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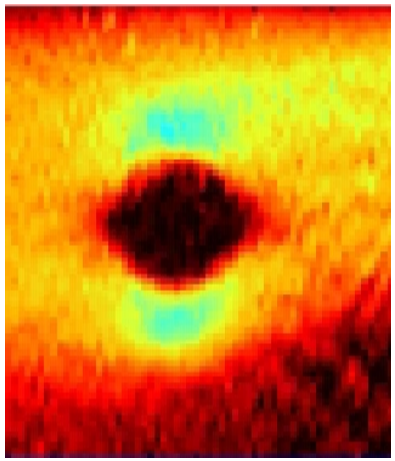
Real Time Strain Imaging Guided Prostate Biopsy



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Prostate Strain Imaging - Partners

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- Contribution to the Kompetenzzentrum Ruhr (KMR)

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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)
- Preliminary Results using *Strain Imaging Guided Biopsy*
- Images, Histologies and Movies
- Conclusion

in vivo Strain Imaging of Human Prostate

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- 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
- first in vivo prostate offline strain imaging system in January 1998

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Strain Estimation using Phase Root Seeking

Correlation Methods

Empirical cross-correlation function (CCF)

$$c_{yx}(t') = \int_{T-T_w/2}^{T+T_w/2} y(t+t')x^*(t)dt$$

Conventional TDE: $\tau = \arg\max_{t'} c_{U_1U_2}(t')$

Phase Root Seeking: $\tau = \text{root}_{t'} c_{U_{1+}U_{2+}}(t')$

Phase Root Seeking

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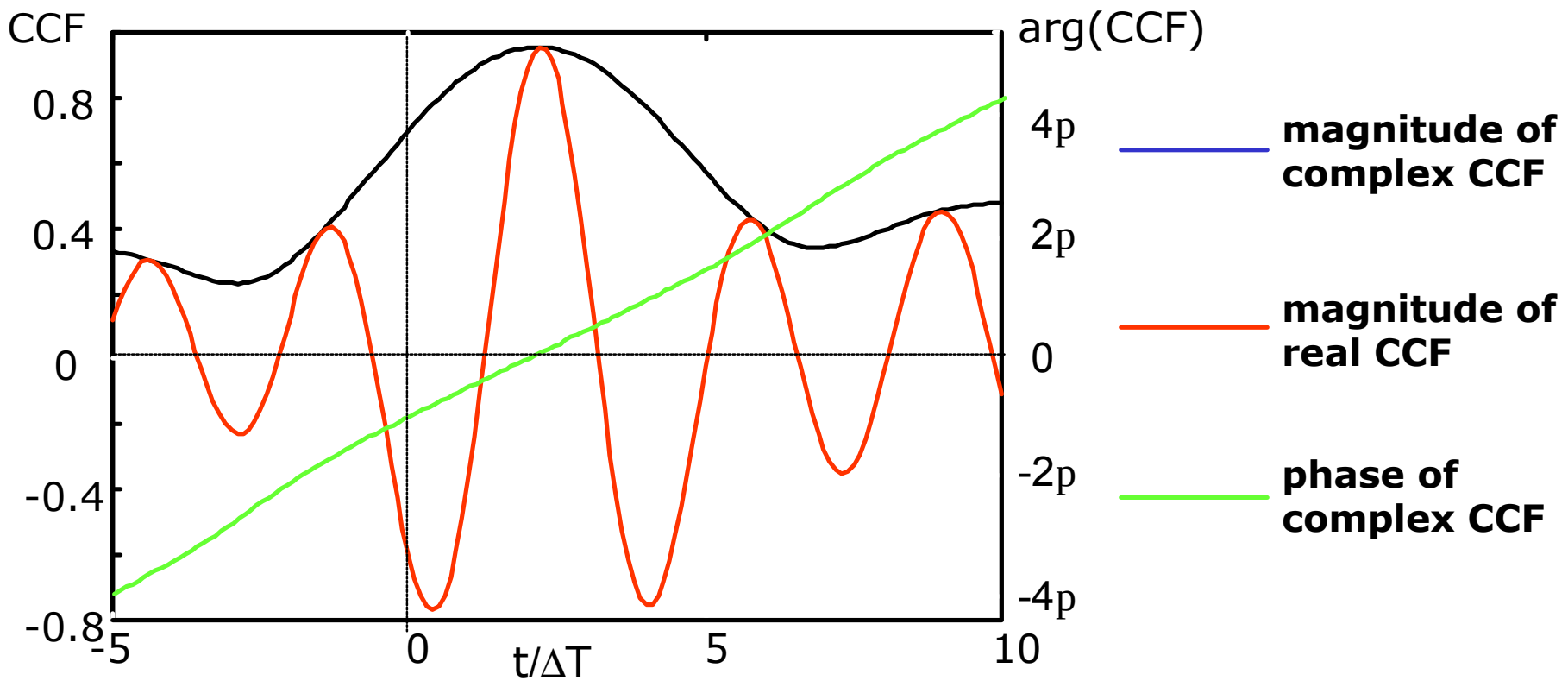
- Time Delay Estimation by finding the root of the complex correlation function



