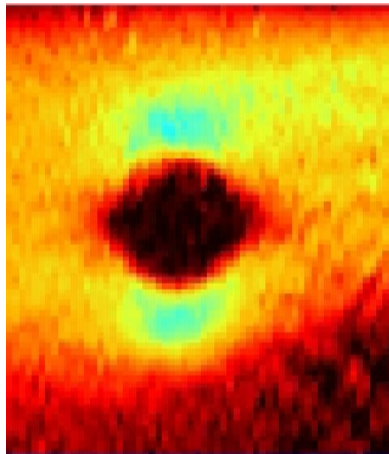# Real Time Strain Imaging

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Overview

- Introduction

- Strain Estimation using Phase Root Seeking

- Our Real Time Strain Imaging Approach

- Phantom Images

- Clinical Study on Prostate Strain Imaging (260 patients)

- Results using *Strain Imaging Guided Biopsy*
  (400 patients)

- Images, Histologies and Movies

- Conclusions

Strain Estimation using Phase Root Seeking

Fundamentals of Strain Imaging
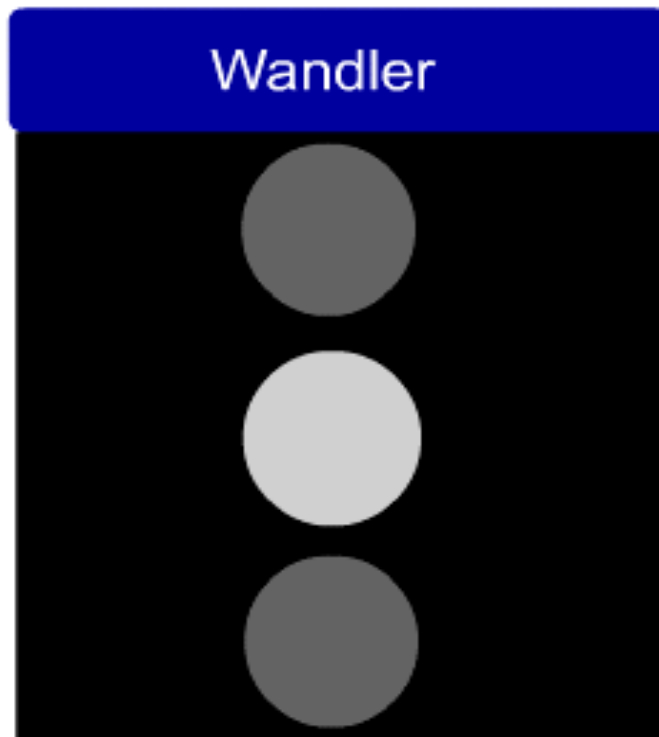
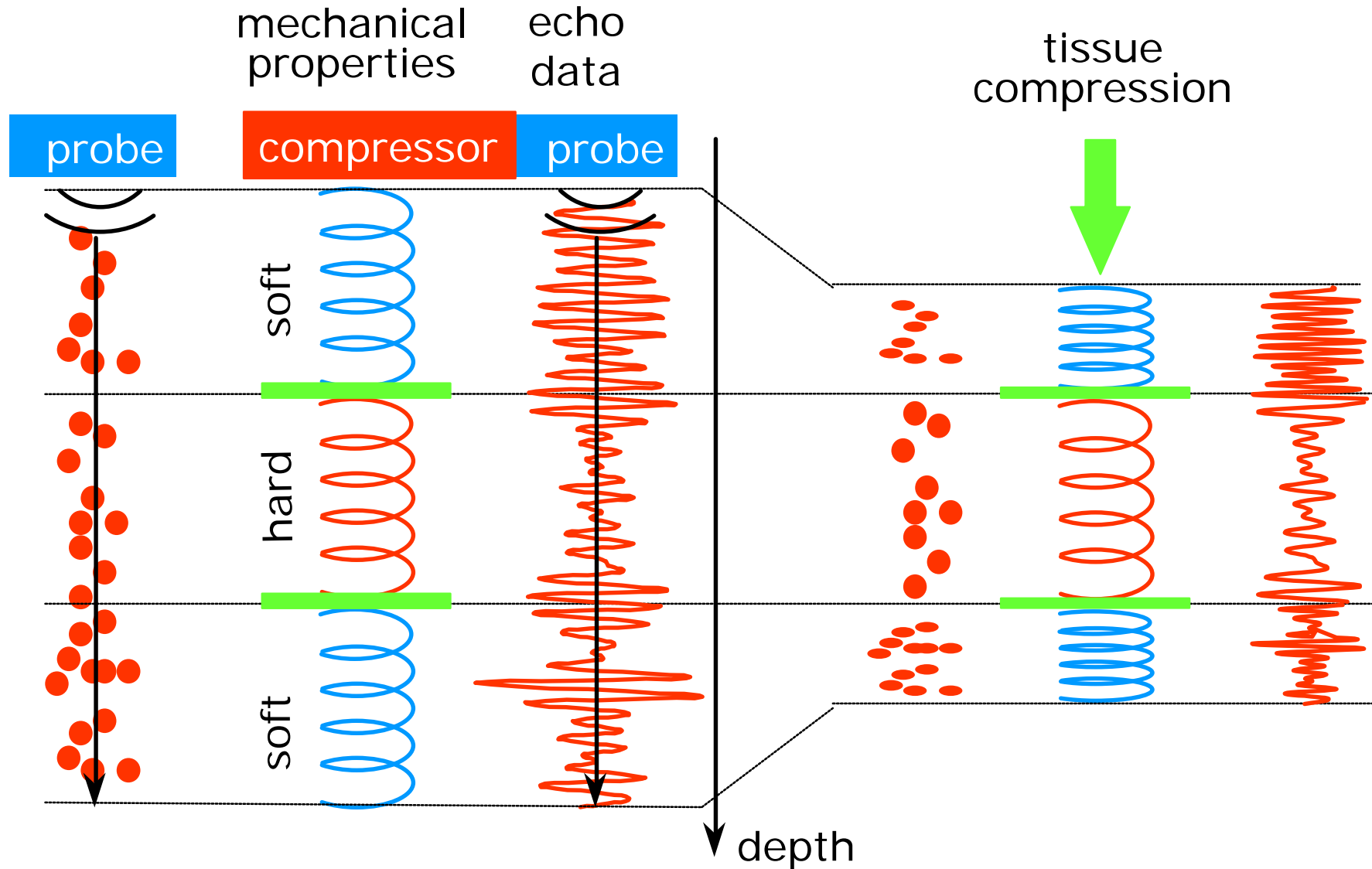the tissue is compressed by the ultrasonic probe

