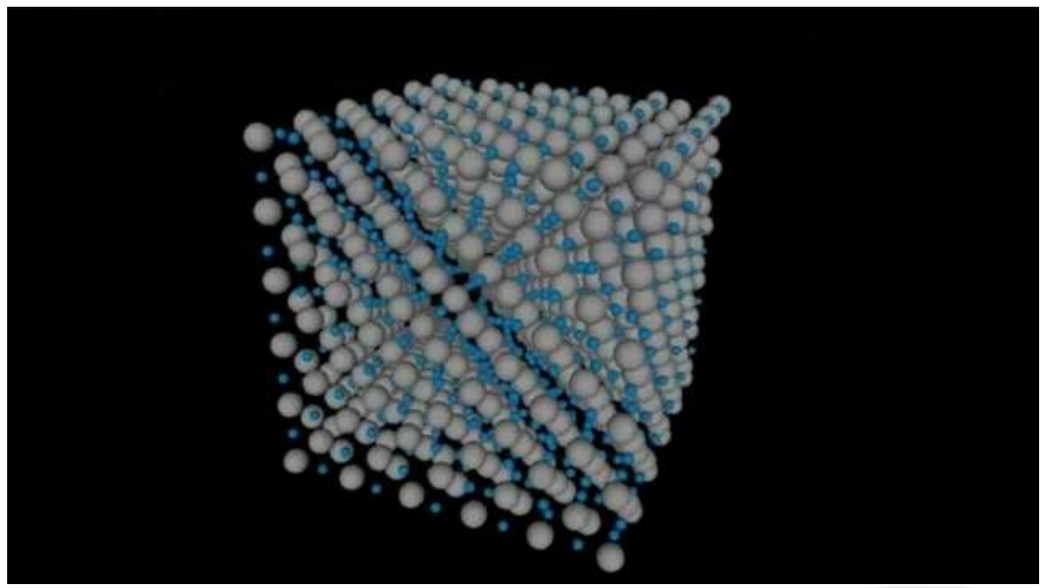
- General principles
- Acoustic radiation force impulse (ARFI)
- Shear wave elastography (SWE)

General Elements

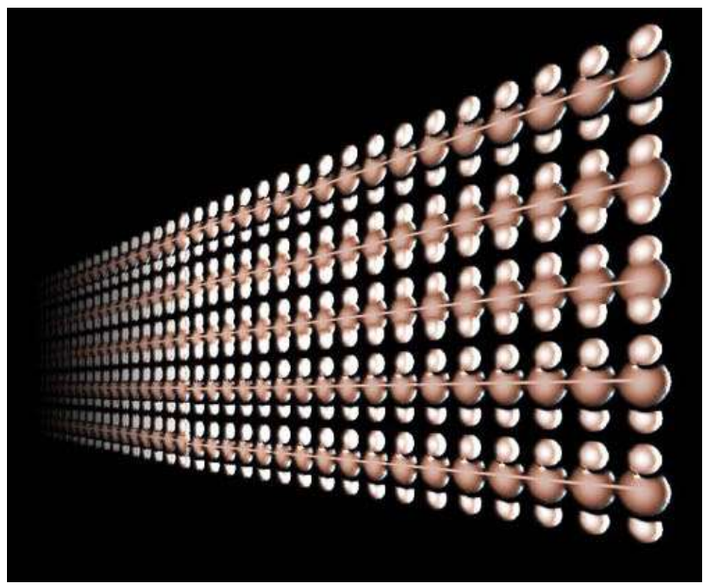
- Noninvasive US method of assessing biomechanical properties of soft tissue
- Palpable “hardness” of human soft tissue
- Difference in cellular composition of one tissue compared to adjacent or “control” tissue
- Biomechanical properties of human soft tissue:
  - Rigidity

Biomechanical Properties

- Determinants of elasticity:
  - Metals & crystals - atomic lattice
  - Polymers - stretchability of polymer chains
  - Human soft tissue - composition of extracellular matrix