Phase Root Seeking

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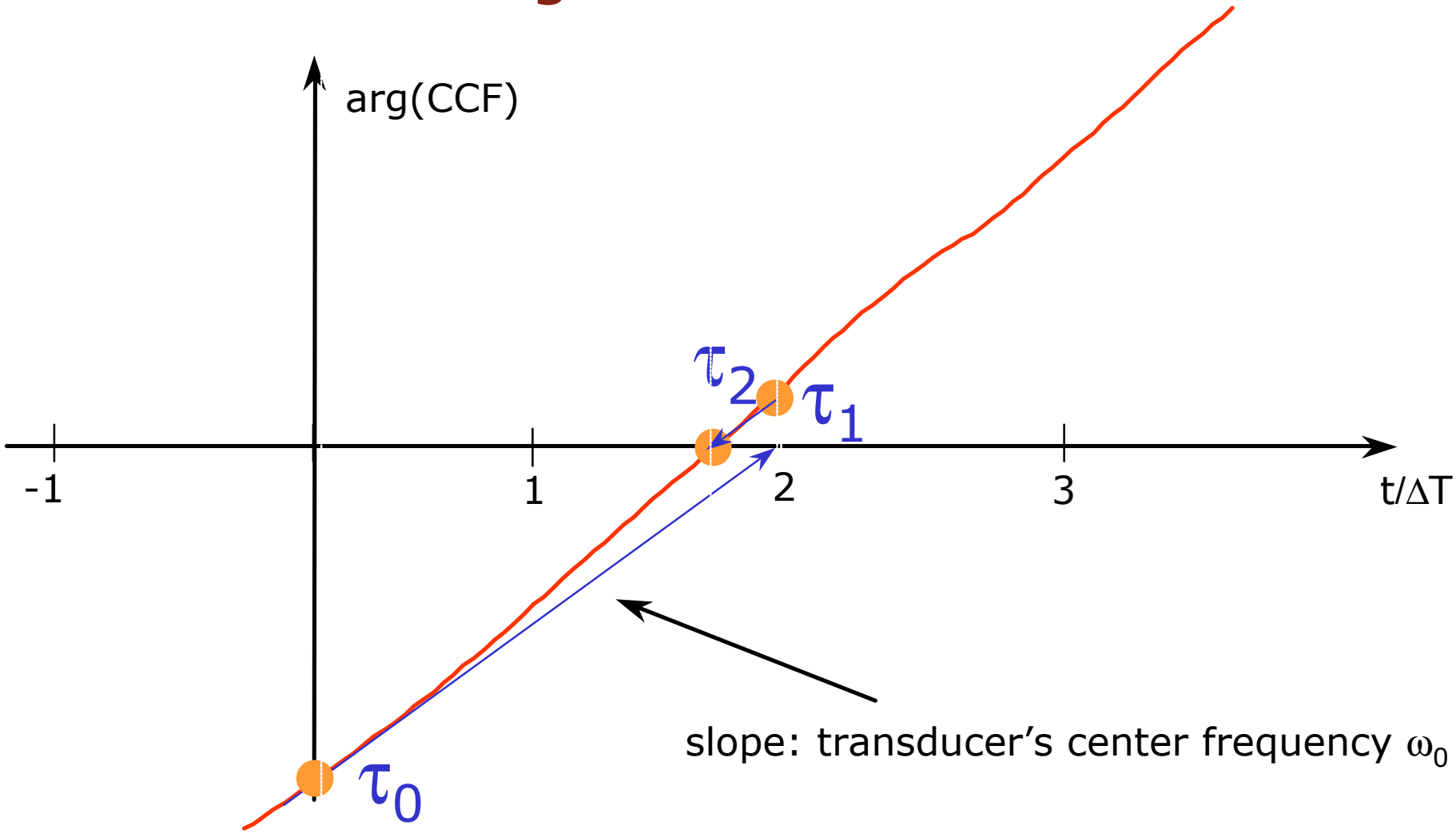