different regions with different hardness are compressed differently

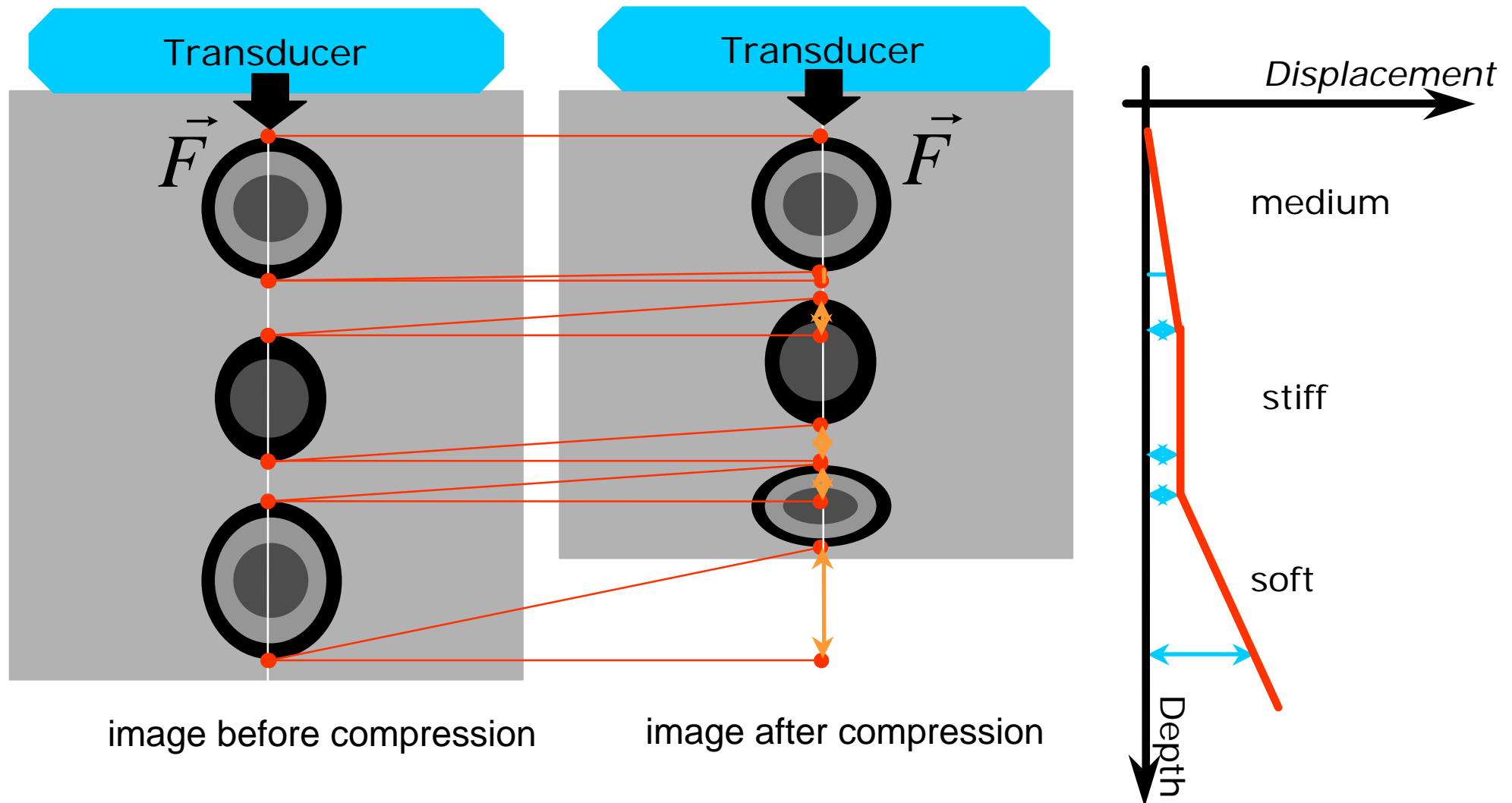the local strain is computed and displayed

real time strain imaging computes and displays the local strain with more than 30 frames per second

the strain is computed by the determination of local displacements between two consecutive images
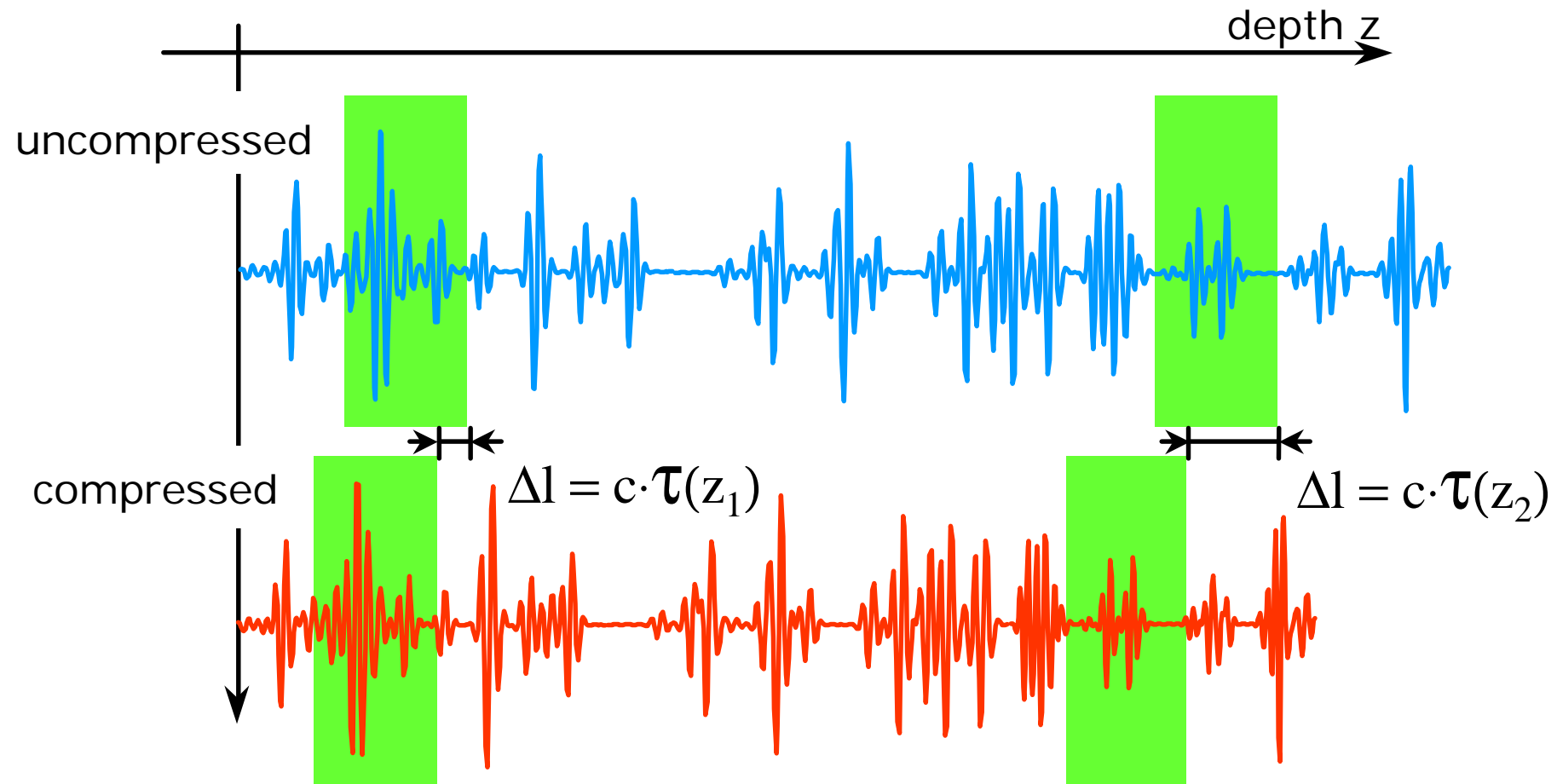
Fundamentals of Strain Imaging

