

# **WOLAXIM –**

## **DESIGN OF A ROTATING PHASED ARRAY SYSTEM FOR THE INSPECTION OF HOLLOW AXLES**

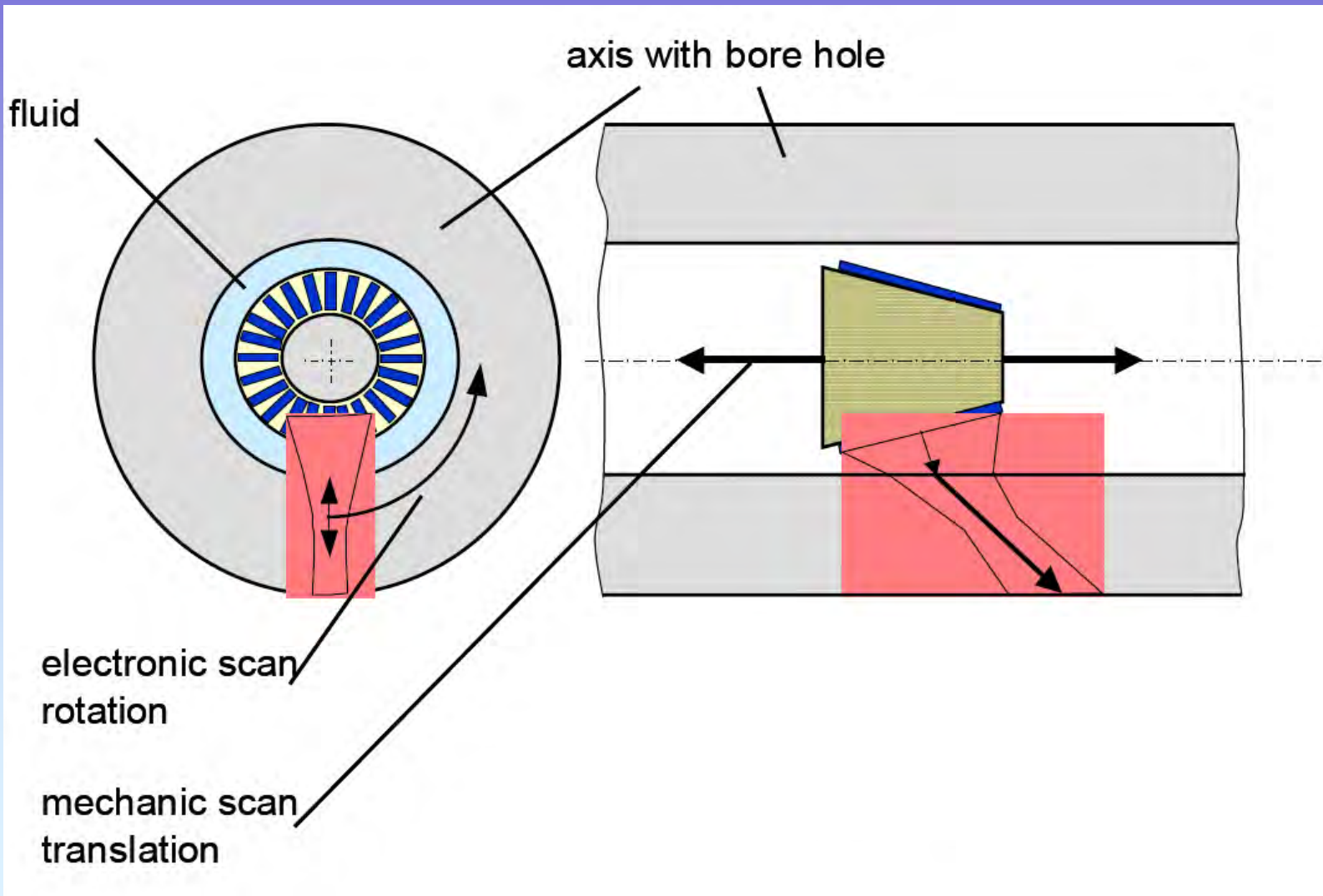
**THOMAS HECKEL, UWE VOELZ, MARC KREUTZBRUCK**

**Bundesanstalt für Materialforschung und -prüfung, BAM Berlin**

Fachgruppe VIII.4, Akustische und Elektromagnetische Verfahren



No manual rotation, Fast scanning,  
High sensitivity, 100% inspection



**Array3dim 4.8**      **Arraycalculus 3D : Eingabedialog**

Datei   Programmfunktion   Extras

ElmNr.   Verz [ns]   Wichtung

1	0	1
2	286	1
3	479	1
4	575	1
5	575	1
6	479	1
7	286	1
8	0	1
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	0	0
15	0	0
16	0	0

**Prüfkopf**

Frequenz [MHz]     EILänge Am [mm]

Schwenkwinkel [°]     ges. Breite Bm [mm]

Keilwinkel [°]     Elmbreith [mm]

Pk Drehwkl. [°]     Lücken [mm]

SchwDrehwkl. [°]     C Keil [m/s]

Vorlaufstrecke [mm]     Dämpfung [dB/m] für 2 MHz

monochromatisch

zyl. Schwinger     Long-Welle (sonst trans)

ellip. SchwElem

Kegellaray  kleiner KR Radius  großer

Mittenradius [mm]     Neigungswkl. [°]

Elemente am Umfang     SchwKippwkl. [°]

Versch. SAPunkt(Schwenkw.)