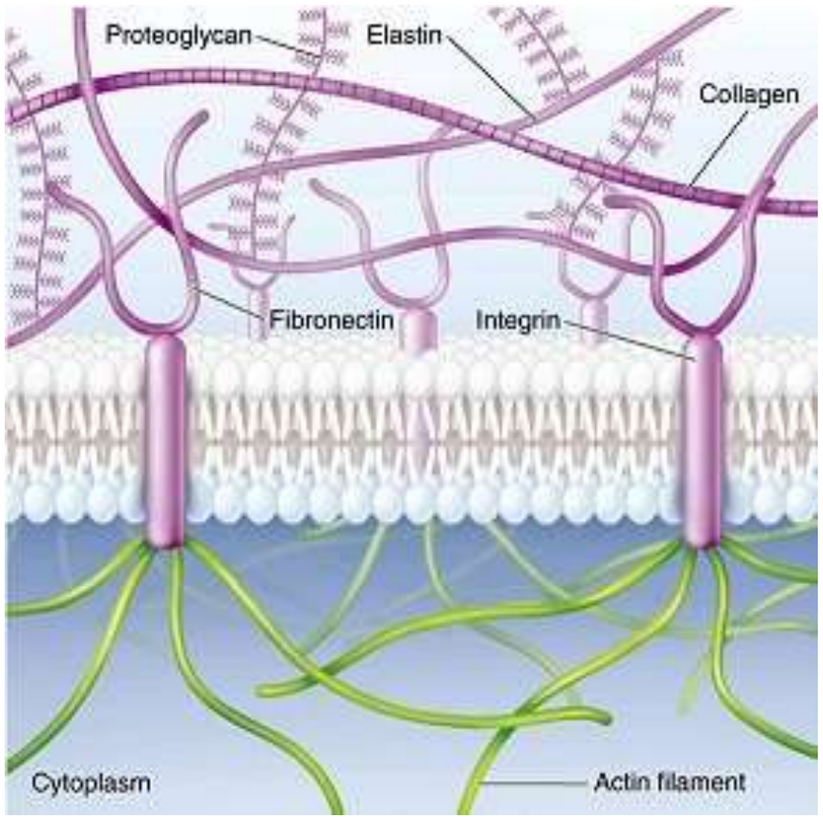


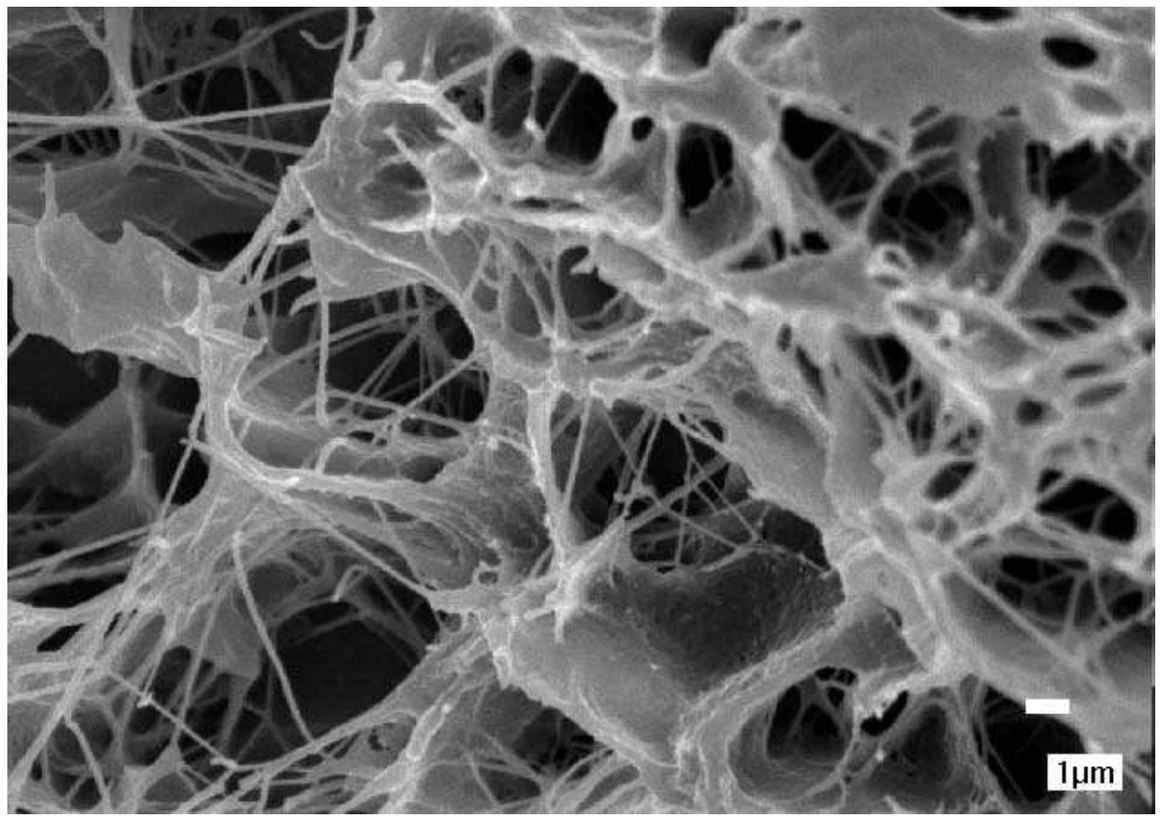
Atomic lattice



Polymer chains

Biomechanical Properties



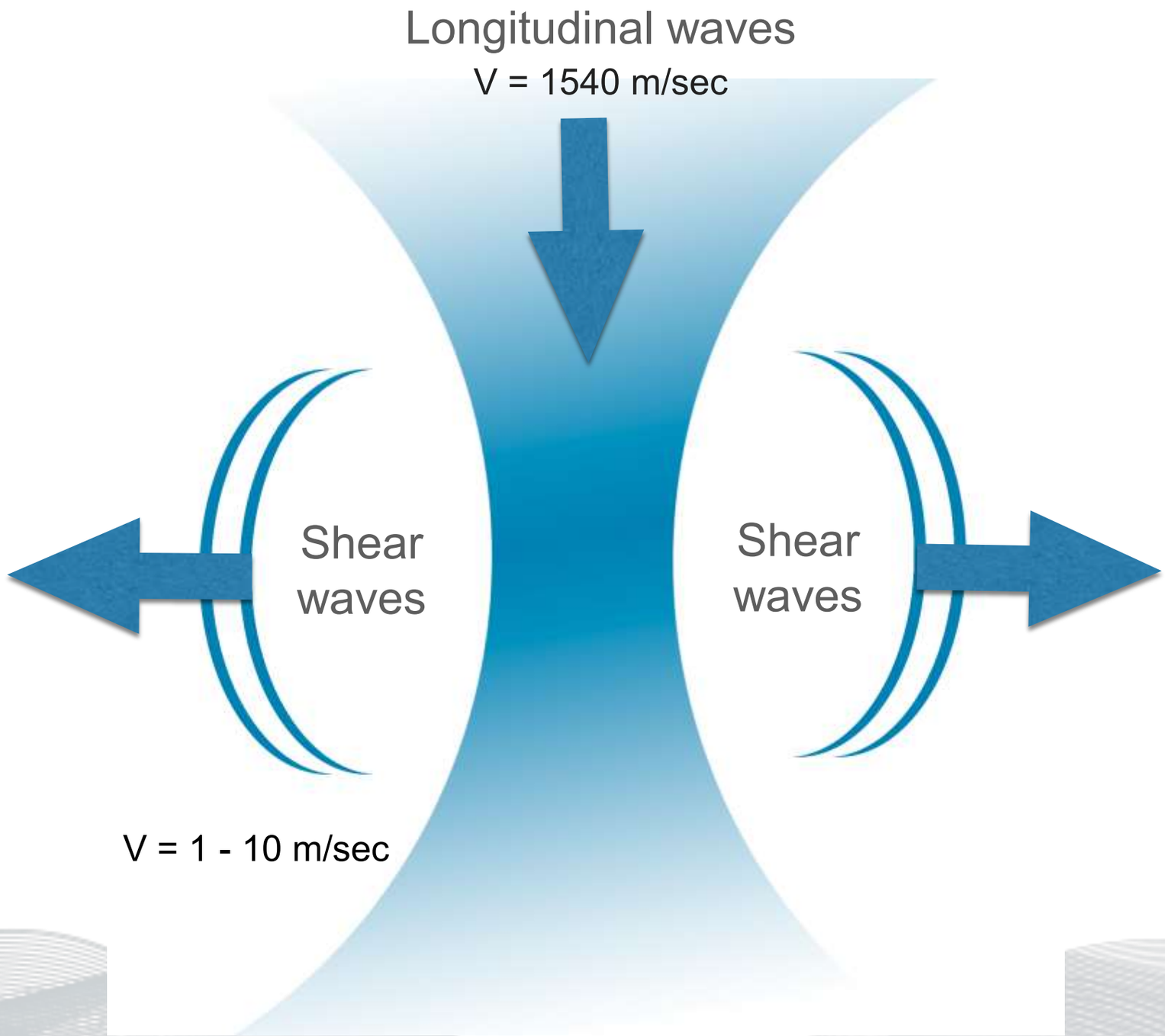


Extracellular Matrix

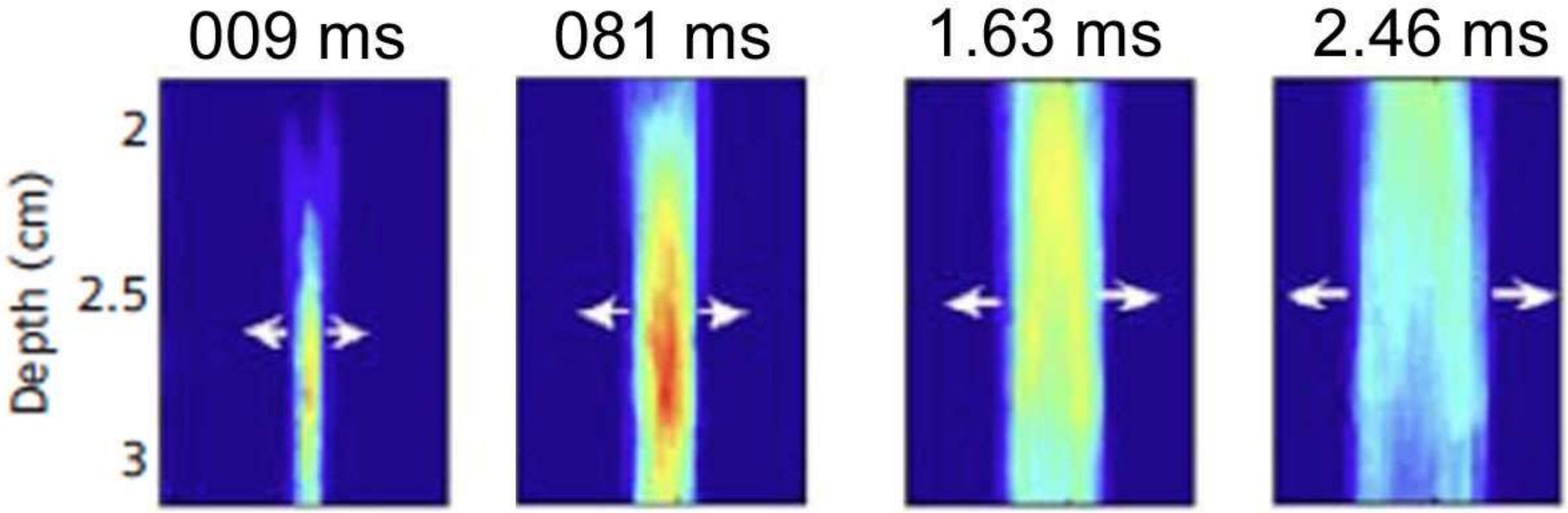
Physical Principles

- Acoustic (US) wave propagation:
  - Mechanical waves
  - Longitudinal vs. transverse waves