mechanical properties

echo data
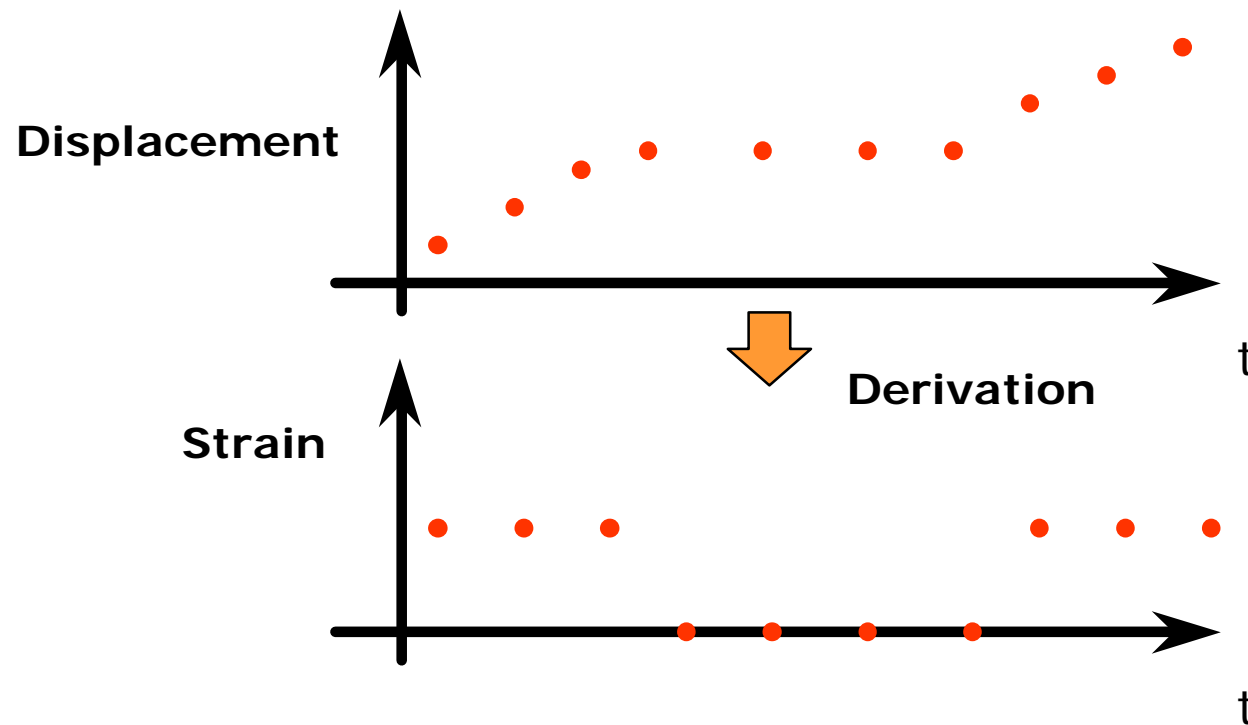
tissue compression

probe

compressor

probe

soft

hard

soft

depth

Fundamentals of Strain Imaging

Transducer

$\vec{F}$

Transducer

$\vec{F}$

Displacement

medium

stiff

soft

Depth

image before compression

image after compression

Displacement estimation from rf-echoes

depth z

uncompressed

compressed

$\Delta l = c \cdot \tau(z_1)$

$\Delta l = c \cdot \tau(z_2)$

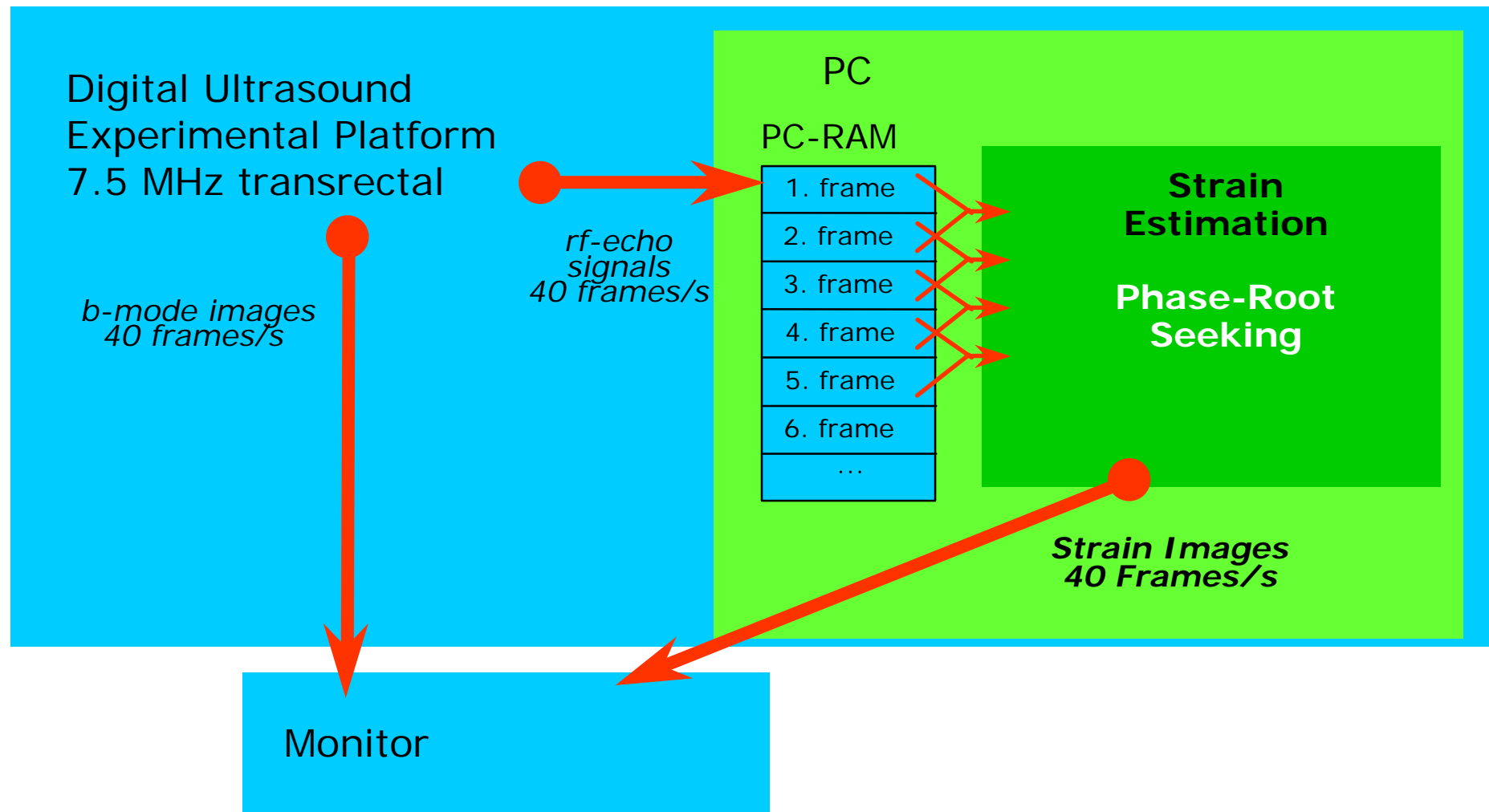# Calculation of Strain from Displacements