**Fokussierung**

Fokussfaktor fak/No    

Eingabe manuell

Zahl der Elem.

dT in 1 ns Schritten

dPhase Integration Teile von Lambda

**Aufpunkte, Darstellung**

Lage der Aufpunktlinie  Achse  Polar

Abstand

Nutation

Präzession            

Drehung     Anf [°]    End [°]    Anzahl

radial um Achse

**Material, Bauteil**

C trans [m/s]

C long [m/s]

Dämpfung [dB/m] für 2 MHz

Krümmungsradius [mm]      zyl. Bauteil

Ursprungsdatensatz Variante2.Par

xyzAnsichten

**xyz Ansichten**

Position

Vergößerung

**Schwinger**

18°     Beta     42.8°

0°     Kopfdrehung     0°

0°     Schwingerdrehung     0°

100mm     KR Radius

Normalenvektoren

PhiG = .04  
Alpha = 42.8  
Beta = 18

**Aufpunktlinie**

0°     Nutation     0°

90°     Präzession     90°

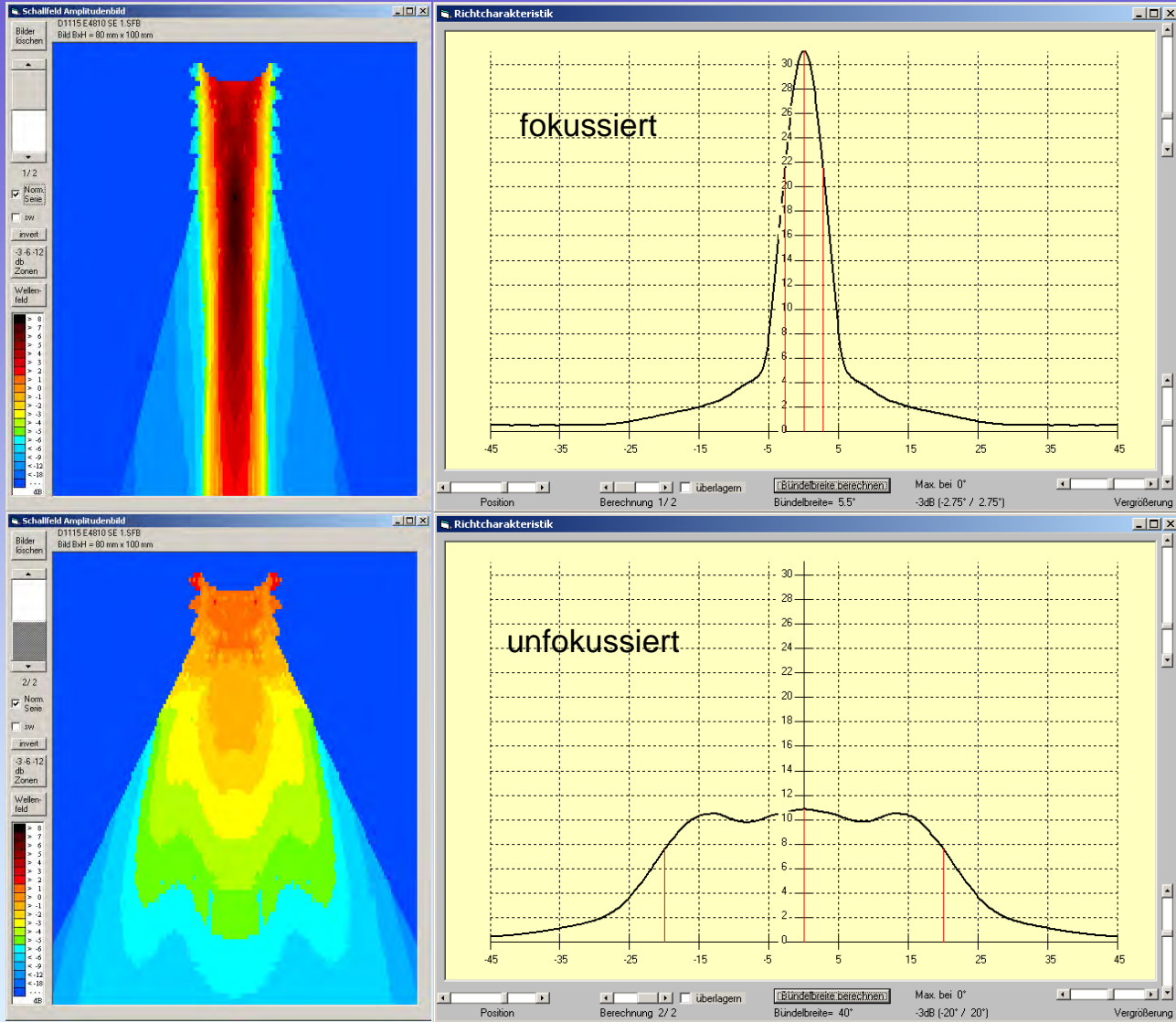
Drehung     AufPkt bei 0°

FokPkt

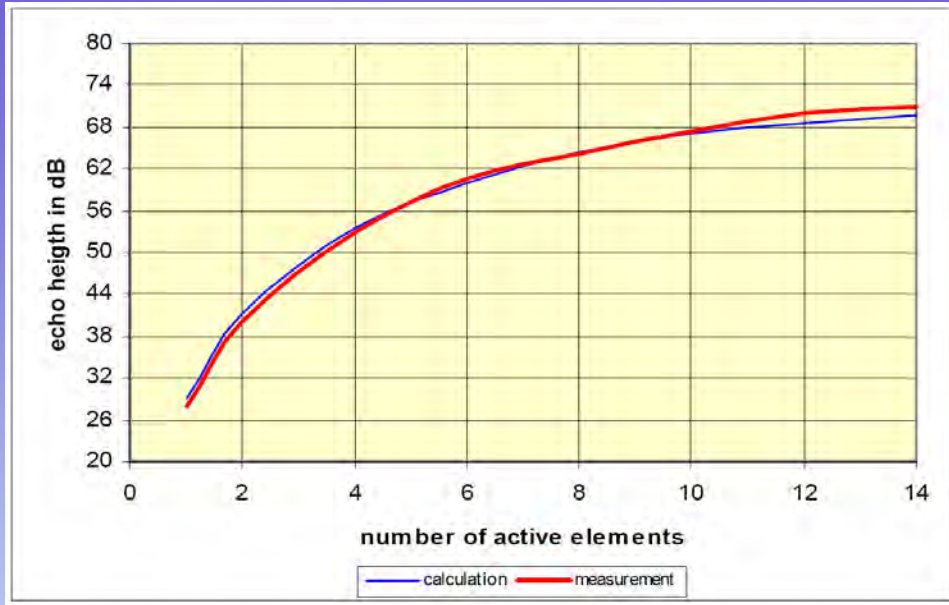
gebr. Stahl zeichnen

geom. Hauptstrahl

Modelling parameters, left: numerical, right: geometric



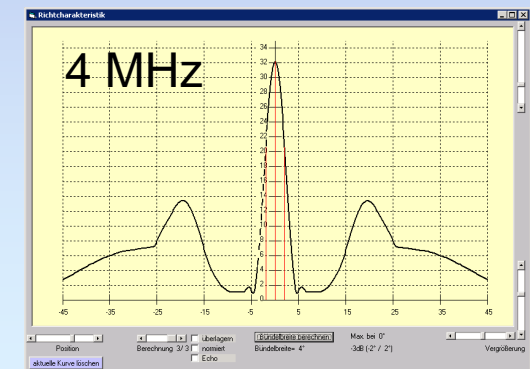
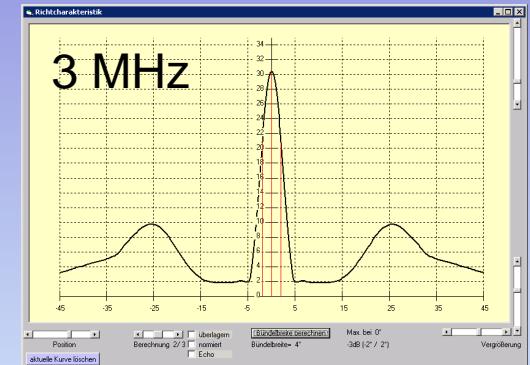
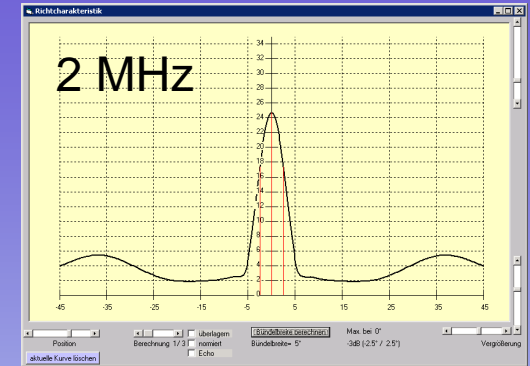
Modelling of the circumferential sound field, top: focused, bottom: non focused, left: sound field with color coded amplitudes, right: circumferential directivity pattern