Phase Root Seeking

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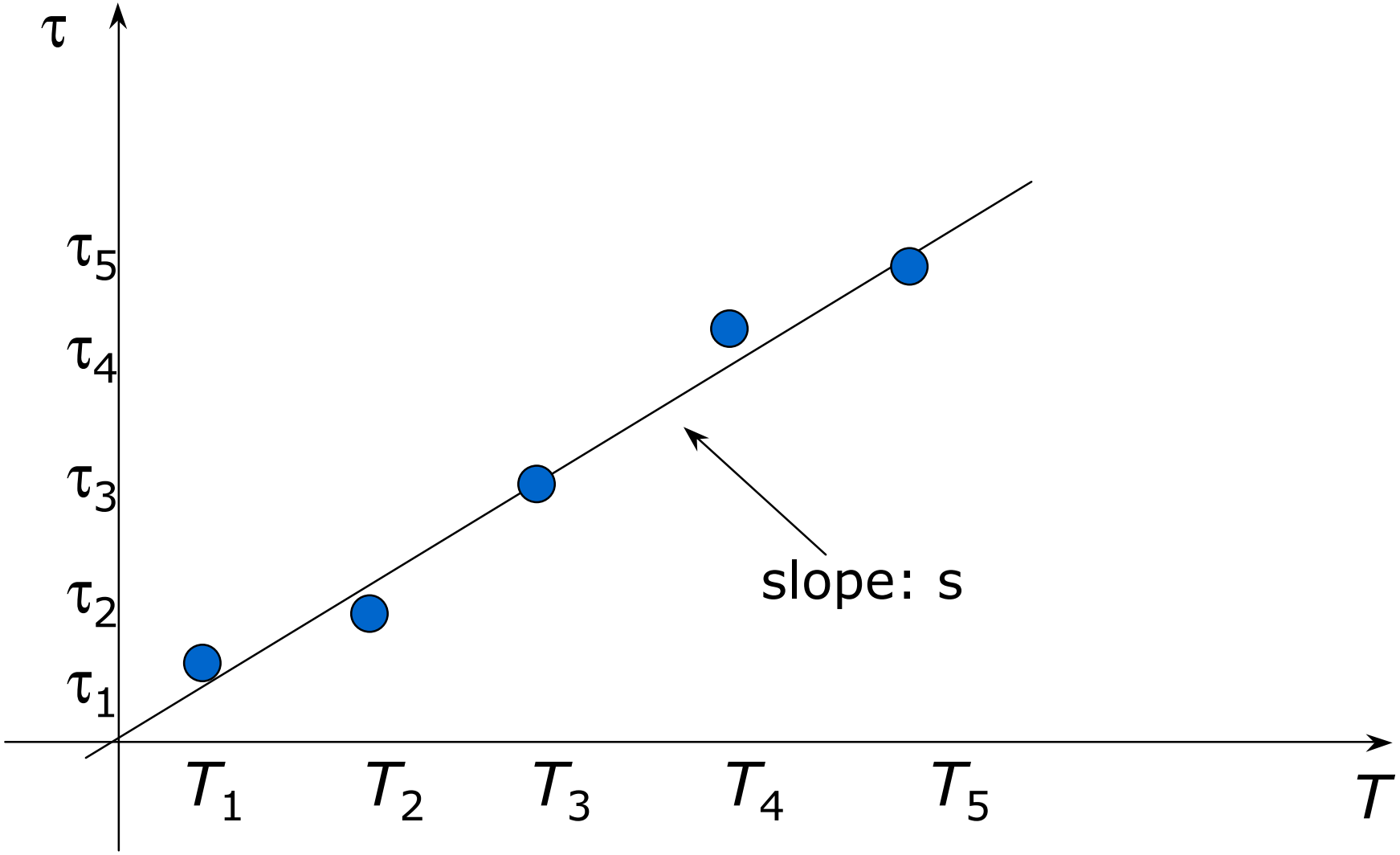
- Searching the root using a modified Newton Iteration:

$$\tau^{(n+1)} = \tau^{(n)} - \frac{\arg(c_{U_{1+}U_{2+}}(\tau^{(n)}))}{\omega_0}$$

- Start value $\tau^{(0)}$: result of the preceding window
- Convergence can be shown for noiseless echo data

Data model



Estimation of strain from time delays

- Time delay estimates obtained from overlapping windows are correlated
- Estimation of strain from time delays using the generalized least square estimator, which considers the correlation of time delays:

$$\begin{pmatrix} \hat{s} \\ \hat{t}_0 \end{pmatrix} = (A^T W^{-1} A)^{-1} A^T W^{-1} \, \hat{t}$$

W: covariance matrix of time delays $\hat{t}$

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PC based Real Time Strain Imaging Systems

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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