Data model

slope: s
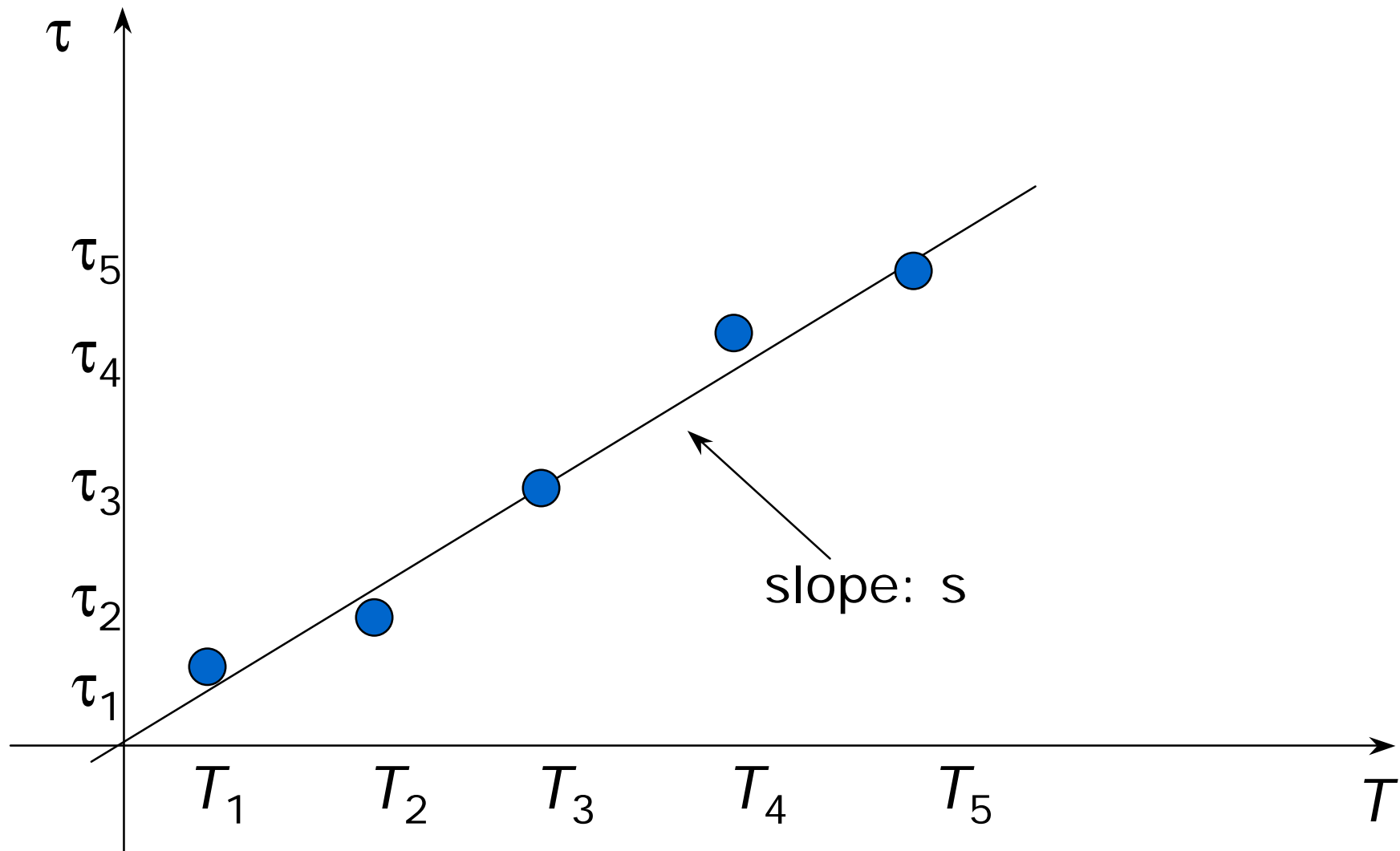
PC based Real Time Strain Imaging Systems

Real Time Strain Imaging

- first real time strain imaging system worldwide (1999)

- use of Phase Root Seeking and temporal filtering of strain images (7.5 Hz)

- *now*: > 40 frames per second with approximately 100 x 100 calculated strain values

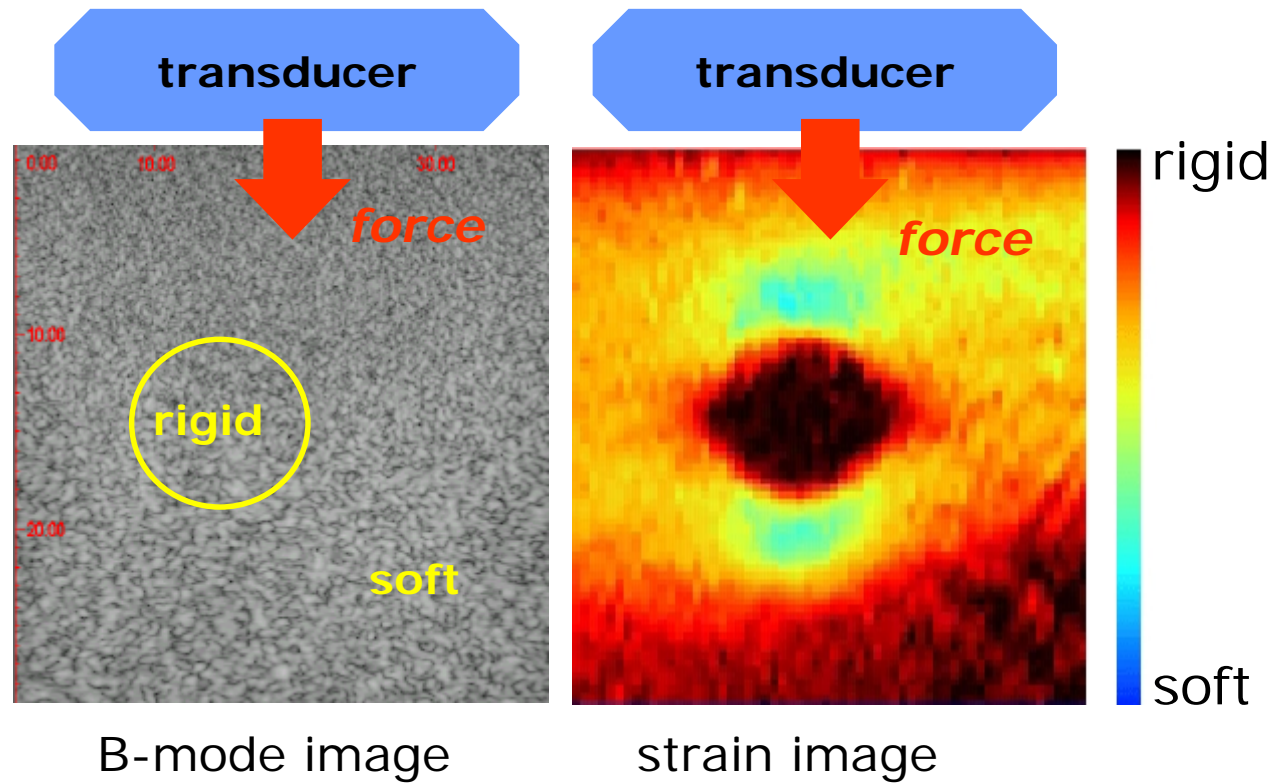- PC-based acquisition and imaging system

Real Time Strain Imaging System

Digital Ultrasound
Experimental Platform
7.5 MHz transrectal

b-mode images
40 frames/s

rf-echo
signals
40 frames/s

PC

PC-RAM

1. frame
2. frame
3. frame
4. frame
5. frame
6. frame
...