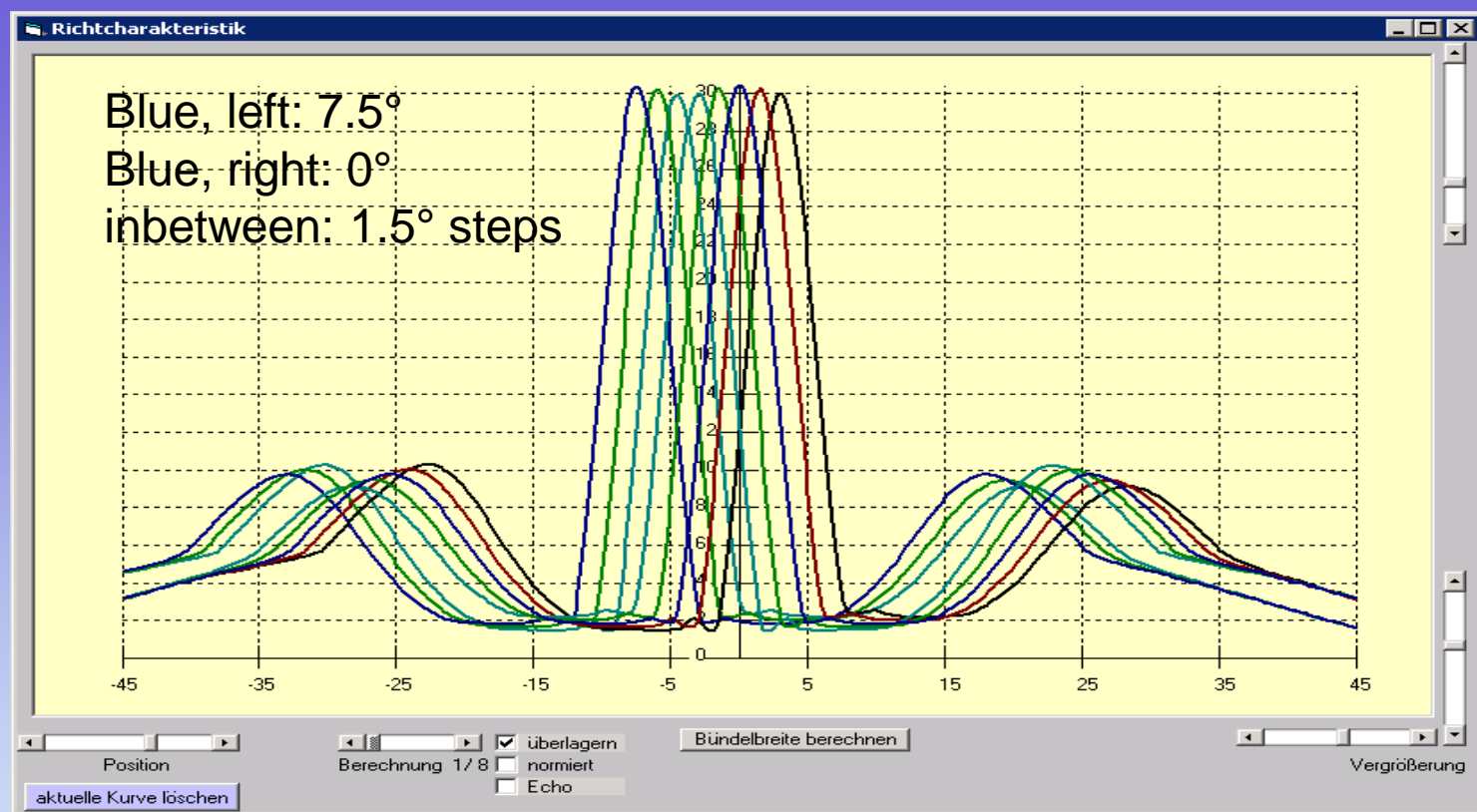


Reasonable numbers of elements in the PA system: 8

No significant increase in SNR for larger amount of elements simultaneously operated

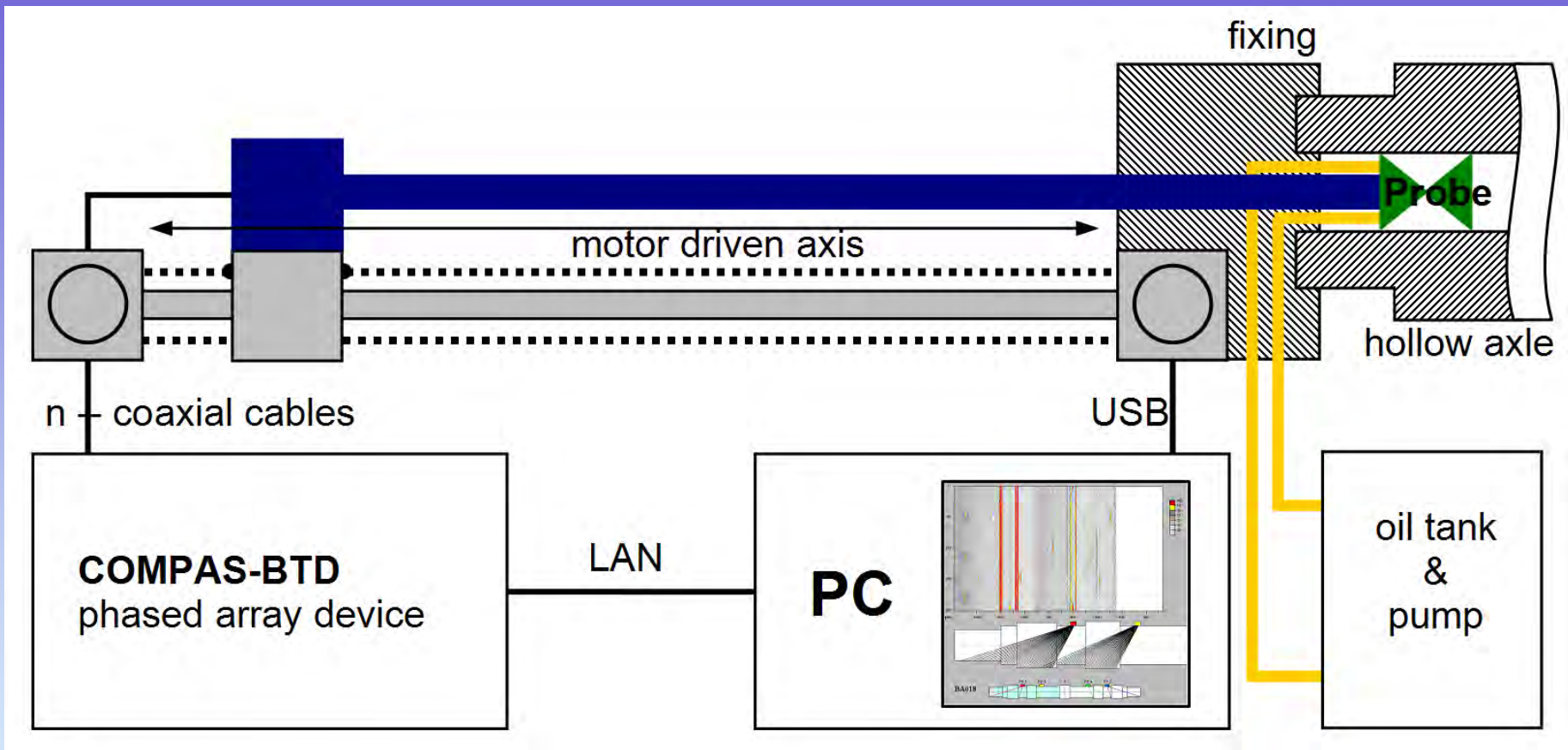
Grating lobes are tolerable for  $f = 3$  MHz (see fig. Right)