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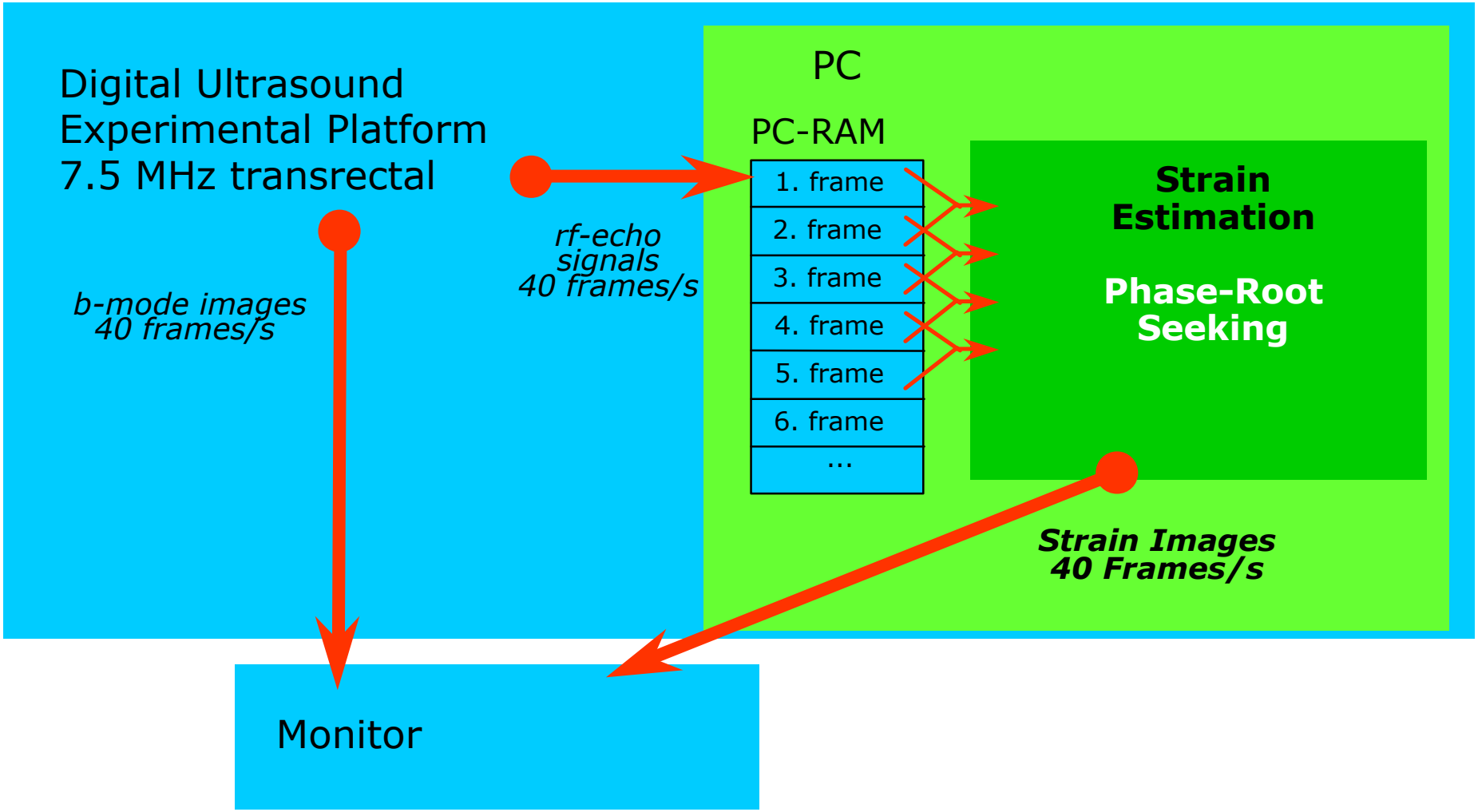

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Phantom Images

Phantom Experiments - Real Time Strain Imaging

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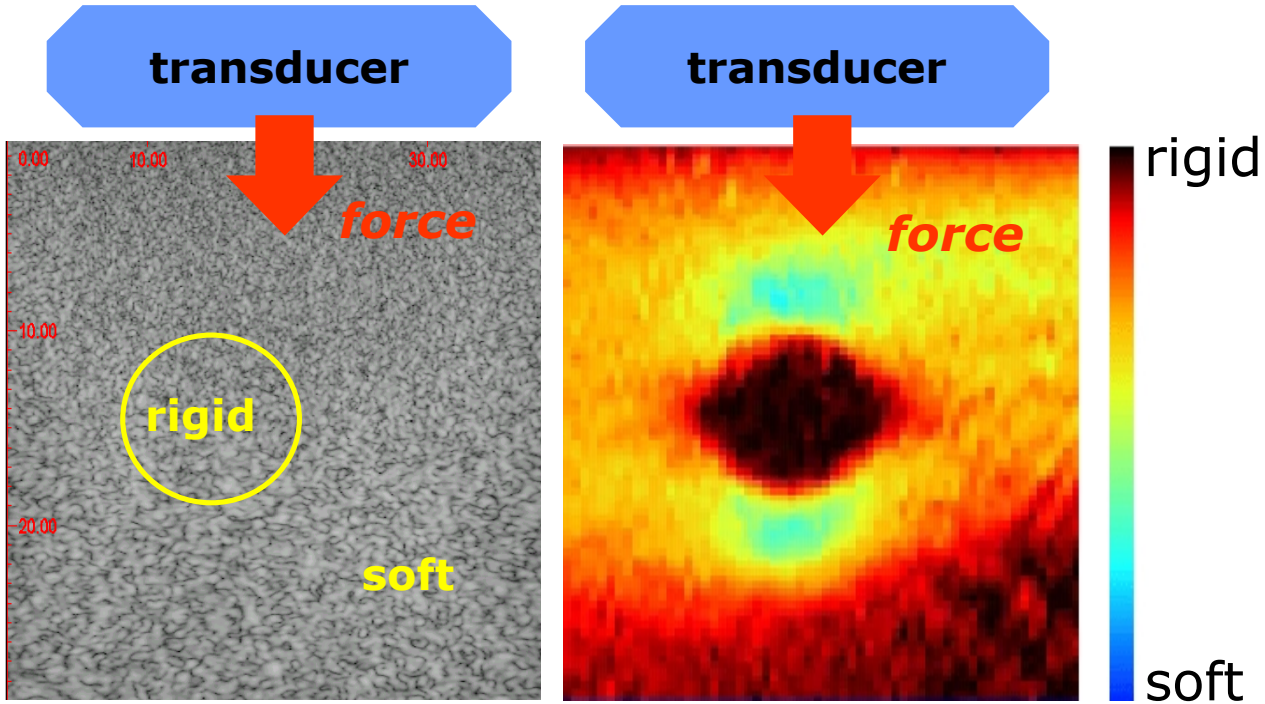