Strain Estimation

Phase-Root Seeking

Strain Images
40 Frames/s

Monitor

Phantom Images

Phantom Experiments - Real Time Strain Imaging

B-mode image

strain image

- hard inclusion in a soft sponge
- constructed by injecting agar-agar

Phantom Experiments - Real Time Strain Imaging
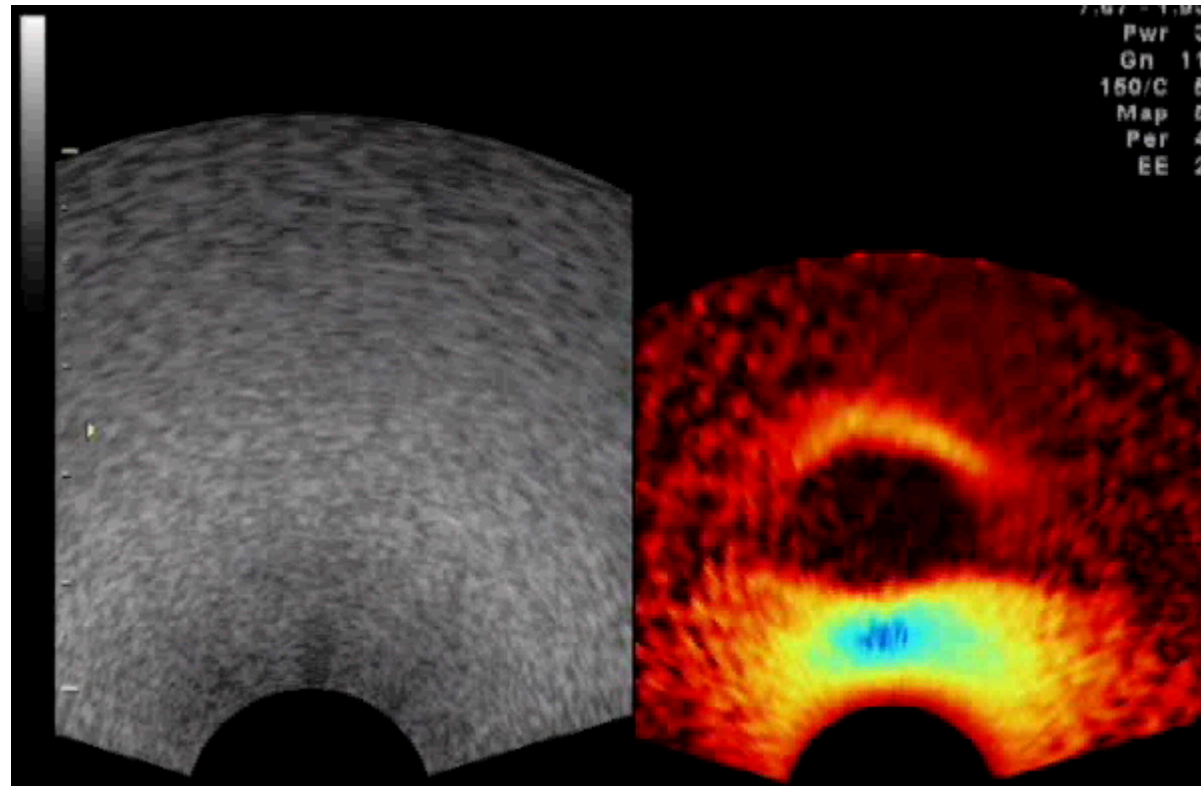
Clinical Study on Prostate Imaging

Prostate Strain Imaging - Clinical Partners

- A. Lorenz, A. Pesavento, LP-IT Innovative Technologies GmbH

- T. Senge, K. Kühne, H.-J. Sommerfeld, M. Garcia-Schürmann, Department of Urology, Ruhr University Bochum

- S. Philippou, Department of Pathology, Ruhr University Bochum

in vivo Strain Imaging of Human Prostate

- for men the prostate carcinoma is the second most important cause of death by cancer

- <u>diagnostics so far:</u> PSA, digital rectal examination (DRE), TRUS

- prostate carcinoma is often hard and palpable, but in most of the cases not visible in the B-mode image

- strain imaging visualizes the tissue hardness by compressing the tissue and calculating the local tissue strain from a sequence of images
  - imaging of a new important diagnostic parameter which is independent from the B-mode reflectivity
  - two dimensional representation of the tissue hardness
  - visualization of deep lying tumors, which is not possible with palpation

Prostate Study I - Real Time Strain Imaging

- Can *real time strain imaging* improve the early detection of prostate carcinoma?

- <u>begin:</u> May 2000, up to now approximately 260 patients

Prostate Study II - Real Time Strain Imaging

- Can *real time strain imaging* improve needle biopsy results?

- <u>begin:</u> April 2002, approximately 400 patients

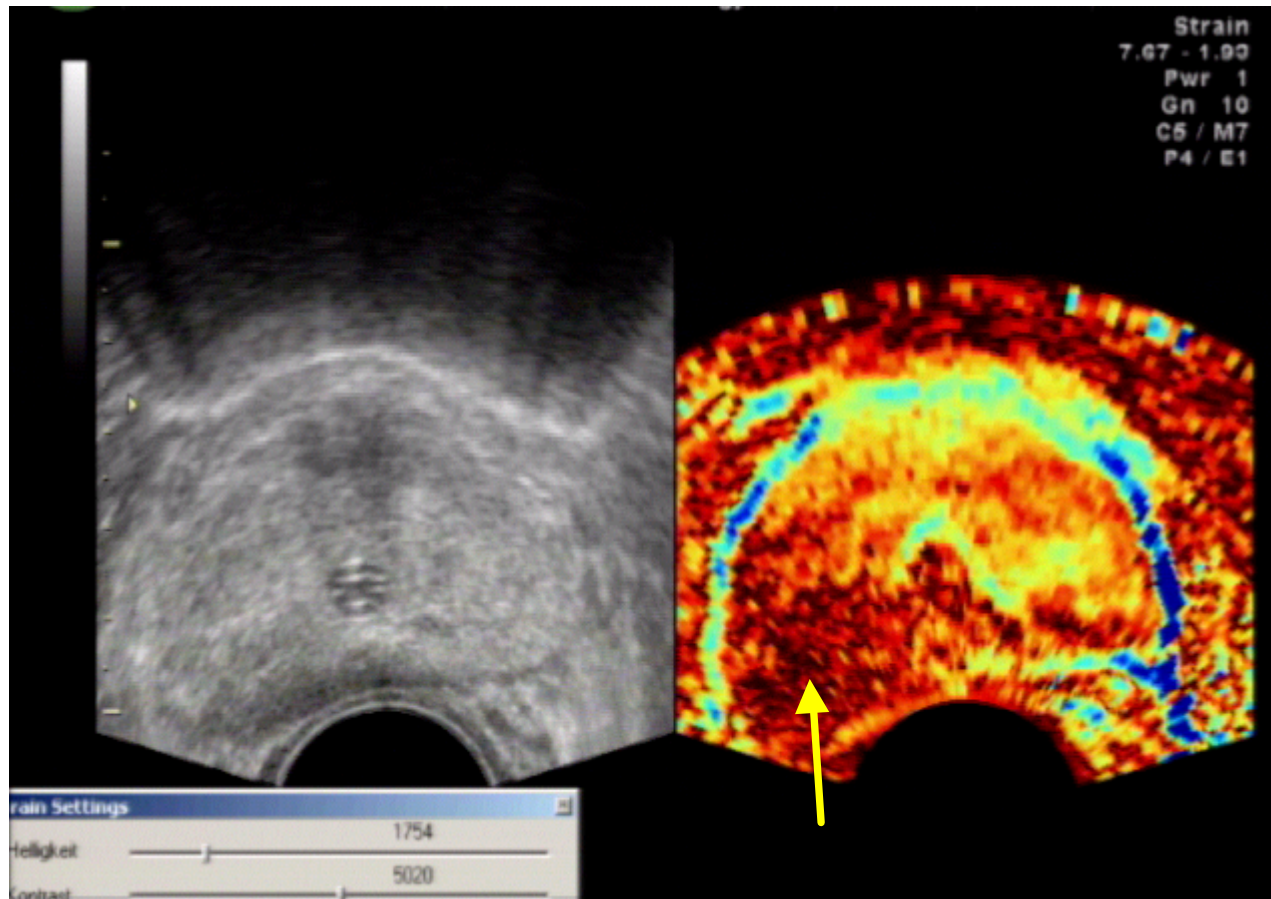# Prostate Study I - Real Time Strain Imaging

- <u>patients:</u> all patients have prostate carcinoma diagnosed by needle biopsy, undergoing prostatectomy

- <u>post-operative control</u>: "gold standard" histology

- pre operative decision after Real Time Strain Imaging about location and size of the carcinoma

- post operative histology results are compared with pre operation decisions

- 260 Patients, approx. 76 % sensitivity and 81 % specificity

- 27 of 42 multi-focal tumors were visualized by Strain Imaging

- <u>B-Mode</u>: only **34%** of all the carcinoma could be recognized correctly using **B-Mode** imaging **alone**