- Speed of sound in soft tissue: how elasticity is calculated

Physical Principles



Physical Principles



Shear Waves - Schlieren Photography

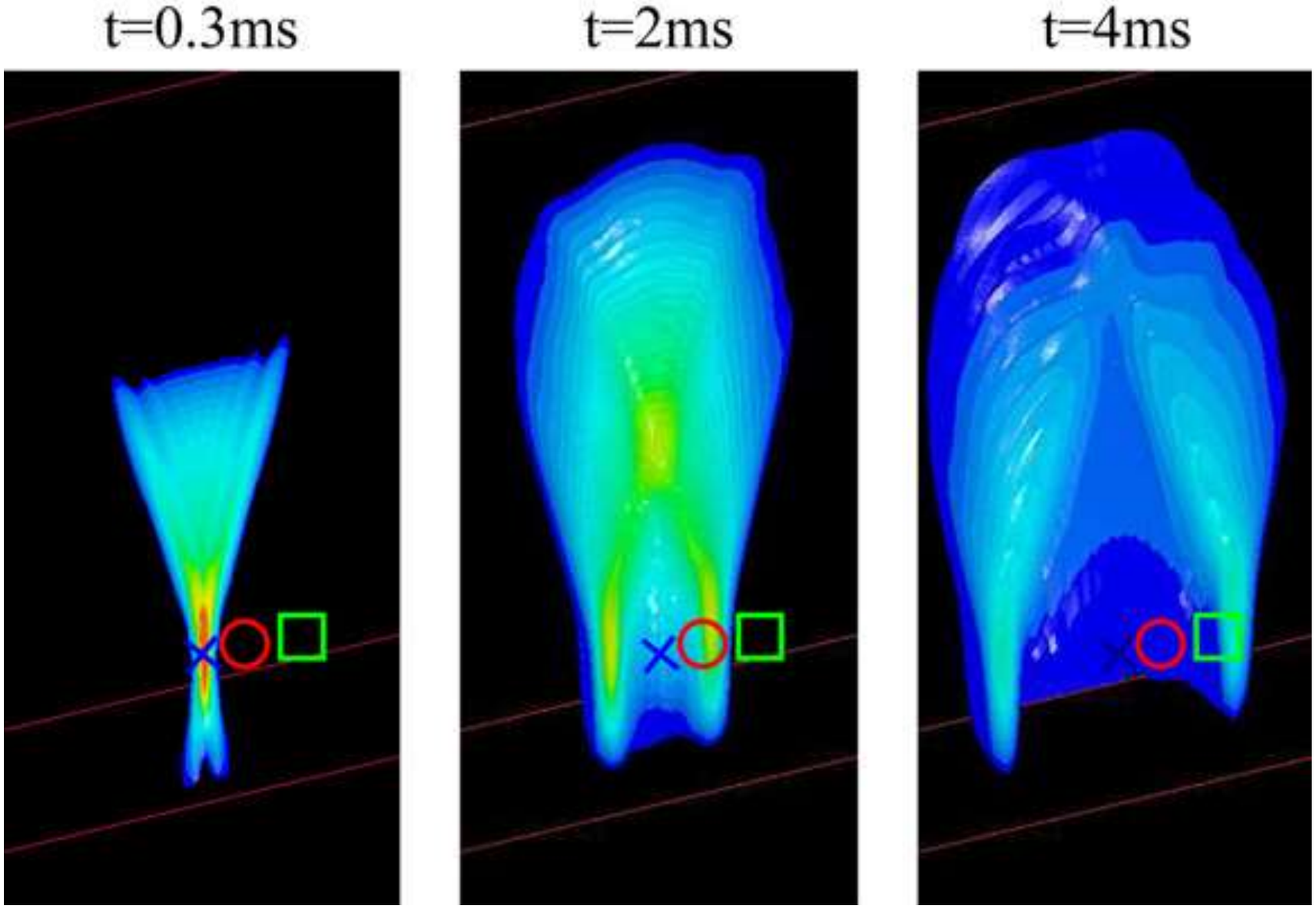
Types of US Elastography

- Transient elastography: electromechanical
- Strain elastography (SE): human mechanical
- Acoustic radiation force impulse imaging: US crystal
- Shear wave elastography imaging: US crystal

