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Radial-Looking Endoscopic Probe based on Annular-Ring Transducer Arrangement for Optoacoustic and Ultrasound Imaging

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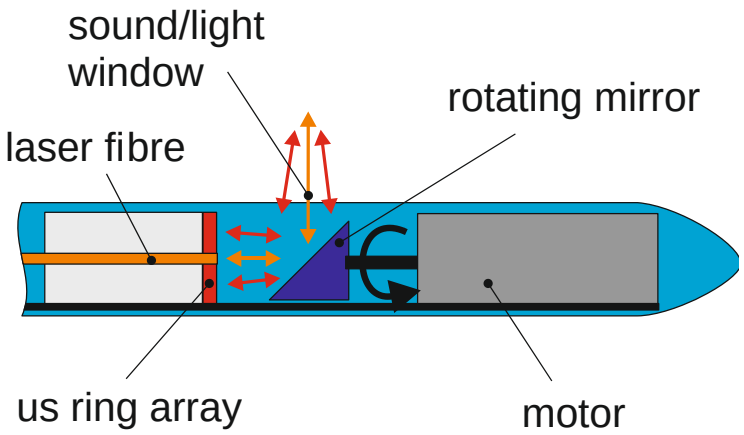
Motivation

- A plurality of ultrasound and optical catheter probes is commercially available:
  - Optical imaging is limited to the range of ballistic photons
  - Ultrasound often has poor contrast
- combination of ultrasound and optoacoustic sensing in a hybrid catheter probe
- Optimization of resolution by the use of an annular ring array (allowing dynamic transmit and receive focusing)

Probe Concept

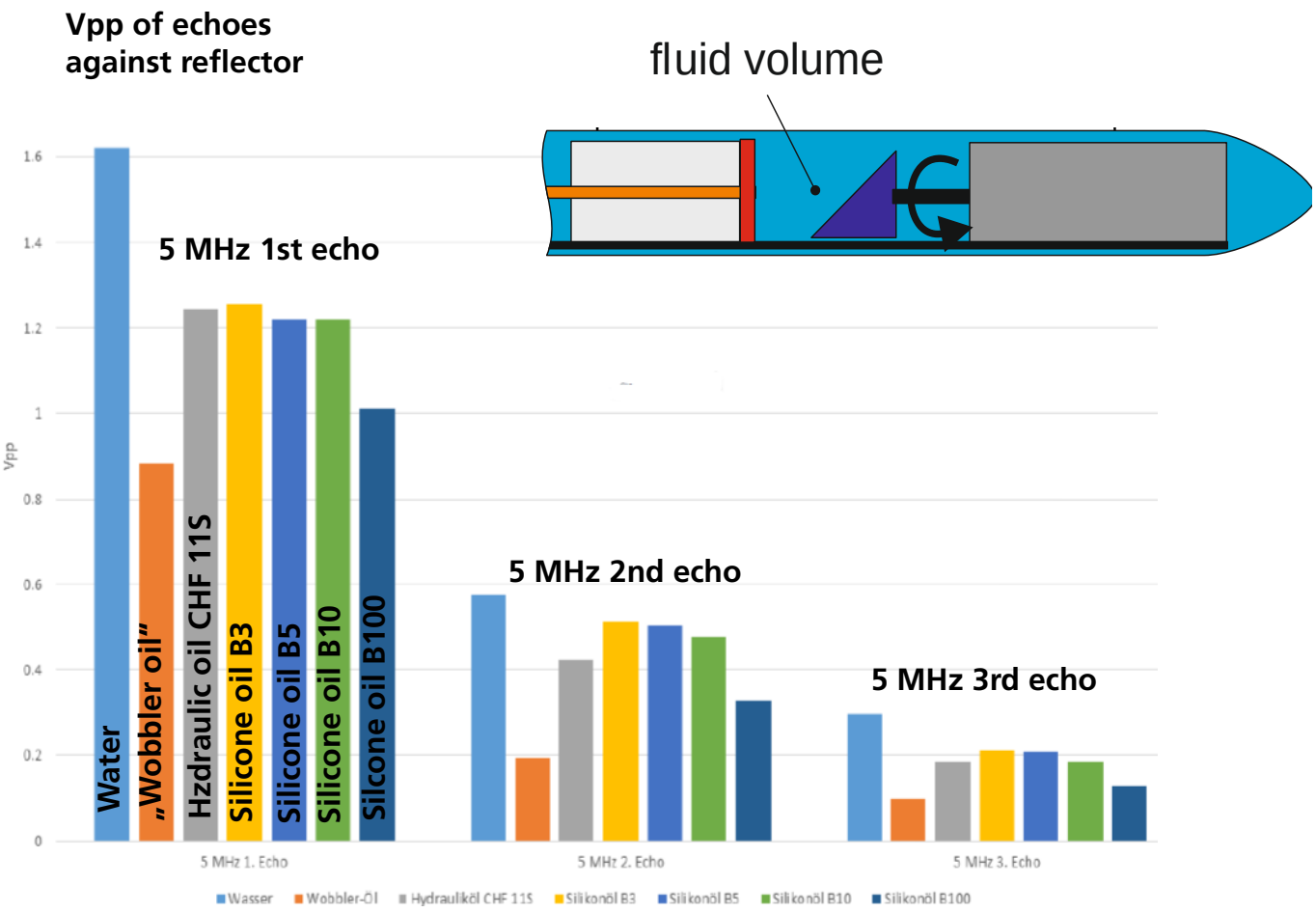
- Transducer transmits sound in the direction of the probe axis
- Mirror reflects sound in radial direction
- Mirror reflects laser pulse in optoacoustic mode