- <u>Strain Imaging</u>: approximately **76%** of all carcinoma could be detected correctly (4 quadrant location and area >50%)

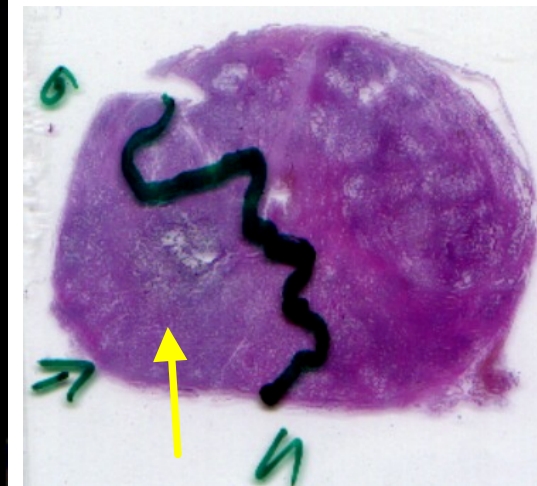# Prostate Study II - Real Time Strain Imaging

- <u>patients:</u> suspect from either digital rectal examination (DRE) **and/or** PSA (blood) **and/or** transrectal ultrasound (TRUS), undergoing sextant needle biopsy

- <u>post-operative control</u>: "gold standard" needle biopsy result

- post operative biopsy results are compared to pre operation decisions

- overall 404 patients

  – prostate cancer found in 151/404 cases (37.4%)

  – in 127/151 cases (84.1%) cancer was detected using real time strain imaging (64.2 % with conventional methods)

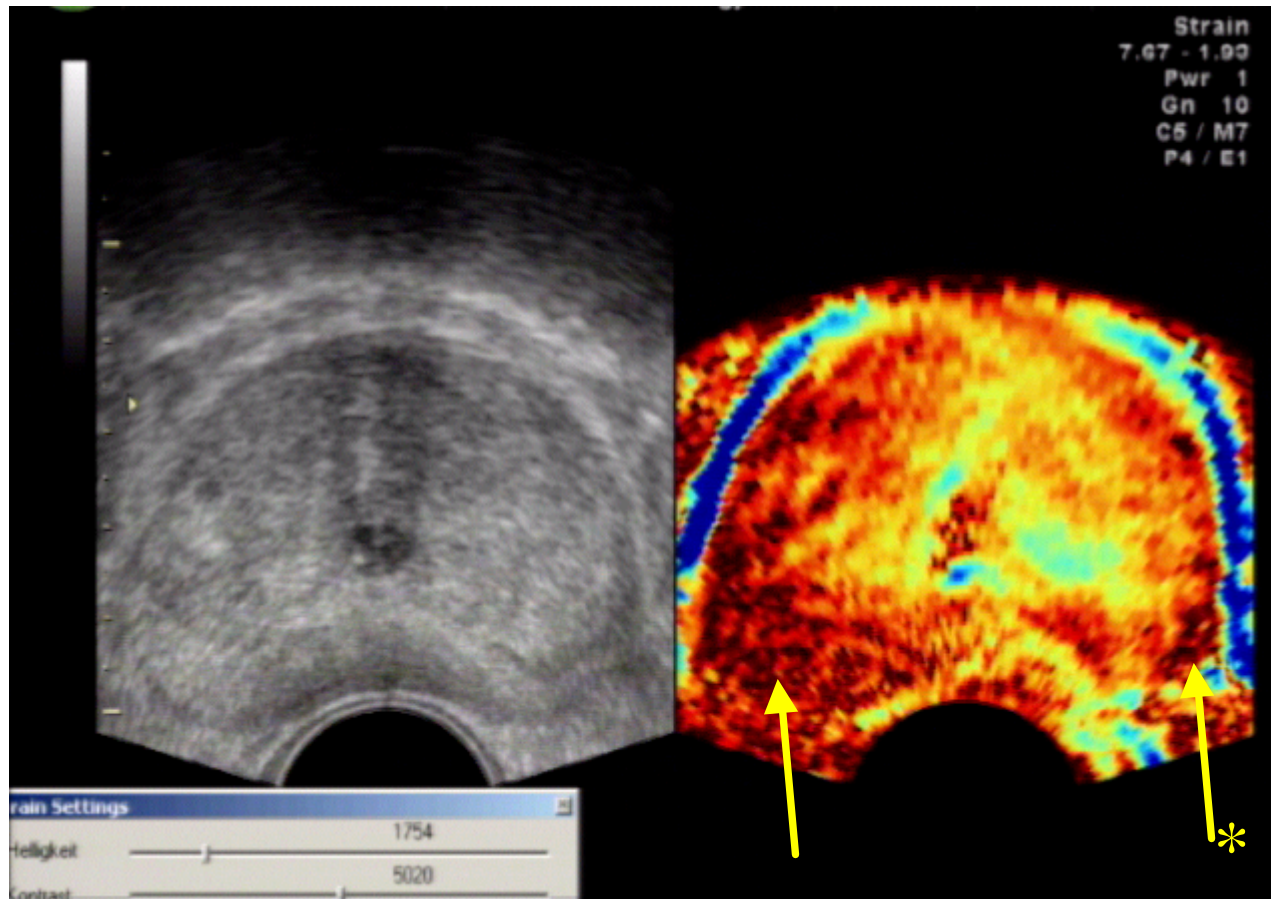 – 179/350 (51.1%) biopsies true positive, 370/556 (66.5%) true negative
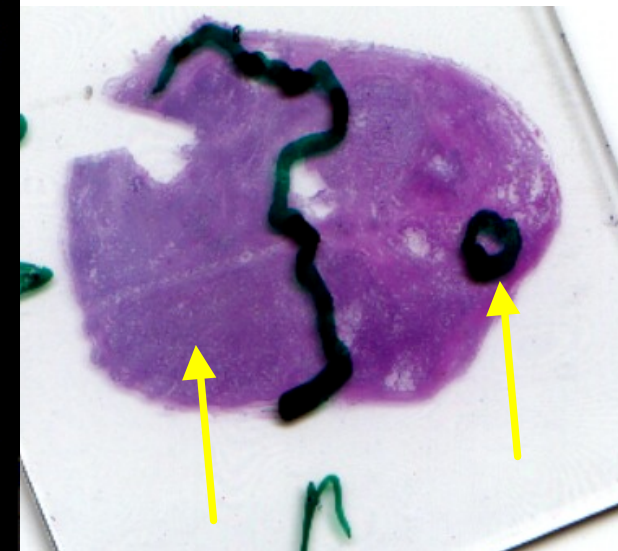
Patient in vivo

B-Mode   Strain Image   Histology

Patient in vivo

*post operative*

B-Mode   Strain Image   Histology

Movies

- *transversal mode*, normal medical examination of the prostate in vivo

- *longitudinal mode*, real time strain image guided biopsy in vivo

the videos were grabbed and digitized in real time from the video output of the ultrasound system, they are displayed here without further processing