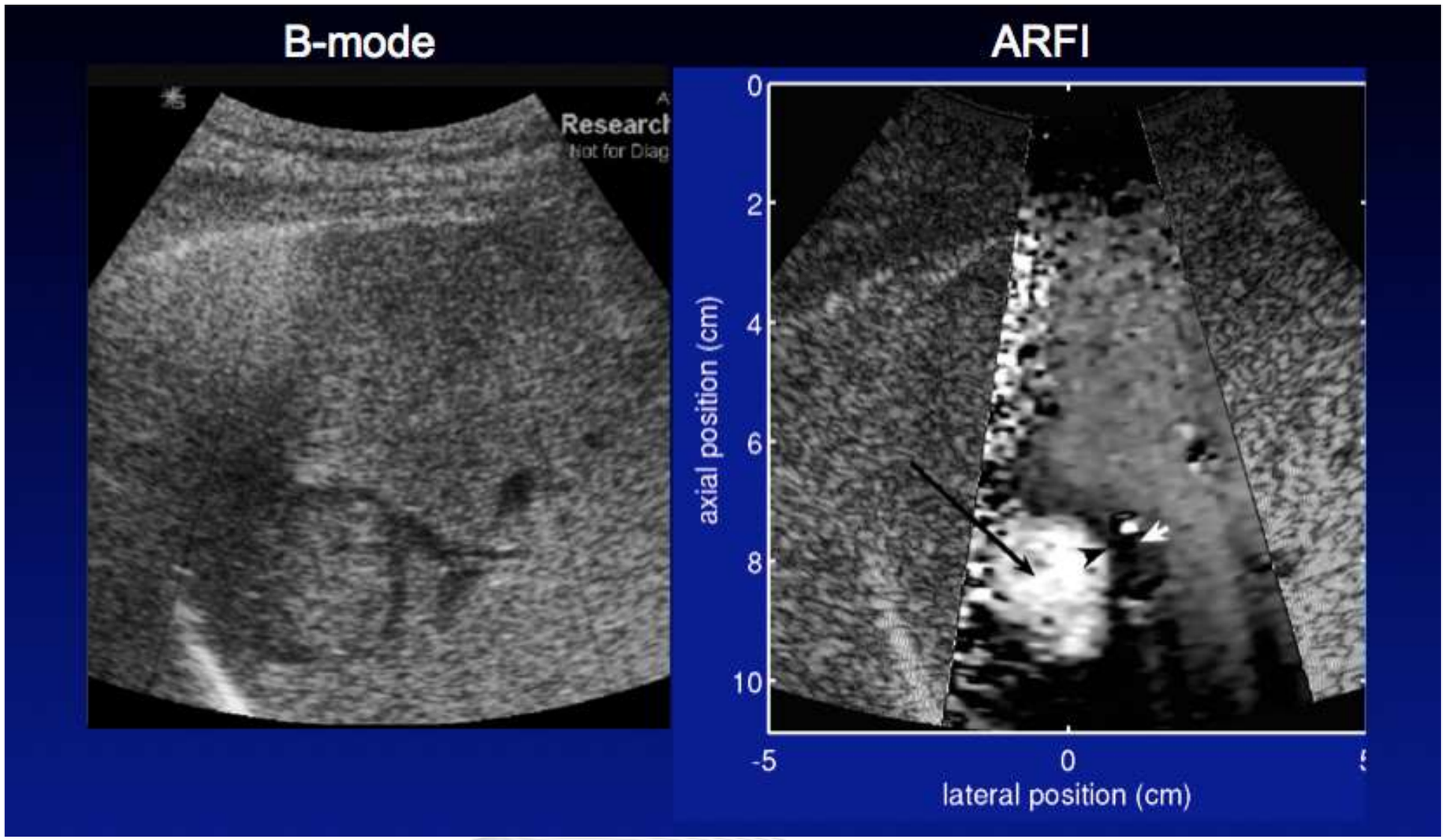
ARFI: General Principles

- Source: focused ultrasound “push pulse”
- Qualitative & quantitative (subjective/objective)
- More consistent & reproducible results
- Less operator dependent
- Data output:
  - Displacement image (elastogram)
  - Quantitative data (kPa calculated from time of flight)
  - Both