- Based on the specifications of the mechanical components and the electronic system, an image rate of 8 Hz is possible

Probe Concept

- Preliminary study for identification of coupling medium
- Silicon oil chosen because of long-term stability and acoustic damping behaviour



Room between transducer and mirror filled with silicone oil B5 (viscosity 5 cSt)

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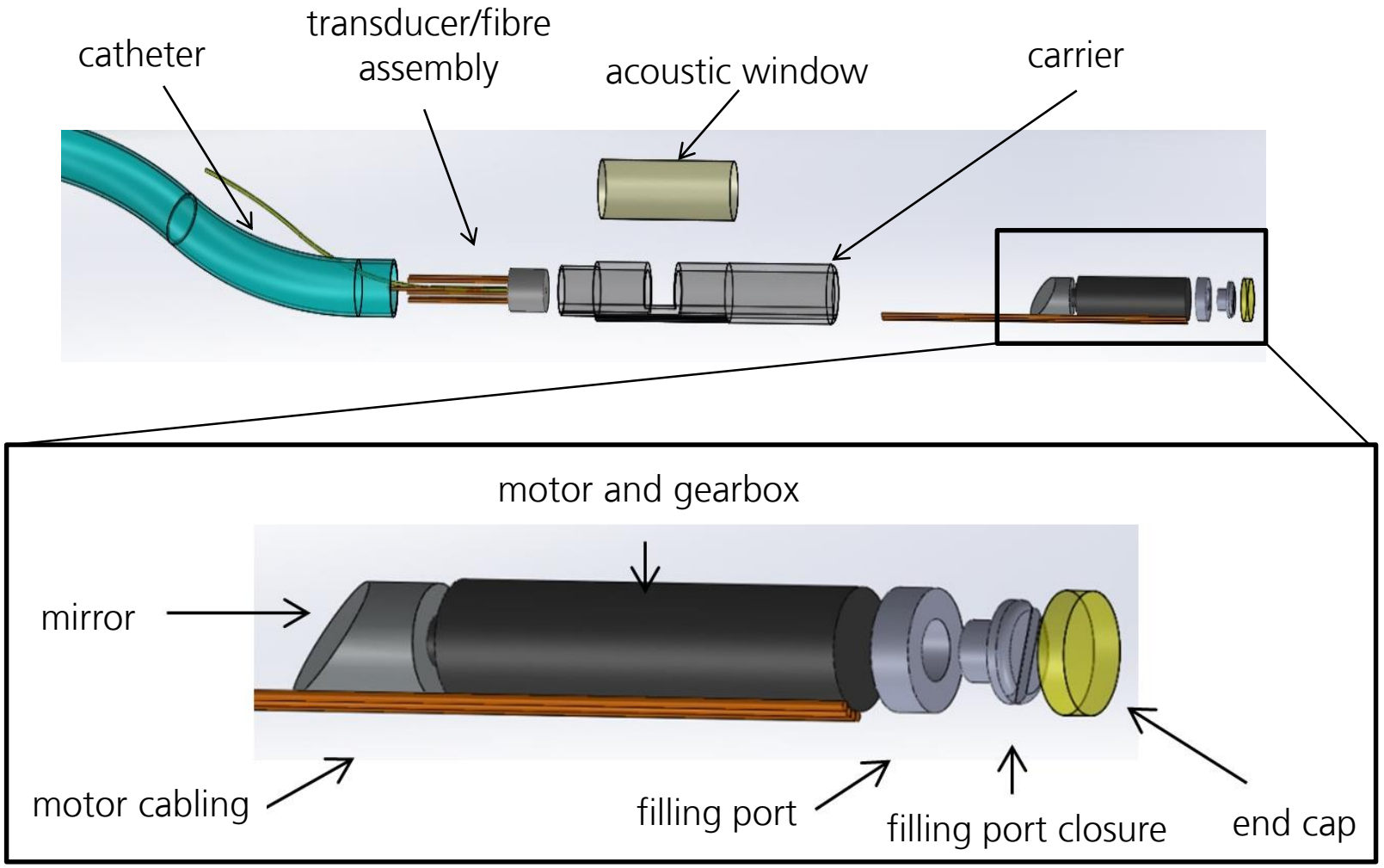
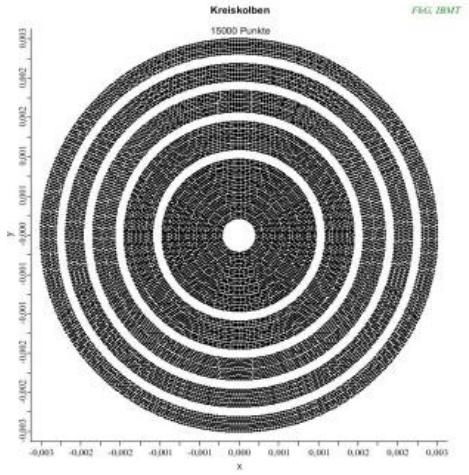
Probe Concept (detailed)