B-mode image strain image

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

Phantom Experiments - Real Time Strain Imaging

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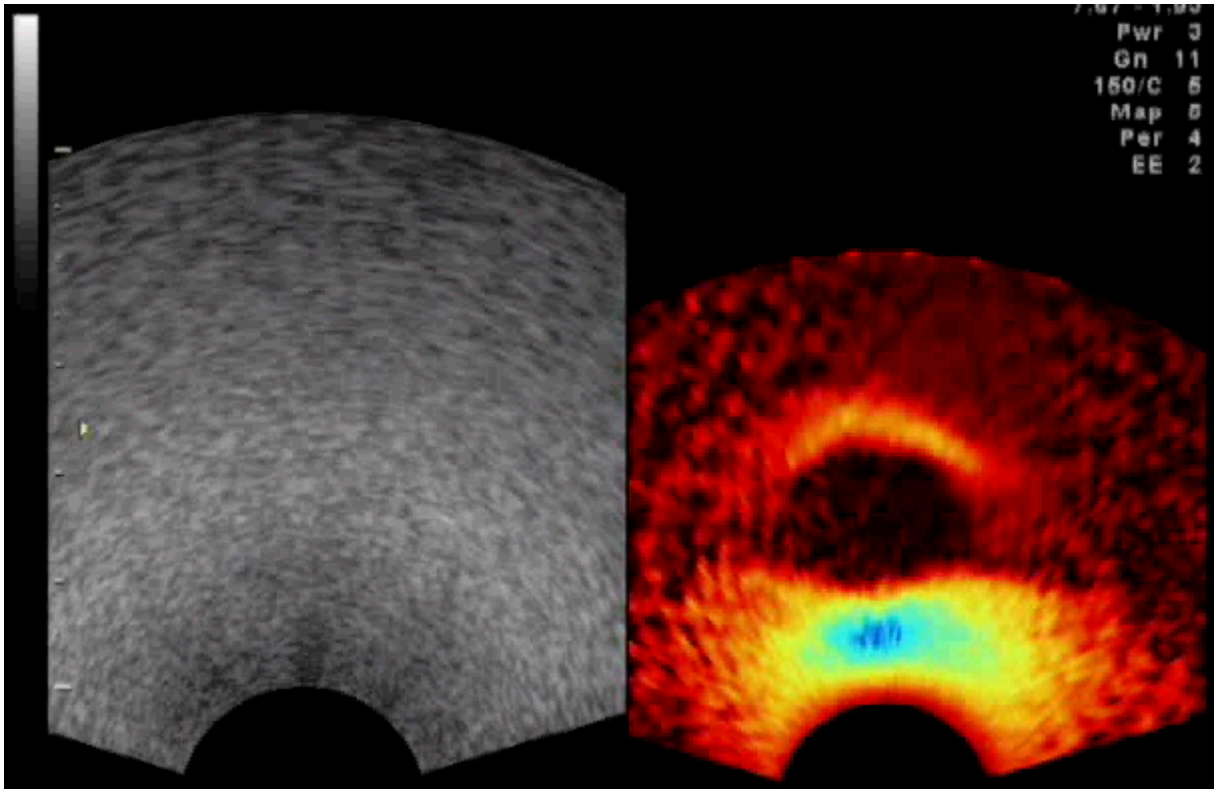

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Clinical Study on Prostate Imaging

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Prostate Study I - Real Time Strain Imaging

- Can *real time strain imaging* improve the early detection of prostate carcinoma?
- begin: May 2000, up to now approximately 260 patients

Prostate Study II - Real Time Strain Imaging

- Can *real time strain imaging* improve needle biopsy results?
- begin: April 2002, up to now approximately 56 patients

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Prostate Study I - Real Time Strain Imaging

- patients: all patients have prostate carcinoma diagnosed by needle biopsy, undergoing prostatectomy
- post-operative control: “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
- B-Mode: only **34%** of all the carcinoma could be recognized correctly using **B-Mode** imaging **alone**
- Strain Imaging: approximately **76%** of all carcinoma could be detected correctly (4 quadrant location and area >50%)

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Prostate Study II - Real Time Strain Imaging

- patients: suspect from either digital rectal examination (DRE) **and/or** PSA (blood) **and/or** transrectal ultrasound (TRUS), undergoing sextant needle biopsy
- post-operative control: "gold standard" needle biopsy result
- post operative biopsy results are compared to pre operation decisions
- 56 patients (preliminary results):
  - 17/20 (85%) of cancer patients recognized
  - 61% of needle specimen correctly classified