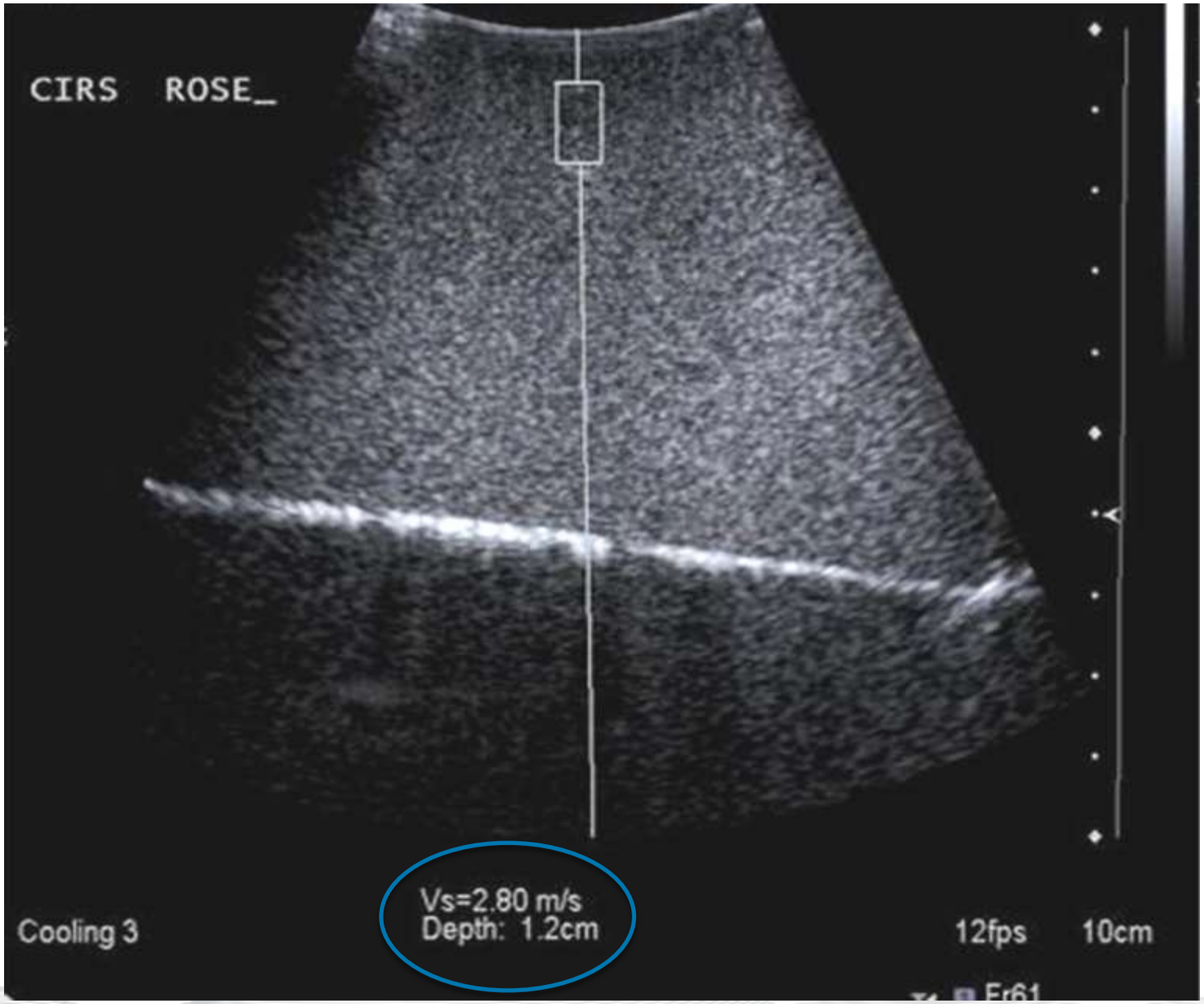
ARFI Elements



ARFI Elements



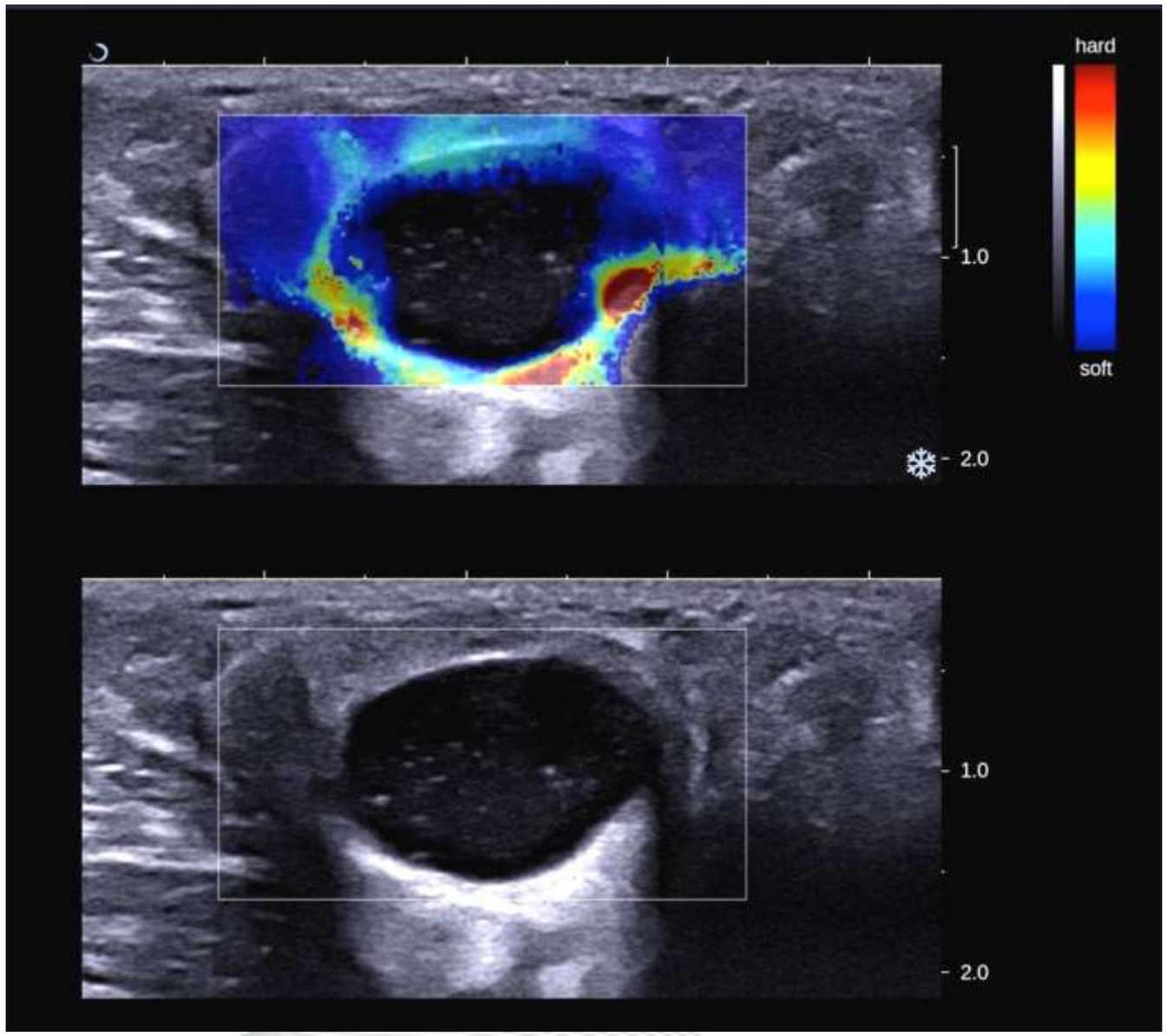
ARFI Elements



SWE: General Principles

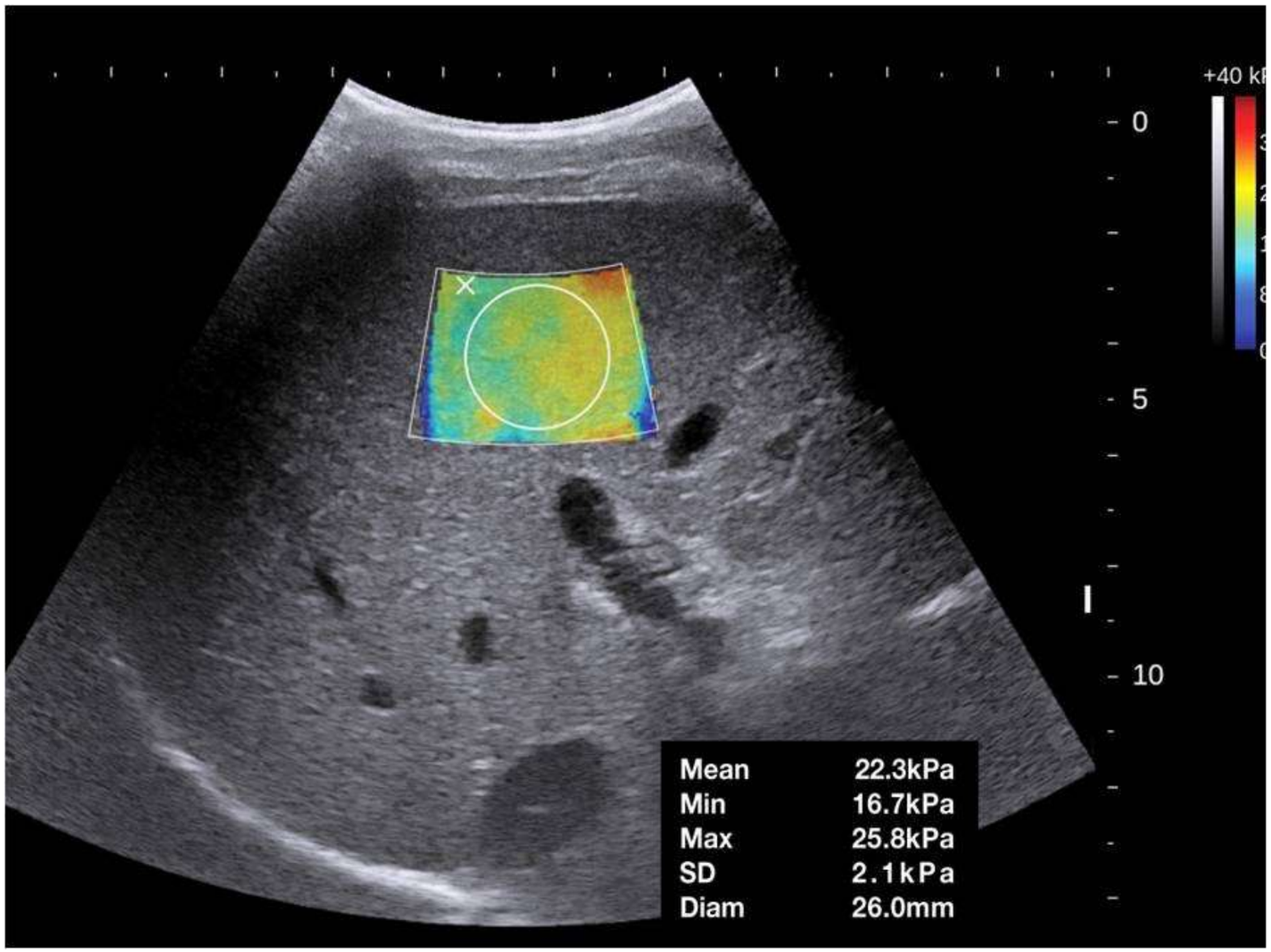
- Source: ARFI
- Qualitative & quantitative
- Real-time elastogram
- Data output:
  - Displacement image (requires ultrafast PRF)
  - Quantitative data (kPa calculated from time of flight)
  - Both

SWE Elements



Real-time Elastogram

SWE Elements



Quantitative Output

Clinical Applications

- Liver - chronic progressive disease
- Breast cancer
- Prostate cancer
- Thyroid cancer