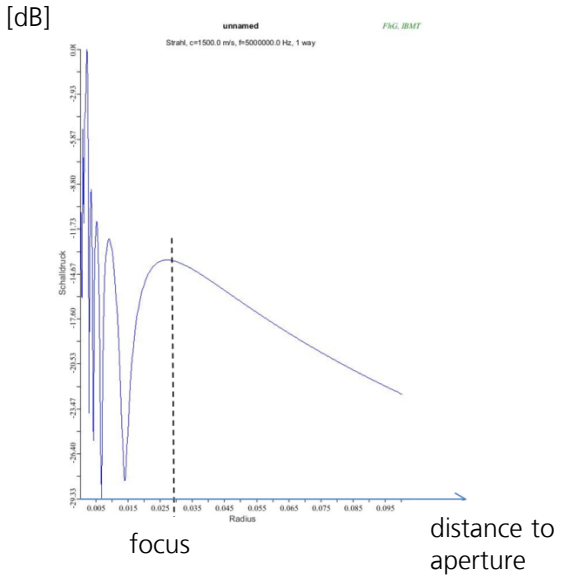


Beam Pattern Simulation

- Simulation of probe behaviour (sound field) using IBMT´s simulation tool SCALP
- Based on point source synthesis
- Each ring element was discretized in 3000 sources