Patient in vivo - frame rate: 43 Hz transversal mode, standard exam
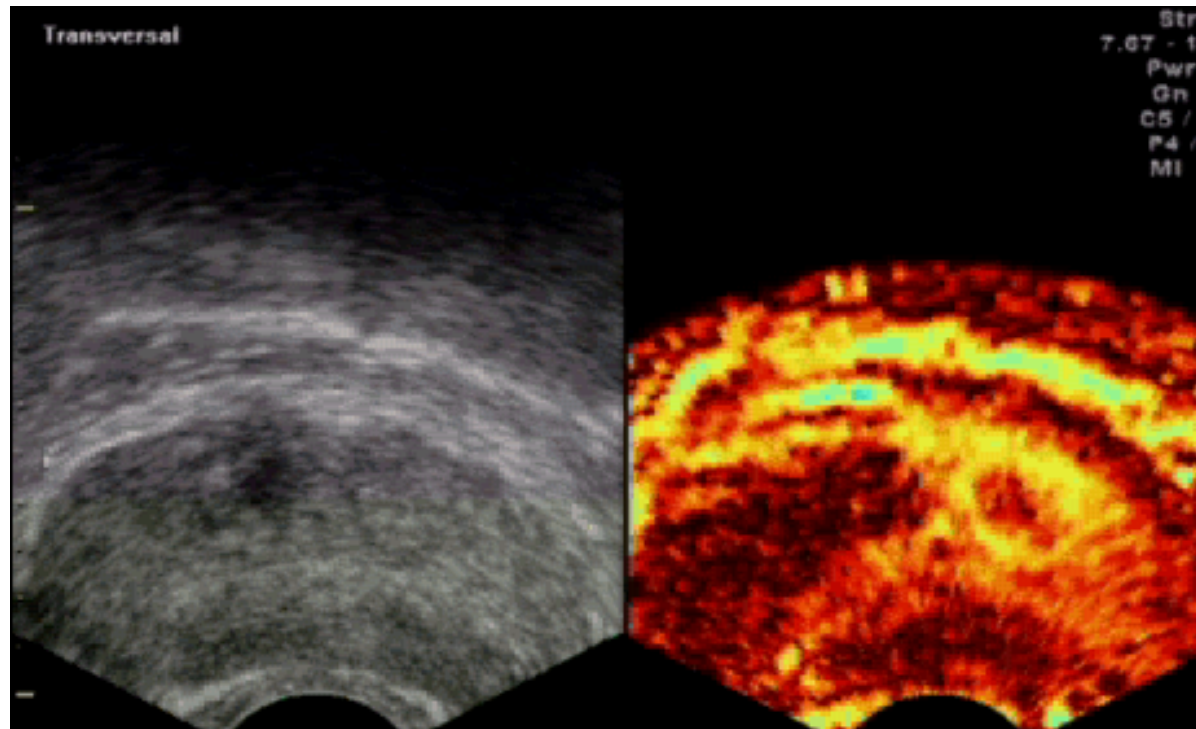
Patient in vivo - frame rate: 43 Hz longitudinal mode, biopsy mode
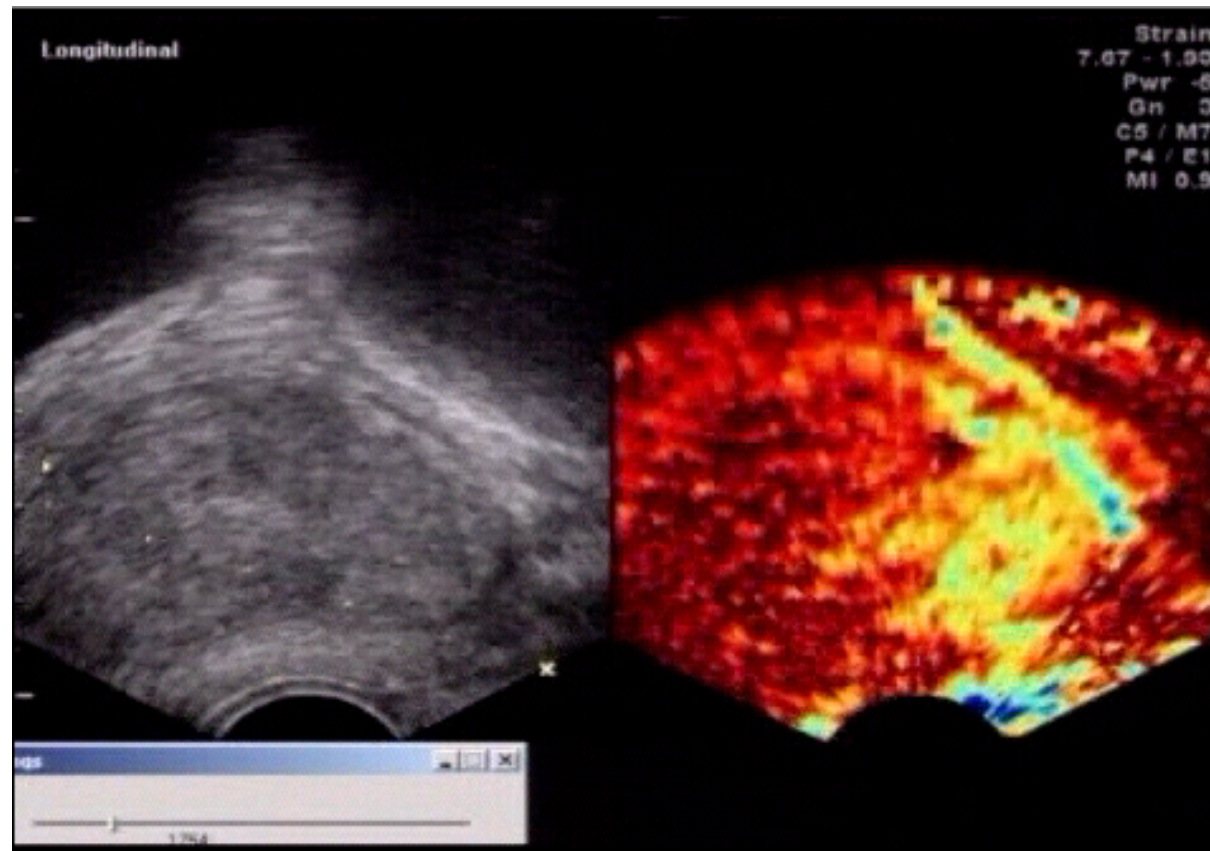
Conclusions

- real time strain imaging can improve the early detection of prostate cancer

- real time strain imaging has the potential to reduce false negative needle biopsy results

- integration of phase root seeking in conventional ultrasound machines is technically feasible with very high frame rates (>40) -> very stable and reproducible images

Neuro Surgery Clinical Study

Real Time Vibrography for Intra-Operative Navigation - Clinical Partners

- A. Lorenz, A. Pesavento, LP-IT Innovative Technologies GmbH

- Martin Scholz, Knappschaftkrankenhaus Bochum

# Real Time Vibrography for Intra-Operative Navigation in Neurosurgery

- can r*eal time vibrography* improve intraoperative navigation during neurosurgery?

- Detection of tumor tissue, extend of tumor and rest tumor tissue during neurosurgery on the human brain

- advantage of using real time vibrography: very small overall compressions (< 0,4 mm)