- Gynecologic - ovary, uterus, tubes
- Obstetric - placenta
- Bowel

Virtual Histology

- General principles
- Research applications
  - Cardiology
  - Liver disease

General Principles

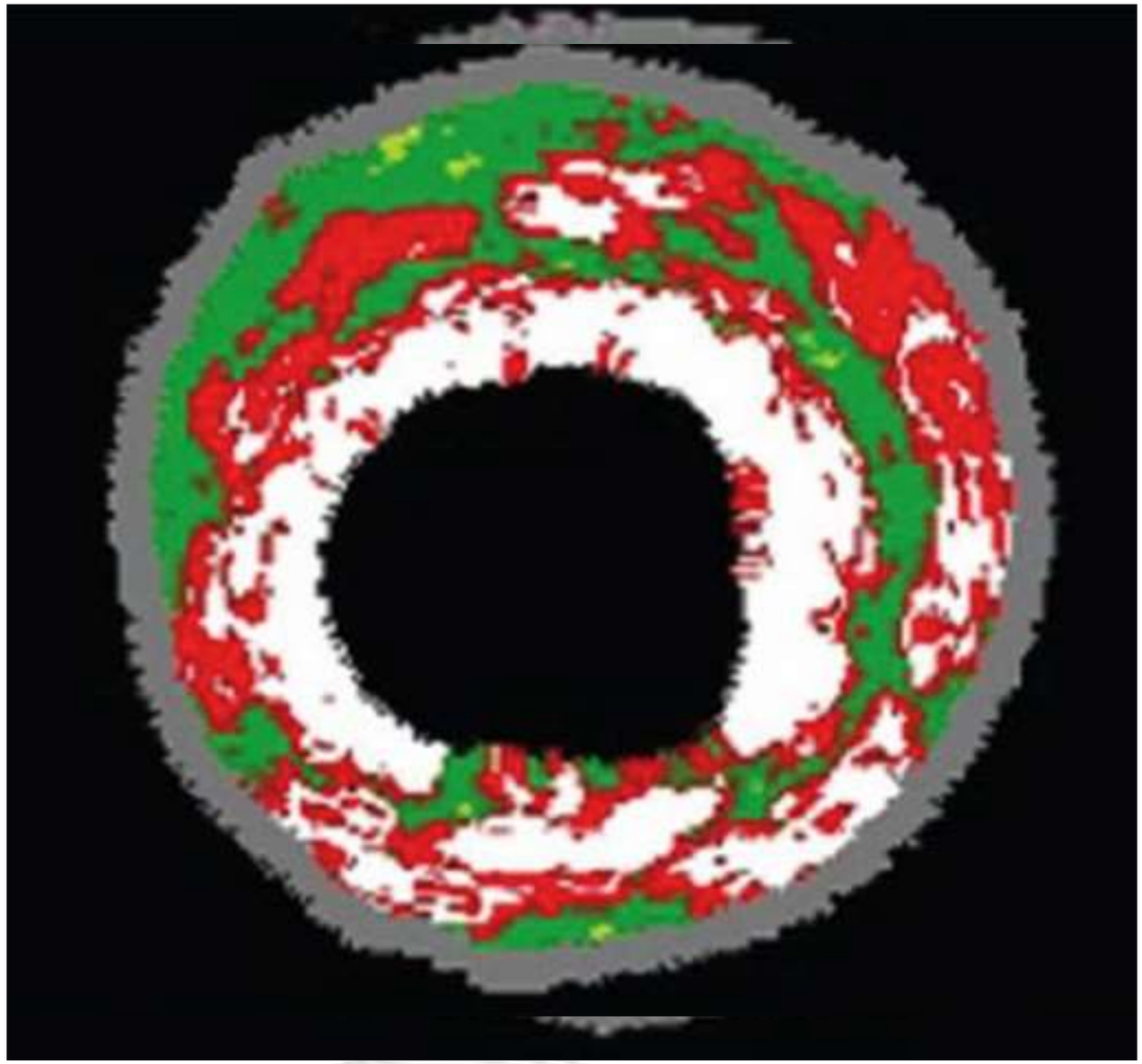
- Quantitative US technique
- Uses RF backscatter for tissue characterization
  - Magnitude and frequency distribution
  - First order statistic properties of echo envelope as a signature of tissue microstructure
- Imaging method: color-coded pixel mapping of different tissue types
- Non-imaging method: IQ data off-boarded to software program (MATLAB)