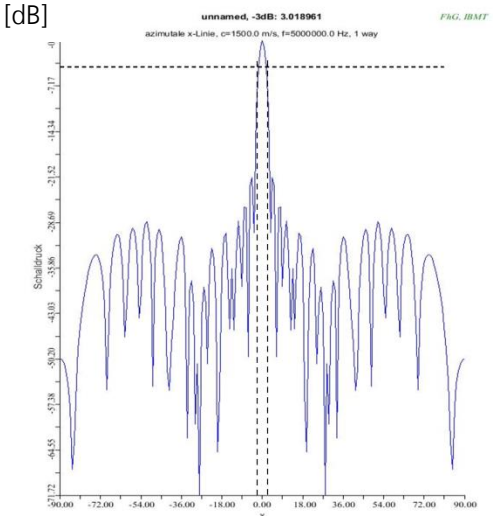


sound pressure on acoustic axis



natural focus: ca. 28 mm

sound pressure azimuthal x-line



natural opening angle: ~3.0°

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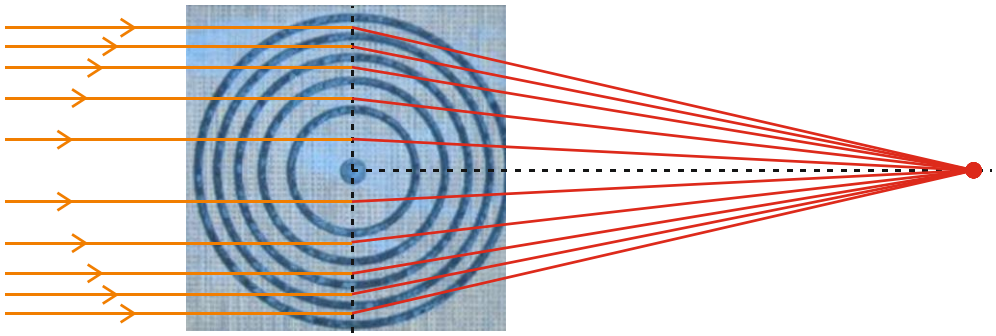
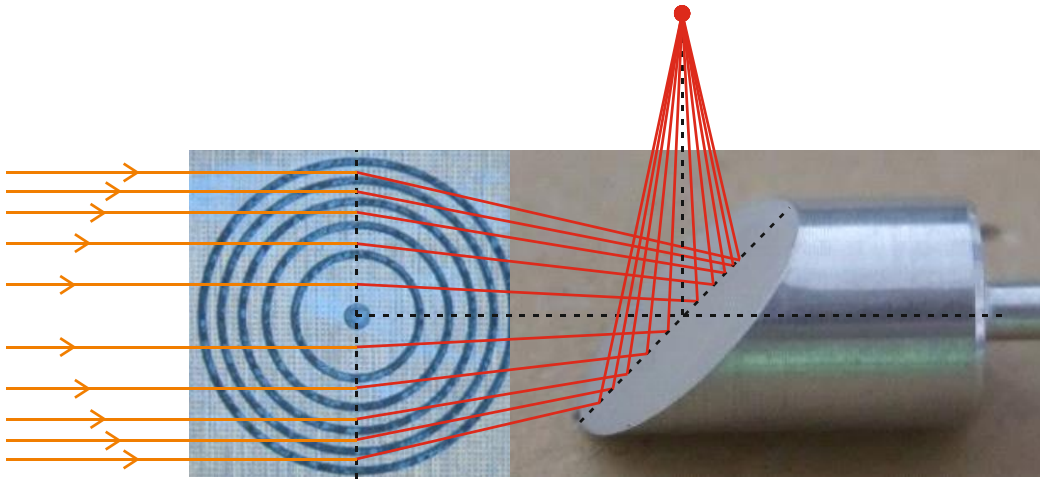
Active Material

- 1-3 piezo composite
- based on Motorola 3230HD:
  - “Dice and Fill” process
  - pitch 140 µm
  - dicing gap 50 µm

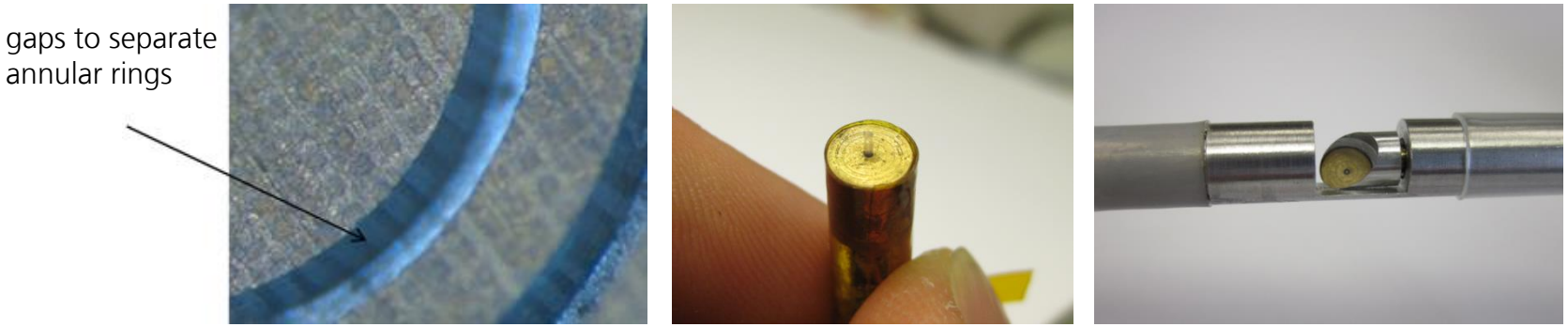


- center frequency 5 MHz
- center hole for laser fibre 0.5 mm
- 5 rings
- 3,5 mm^2 area per ring (constant)
- gap size 0,15 mm (between rings)