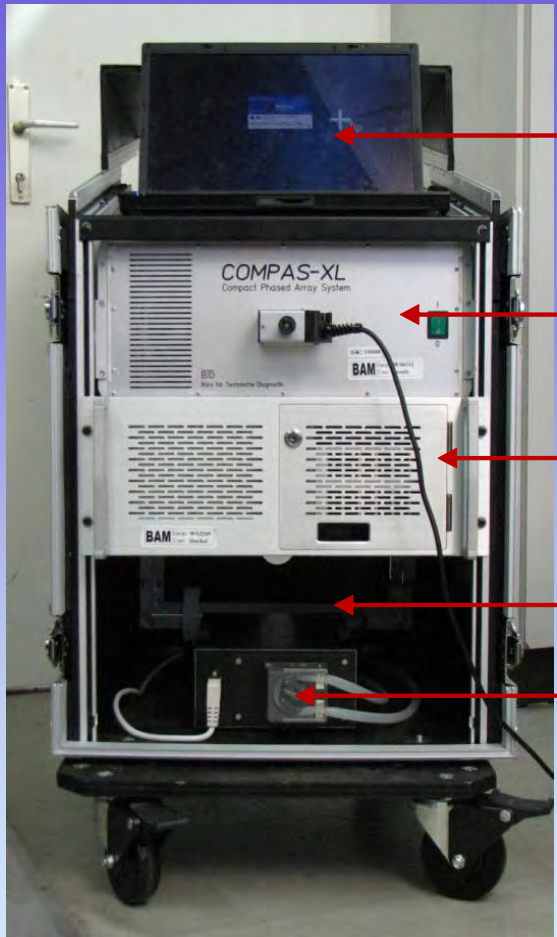


- 48 elements / cone corresponds to 7.5°/element along the circumferential
- Resolution of better 2° is required
- Therefore it is necessary to steer the sound field electronically in 1.5° steps by using the Phased Array
- Delay times for each single element to steer the sound field are calculated
- We observe a constant amplitude for different steering angles



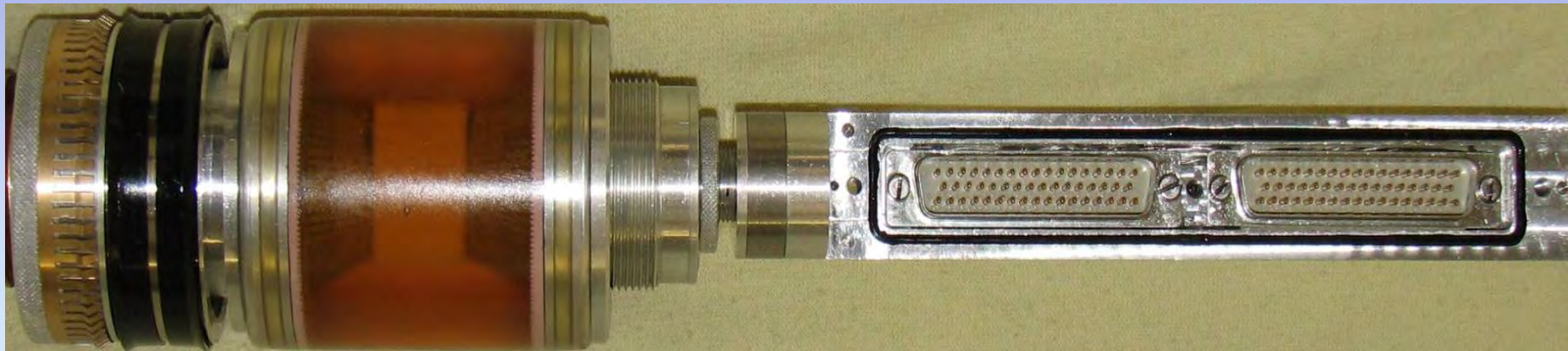
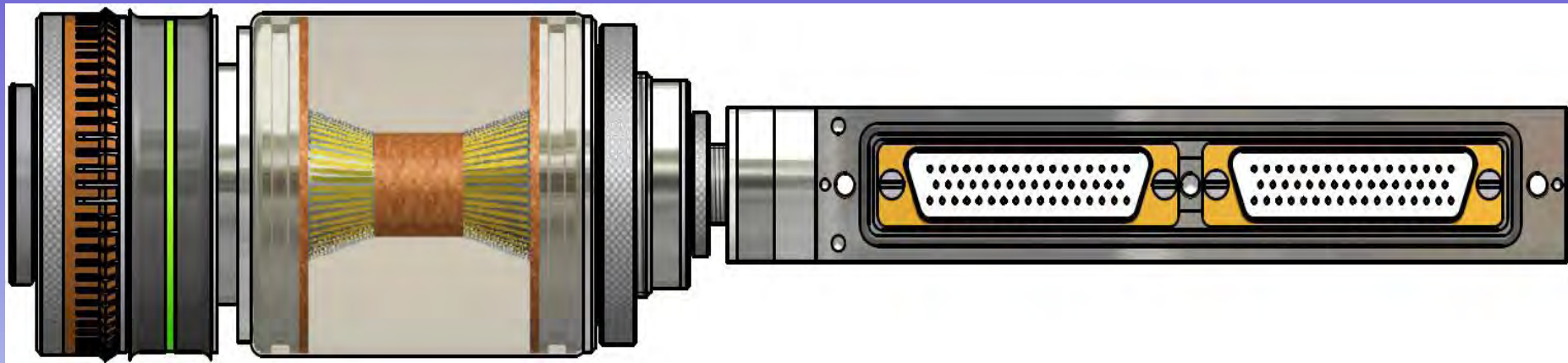