Patient in vivo

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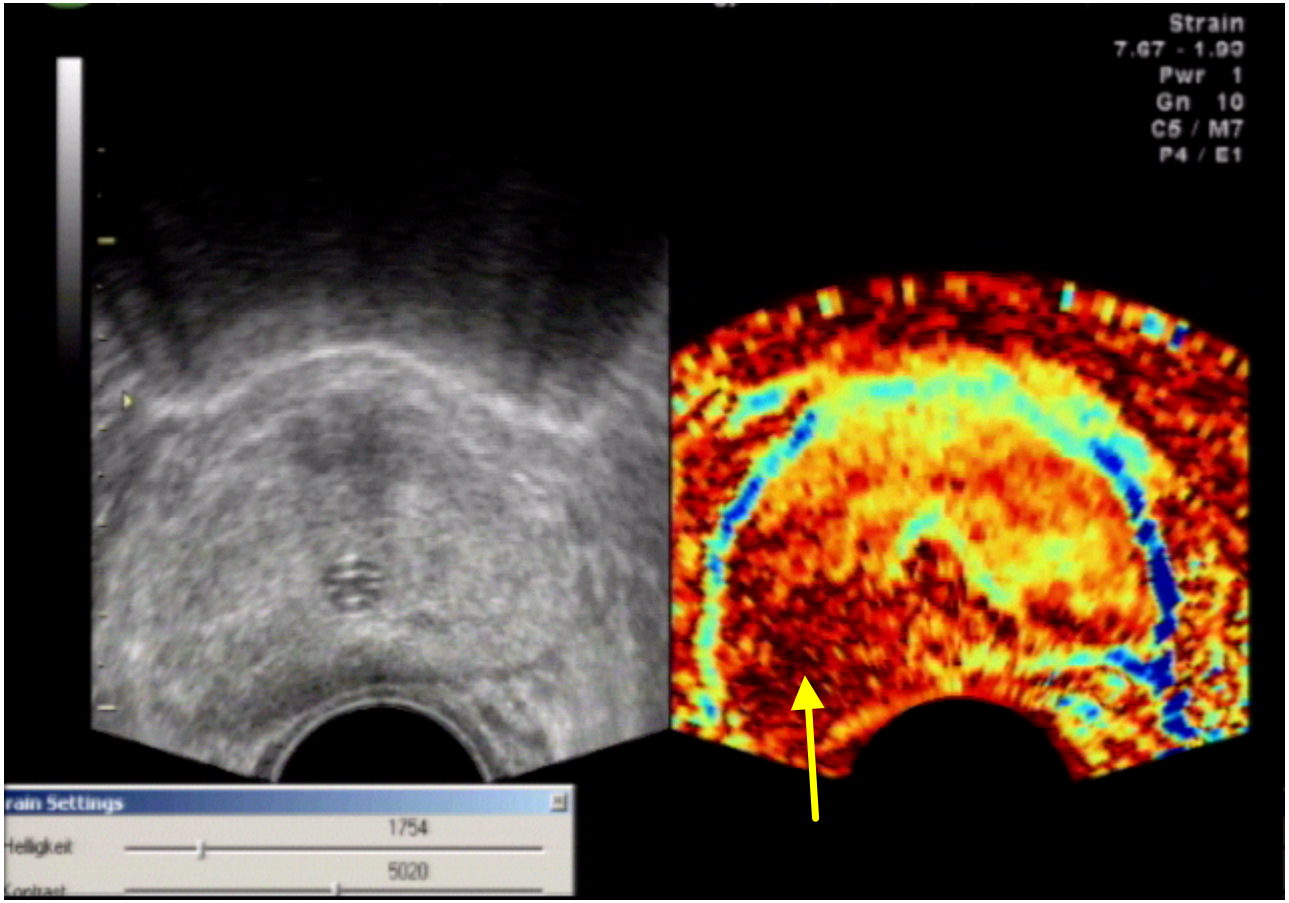