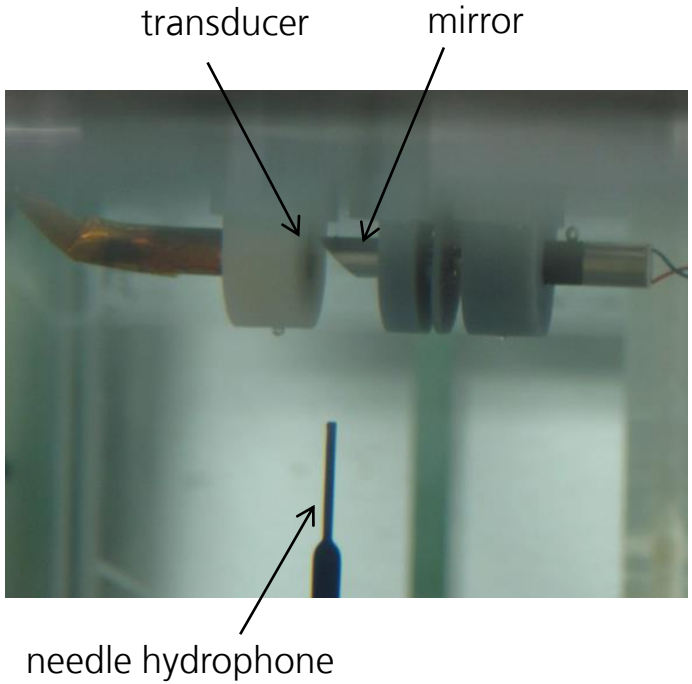
Realization

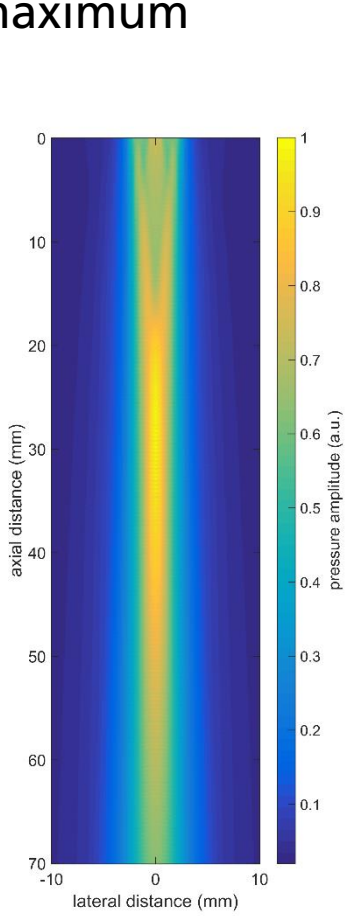
- Realization of piezocomposite starting with bulk material
- Structuring of composite to annular ring structure (milling process)
- Assemblage of acoustic block with laser fibre
- Assemblage of mirror and motor group
- Assemblage of final catheter probe and acoustic/laser window



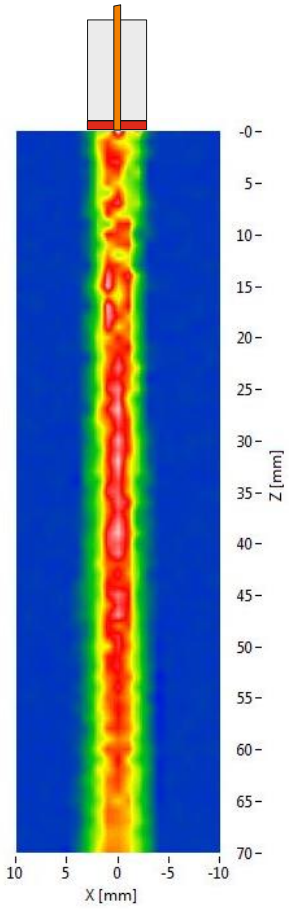
Measured Beam Pattern

- measurement of soundbeam pattern with hydrophone on 3D-scanner
- XZ-pattern in dB-scale to maximum value
- slightly higher opening angle with mirror