# Concept of the ultrasonic testing system



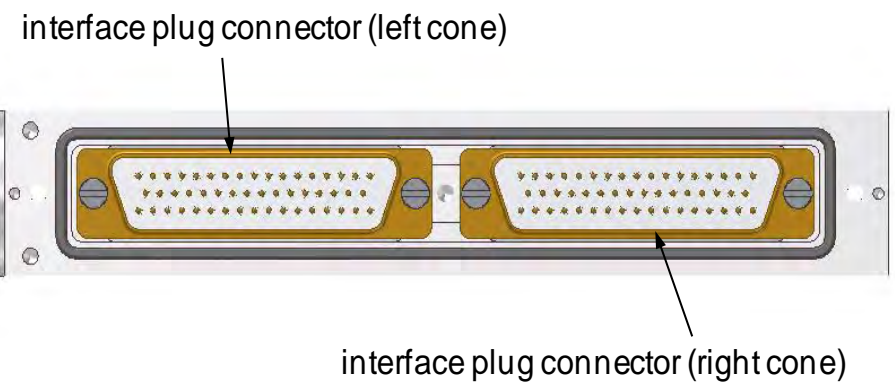
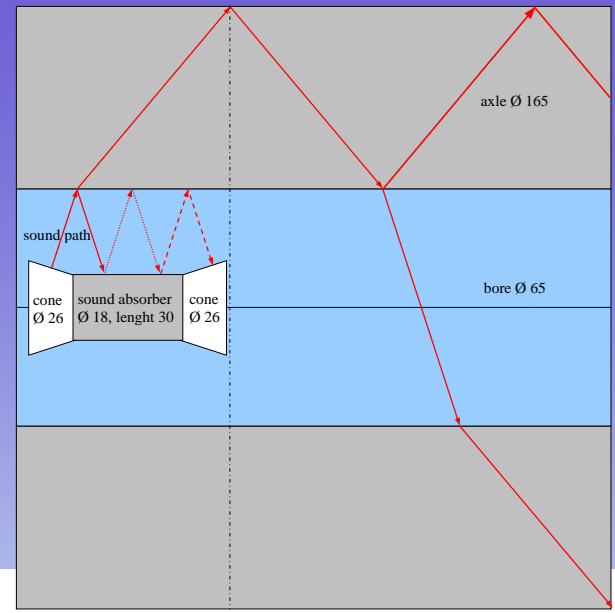
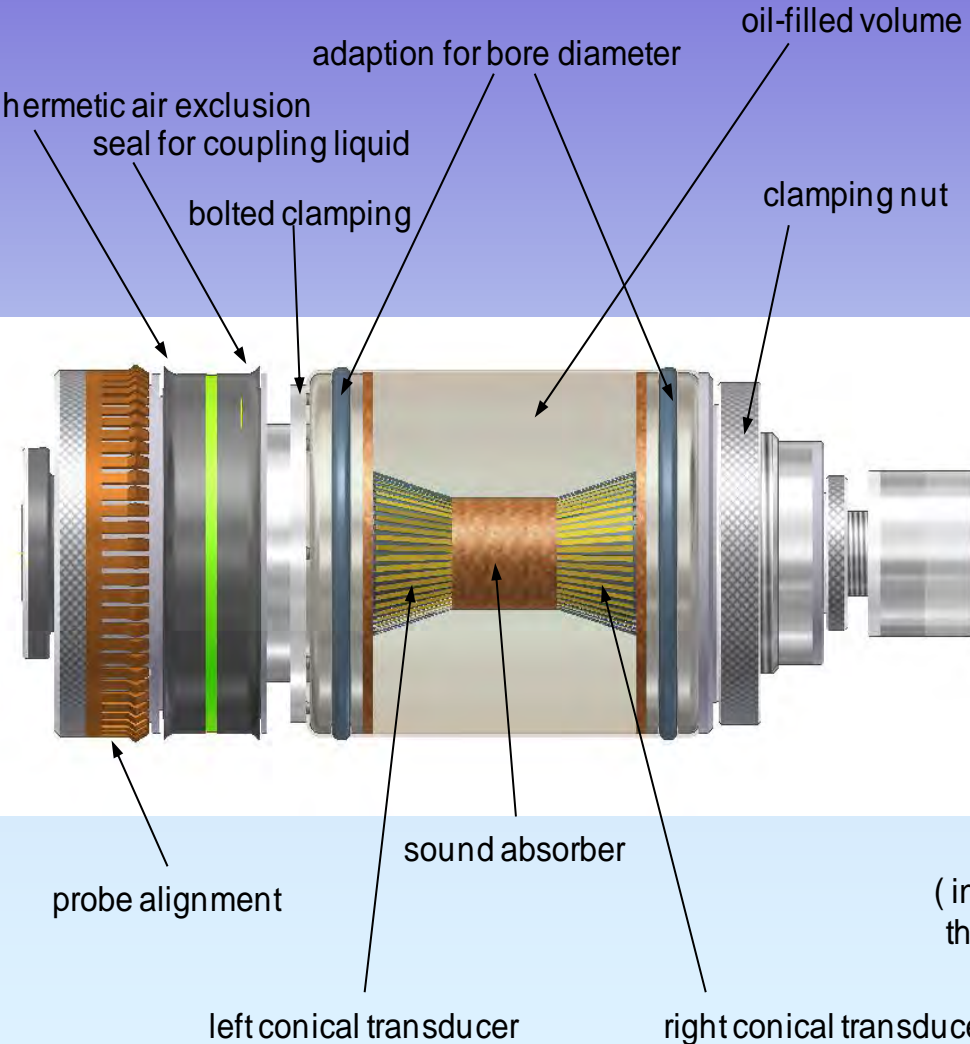
- PC with user interface
- COMPAS device
- motor control device
- oil tank
- oil pump