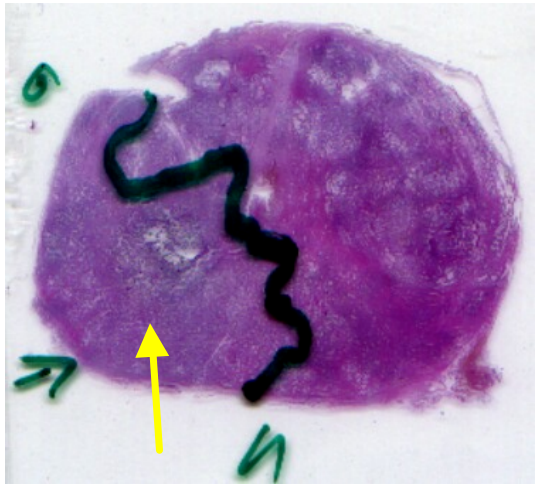

B-Mode Strain Image Histology

Patient in vivo

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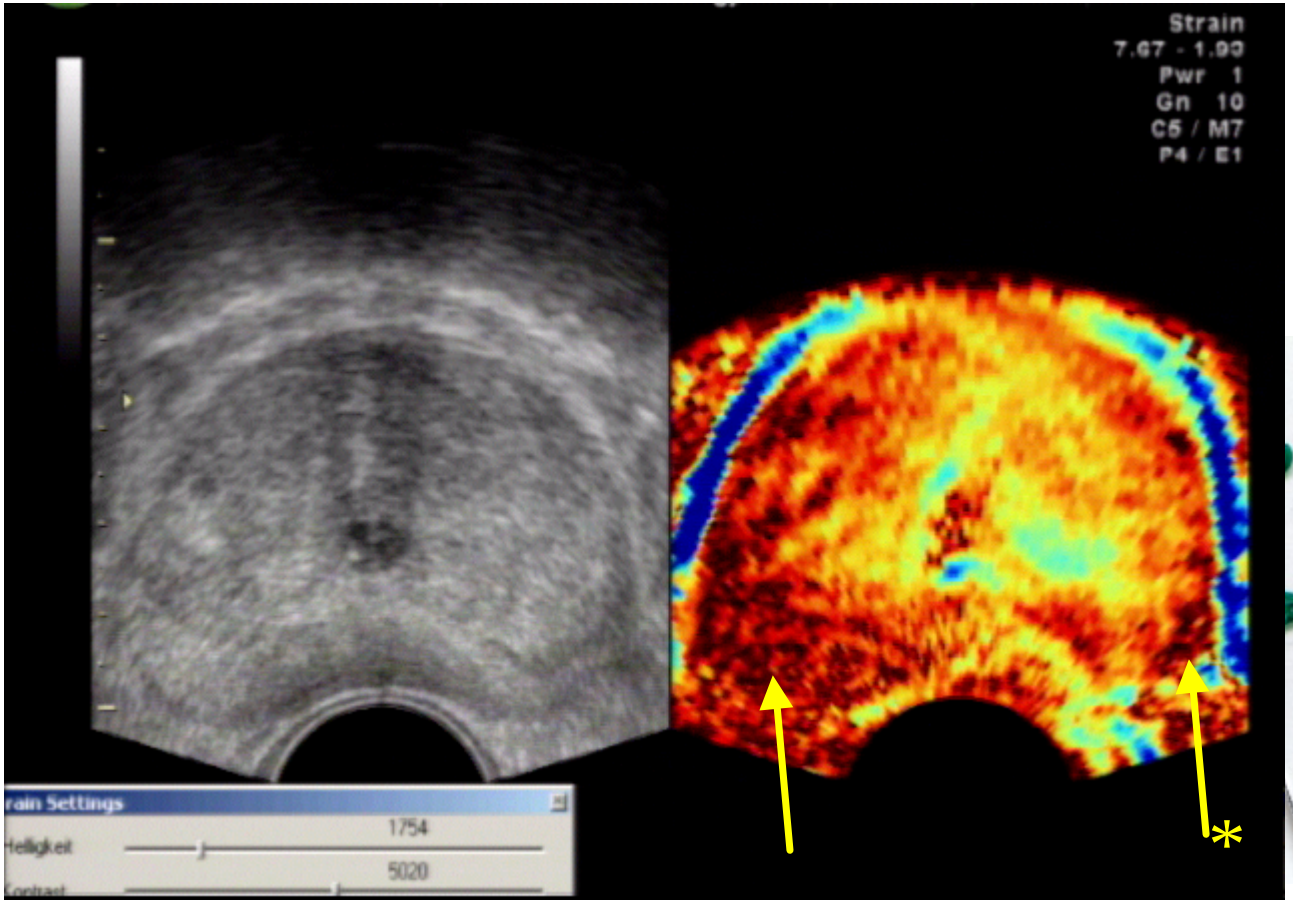
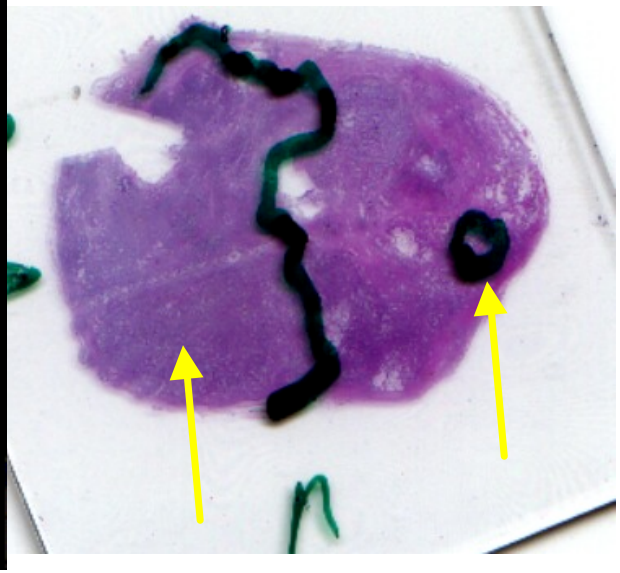


*post operative



B-Mode Strain Image Histology

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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