Research Applications - Cardiology

- IVUS Virtual Histology
- Imaging method
- Transducer catheter passed over coronary guide wire
- Provides detailed histological analysis of plaque
- Plaque types
  - Fibrous
  - Fibrofatty
  - Necrotic core
  - Dense calcium

VIRTUAL HISTOLOGY

Research Applications - Cardiology



Dense Calcium

Research Applications - Liver Disease

- Quantitative assessment of non-alcoholic fatty liver disease (NAFLD)
- Non-imaging method
- Computer-aided analysis of IQ data
- Using hepatic/renal echo-intensity and attenuation ratios
- 89% accuracy compared to quantitative MRI

Viscoelasticity

- Energy source: ARFI
- Shear waves analyzed for dispersion of propagation speed
- Measures elasticity and viscosity using SDUV:
  - Shear wave dispersion ultrasound vibrometry
- Data output:
  - Quantitative measurements (kPa)

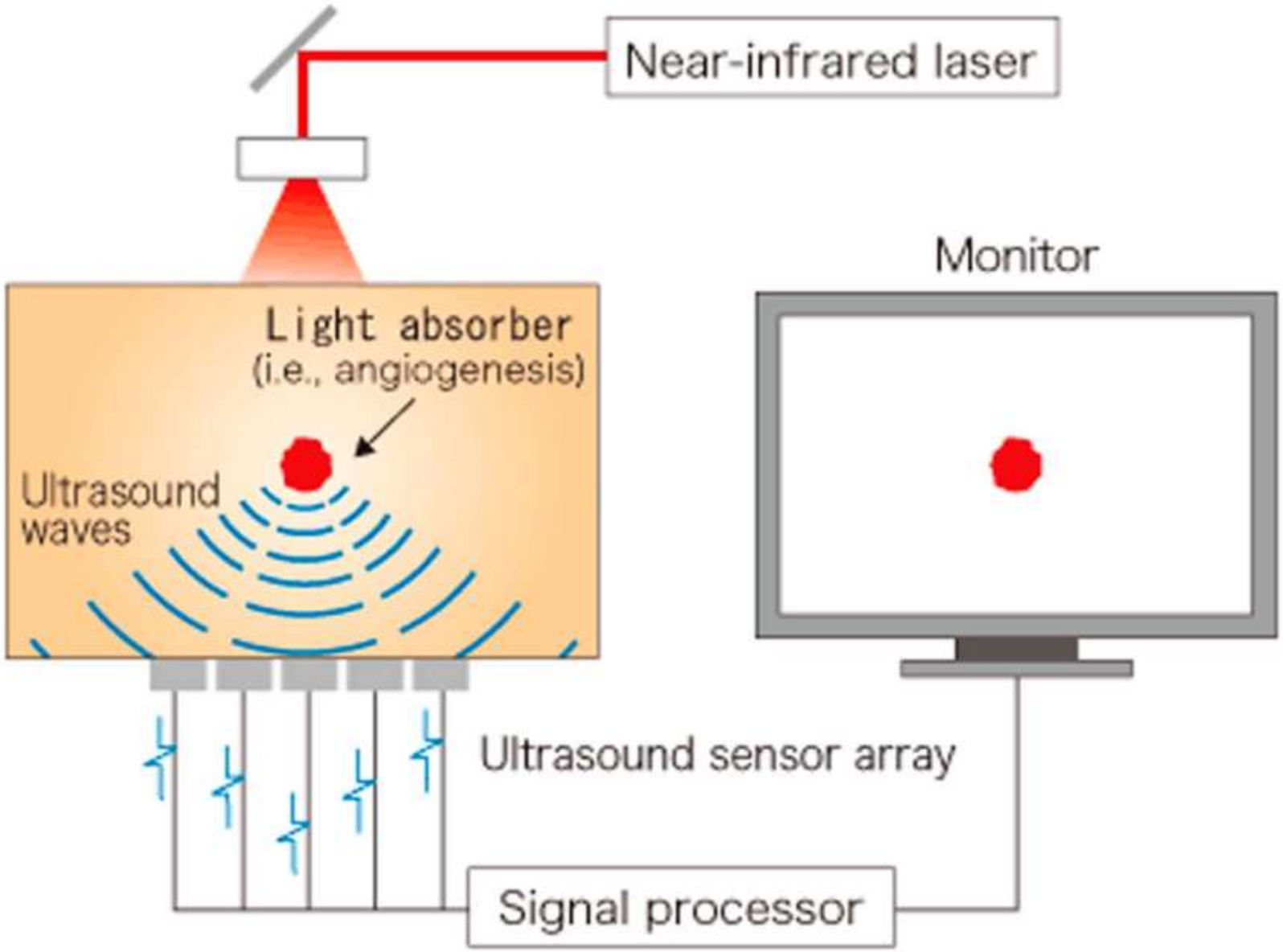
Research Applications

- Urinary bladder
- Liver fibrosis
- Breast cancer
- Renal disease

Photoacoustic Imaging

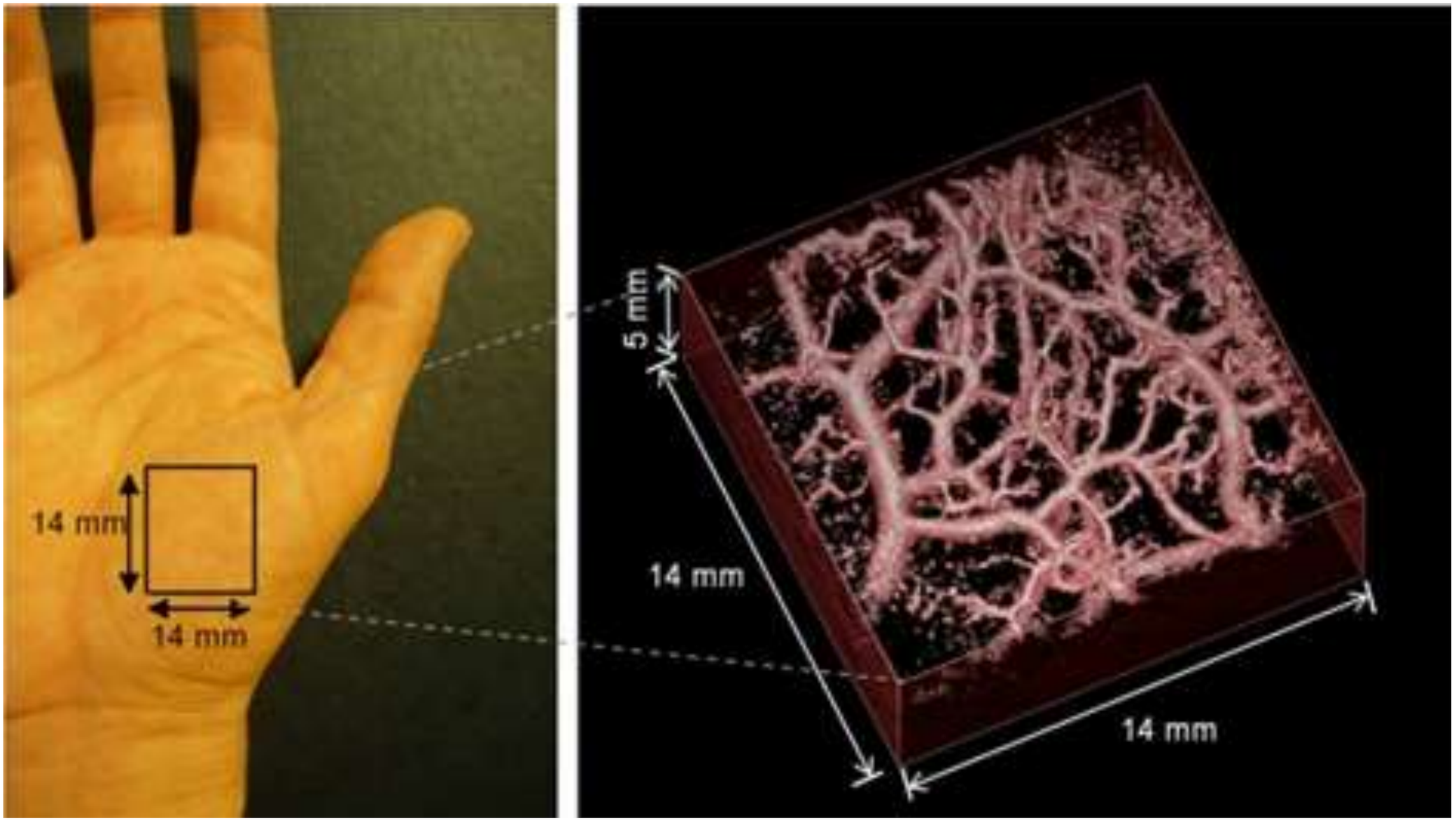
- Hybrid biomedical imaging modality