- first in vivo patient

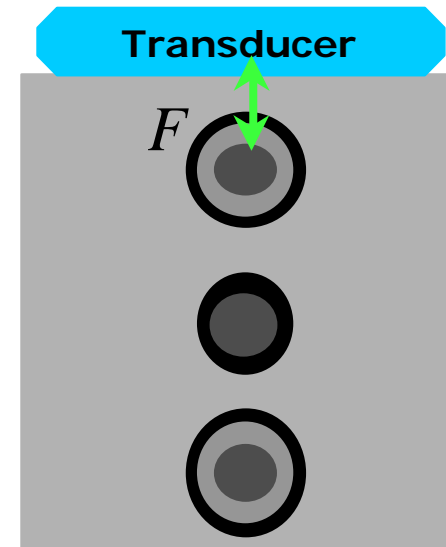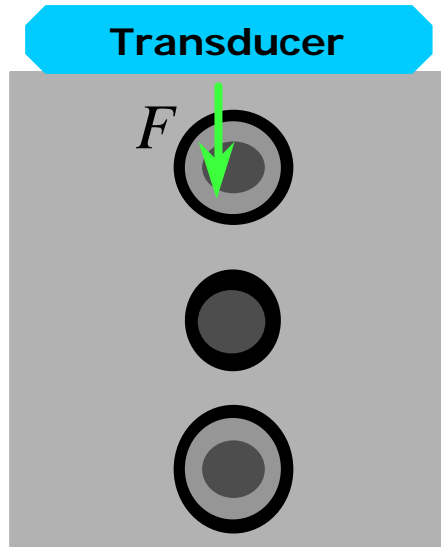# Real Time Vibrography in vivo Results
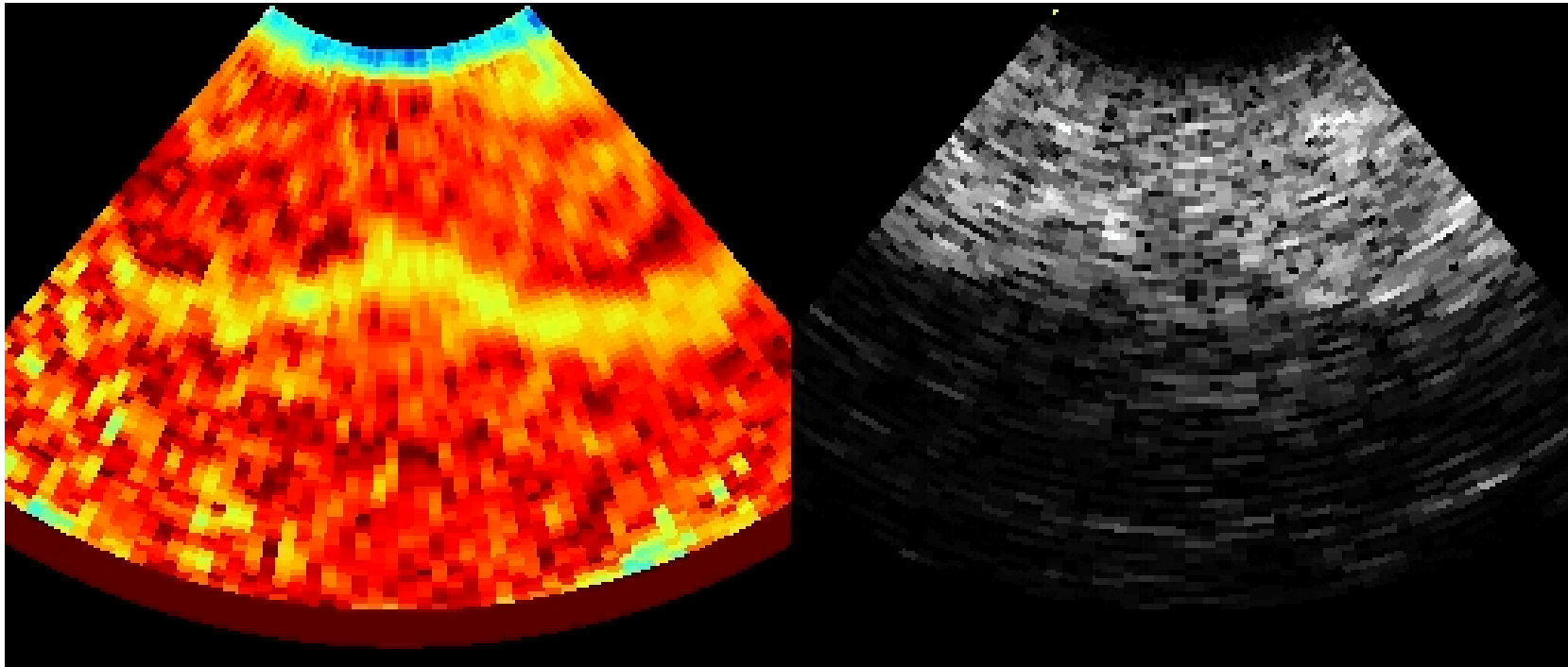
Left strain image, right b-mode image, Omnia with external rf-data acquisition

Real Time Vibrography in vivo Movie
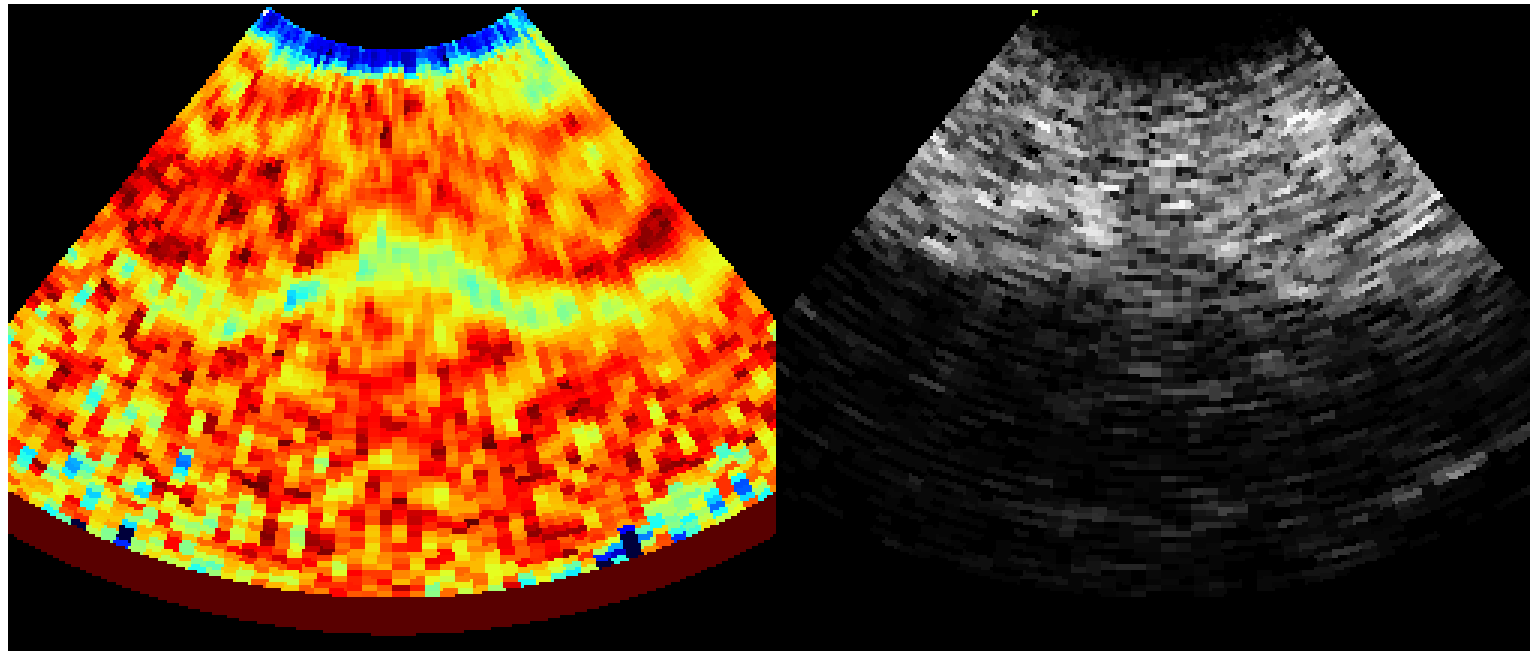
Comparison

Static Strain Imaging

- static compression
- 1 % - 10 %
- manually or automatic
- advantage: high strain SNR
- disadvantage: large overall compression, motion artifacts
- applications: prostate, mamma

Vibrography

- vibration (1-20 Hz)
- < 0.1 %
- advantage: low compression, less motion artifacts
- disadvantage: "less real time"
- applications: neurosurgery, IVUS