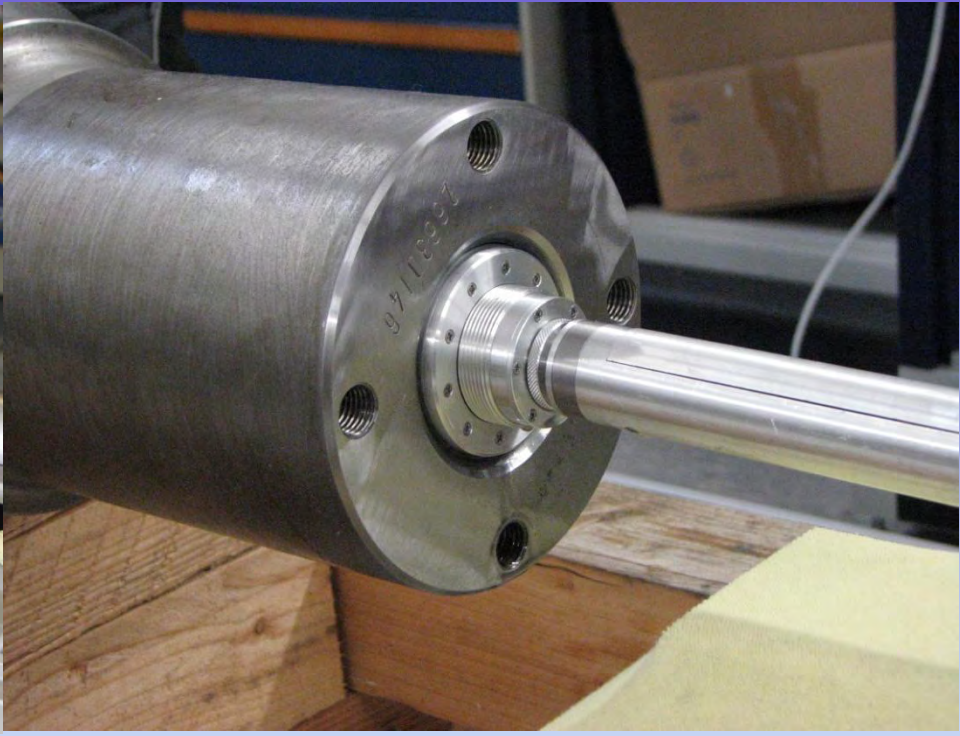
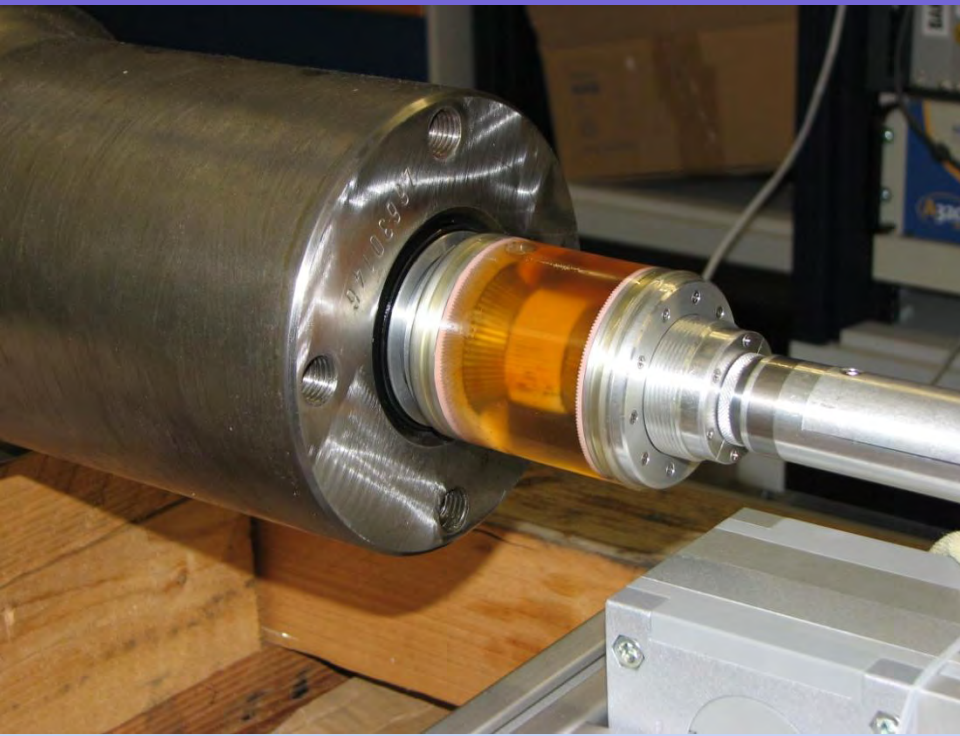