- Energy source: laser pulses
- Light energy → Heat → Acoustic energy
- US waves detected by transducers
- Data is processed to produce images
- RF pulses may be used → thermoacoustic imaging

Photoacoustic Imaging



Courtesy: Canon Medical Imaging

Photoacoustic Imaging



Courtesy: University College London

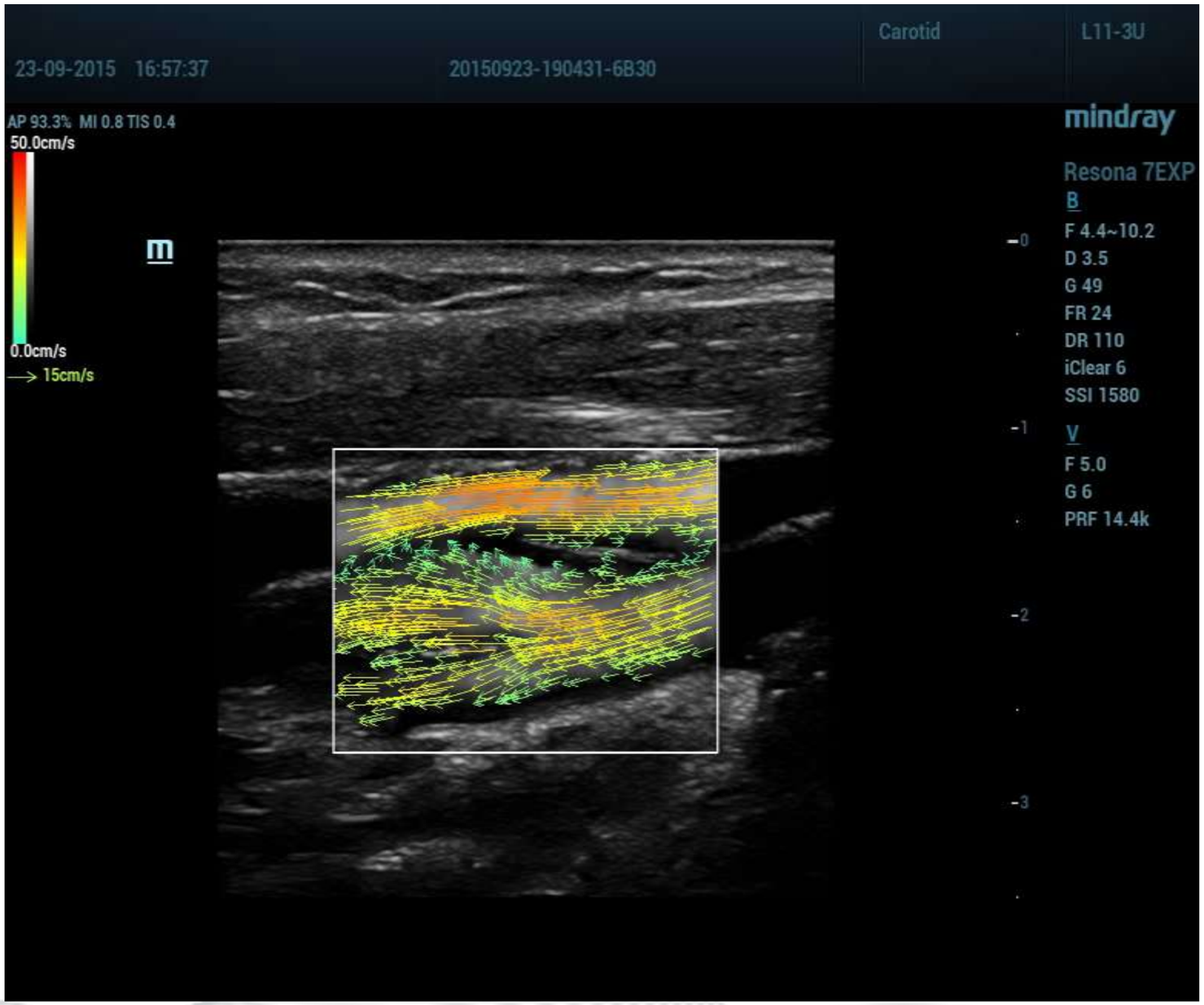
Research Applications

- Angiogenesis and anti-angiogenic response
  - Cancer detection
- Microcirculation (physiology and pathology)
  - Tissue metabolism imaging
- Early response to chemotherapy

Vector Flow Imaging

- Energy source: ultrasound
- Speckle tracking
- Non-angle dependent real-time display of blood flow
- Data output:
  - Color Doppler image
  - Automated flow velocity measurements
  - Automated volume flow measurement

Vector Flow Imaging



Research Applications

- Cardiac hemodynamics
- Arterial vascular hemodynamics
- Intraoperative blood flow estimation in ascending aorta (TEE)
- 3D visualization of velocity vectors.

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