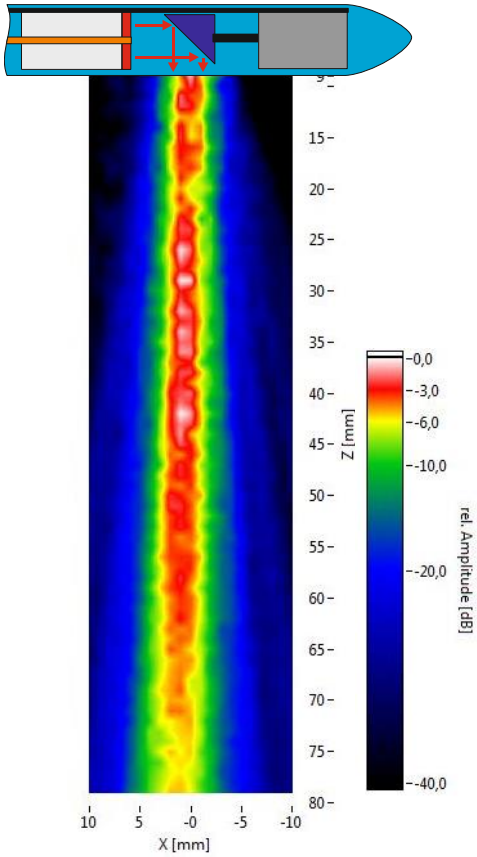




Simulated



exp. without mirror



exp. with mirror

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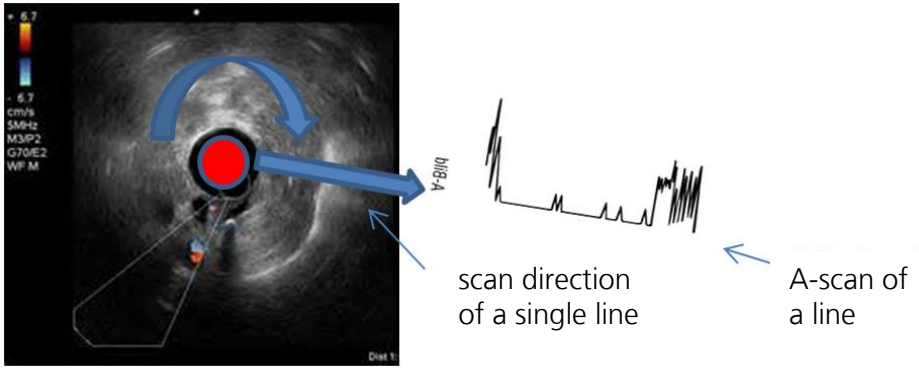
System Concept

- DiPhAS-Digital-Phased-Array-System (existing system) was modified to drive the radial looking probe
- The motor controller reports about the stepping process via a digital pin to trigger scanning process of DiPhAS
- Actual angle information is transferred to DiPhAS
- Scan lines are displayed as circular 2D-information



[Gastroenterologie, 2014]