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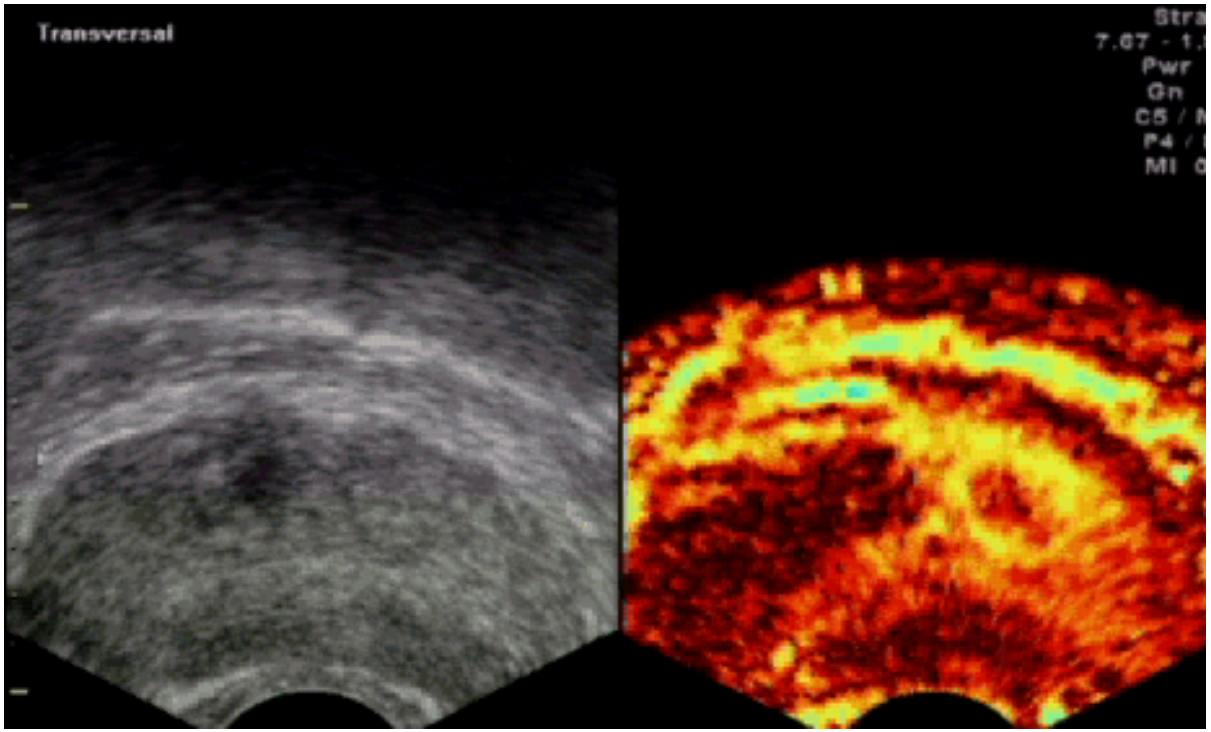

Patient in vivo - frame rate: 43 Hz longitudinal mode, biopsy mode

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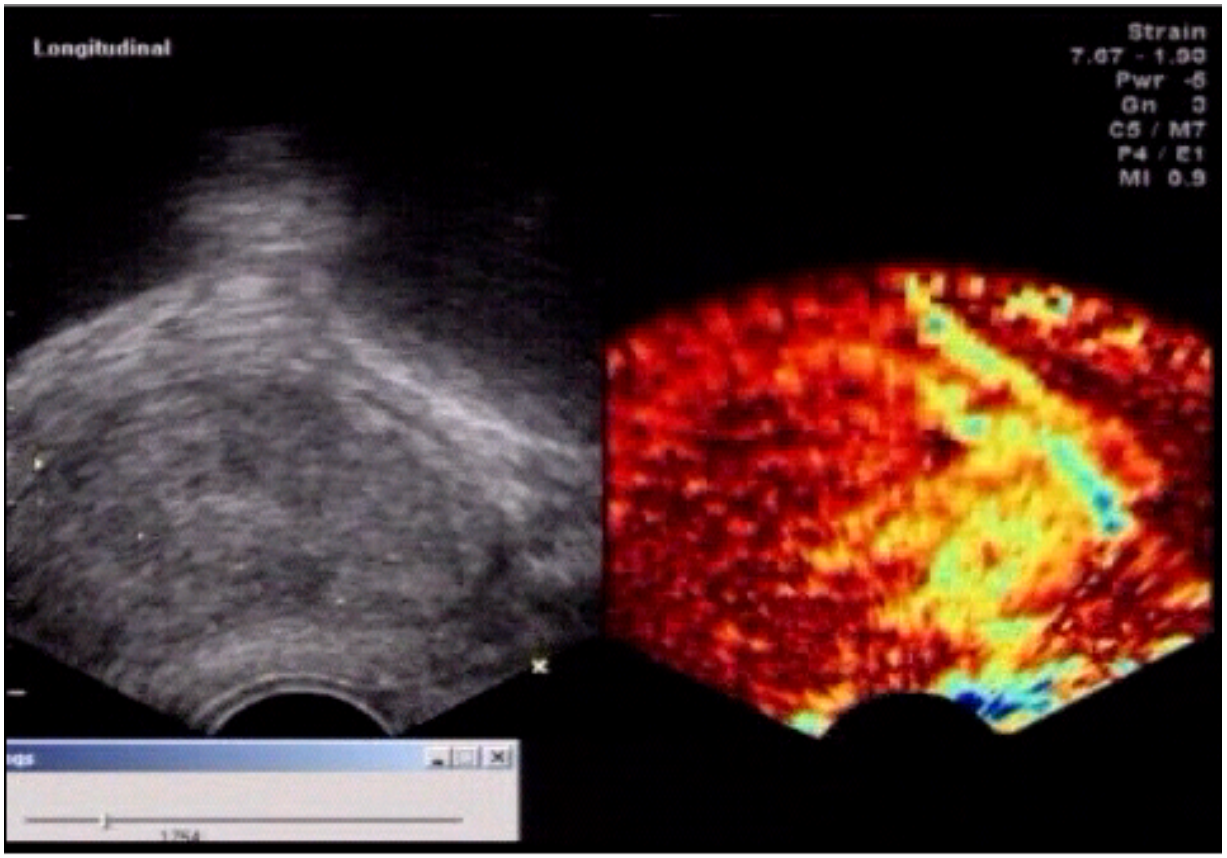

Conclusions

- 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
- Future work: application of real time strain imaging to the female breast