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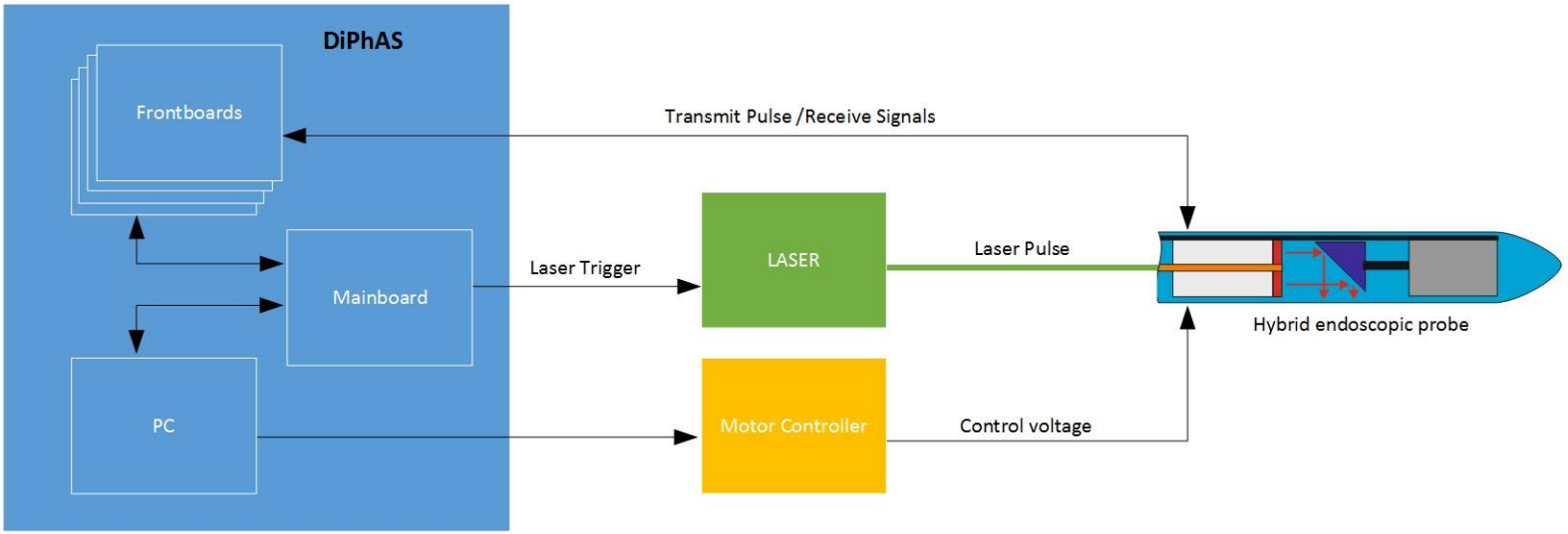
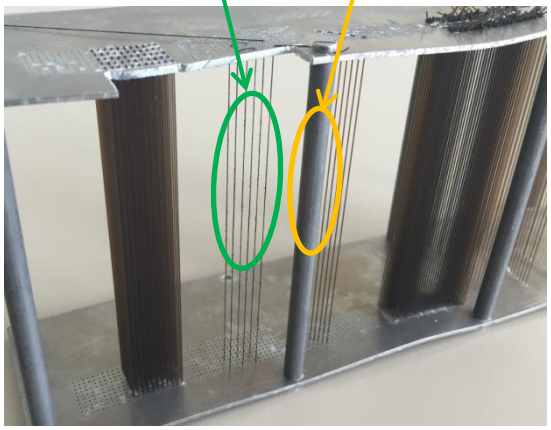
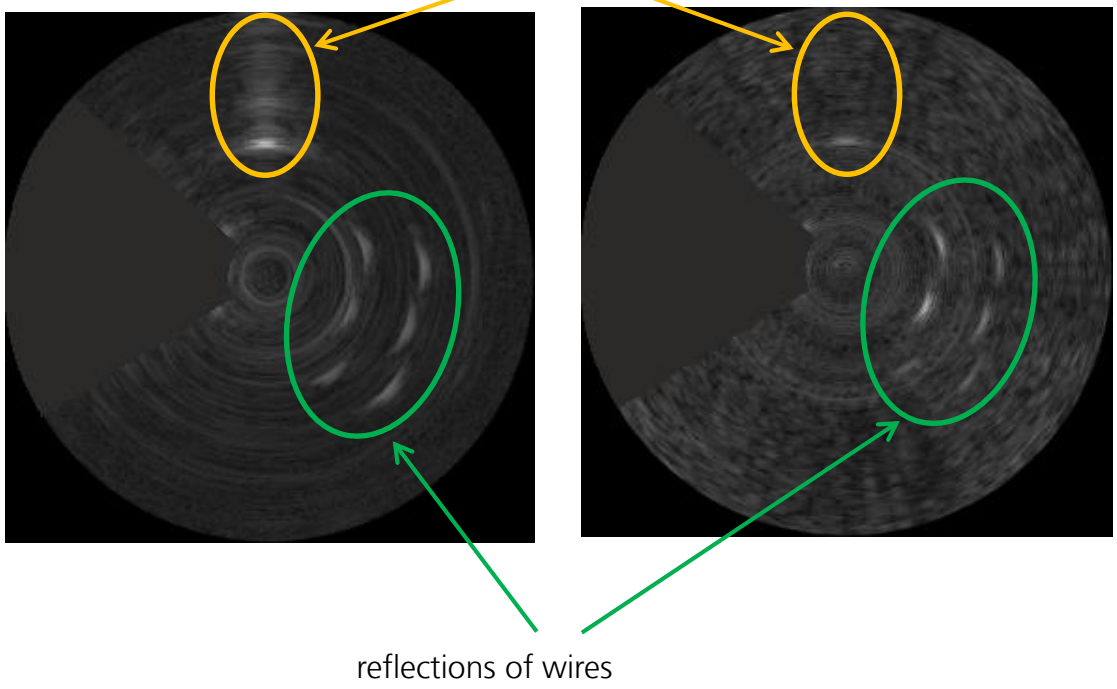


First Measurement Results



wire phantom
(wire distance 5 mm)

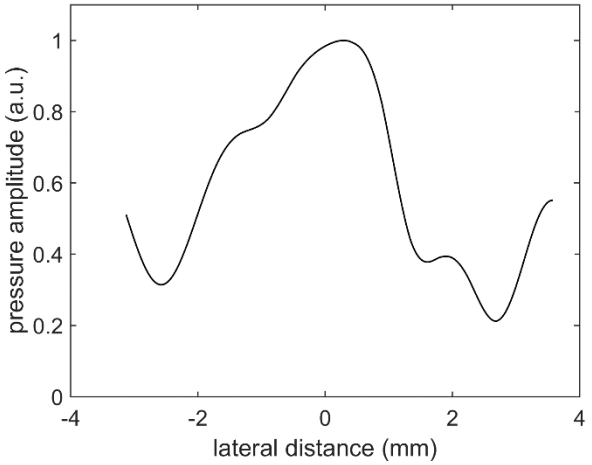
acoustic measurement **optoacoustic measurement**

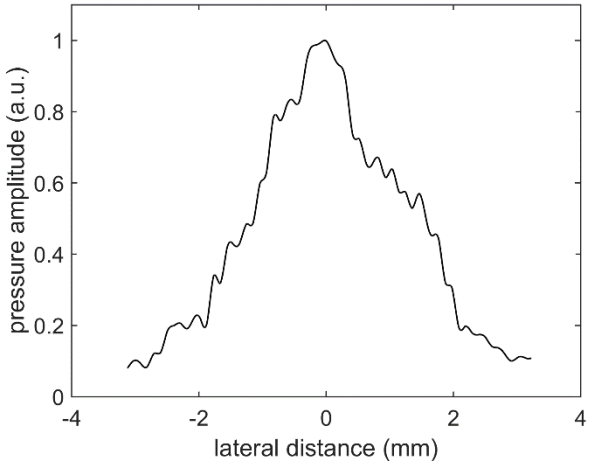


First Measurement Results

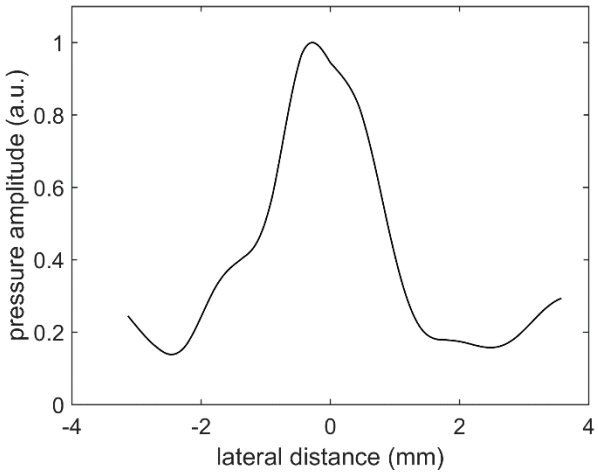
OA **US**

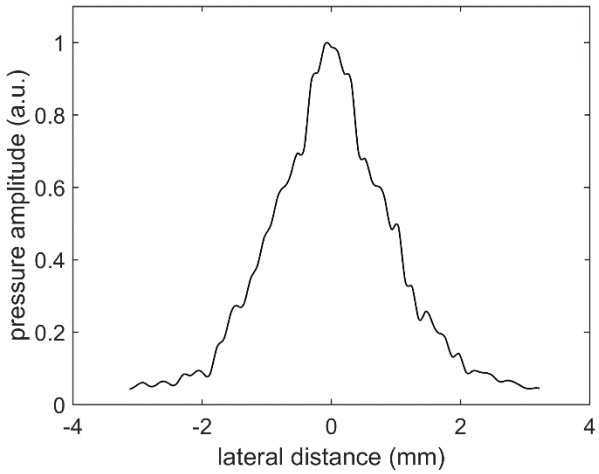
RAW





BEAMFORMED





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Summary and Outlook

- First test sample of radially looking hybrid US/OA probe was developed
- Early testing in phantom experiments:
  - Influence of mirror on sound field geometry is negligible
  - Improvement of lateral resolution from 2,7 mm to 1,8 mm and from 3,3 mm to 1,9 mm by means of beamforming in US and OA mode respectively
- Next steps:
  - Further phantom experiments
  - Redesign for optimization of probe dimensions
  - Increase of resolution (higher frequency, more annular elements for enhanced beamforming)