Phased array probe; top: design drawing; bottom: picture

# Concept of the ultrasonic testing system – Transducer system



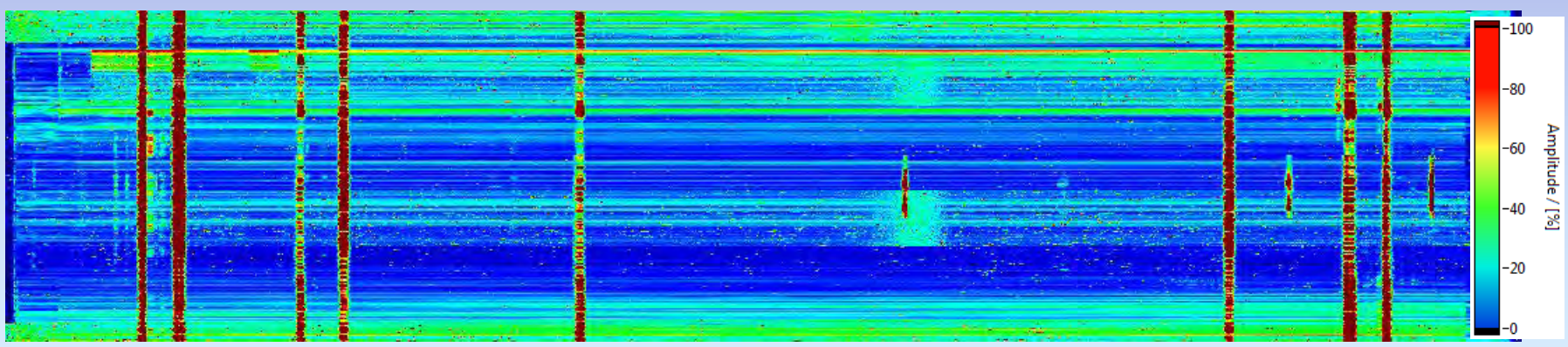
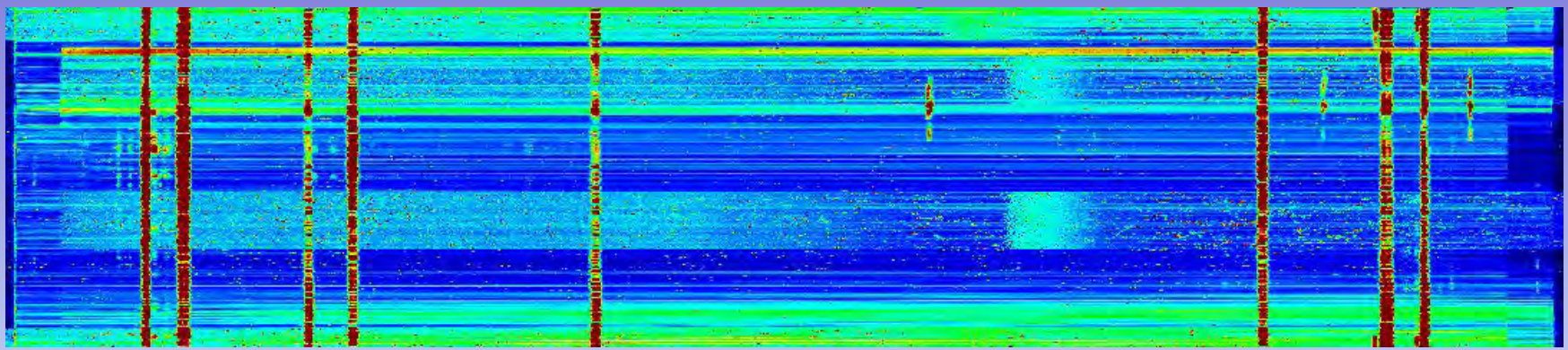
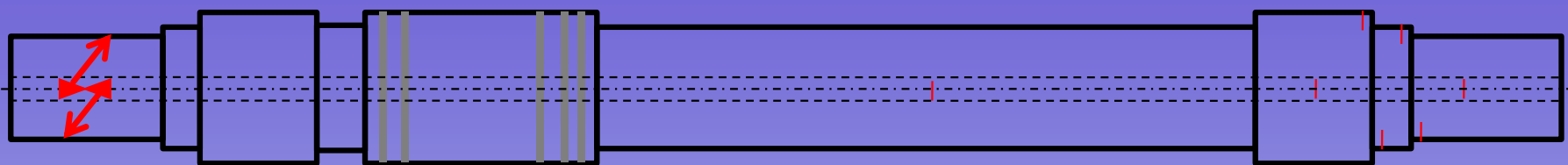
( including a pressure-balance system for a counterforce lower than 4 Newton by air-pressure in a hermetically sealed bore )



Pictures of the probe inside the bore;  
left: before inserting;  
right: starting position for the inspection procedure

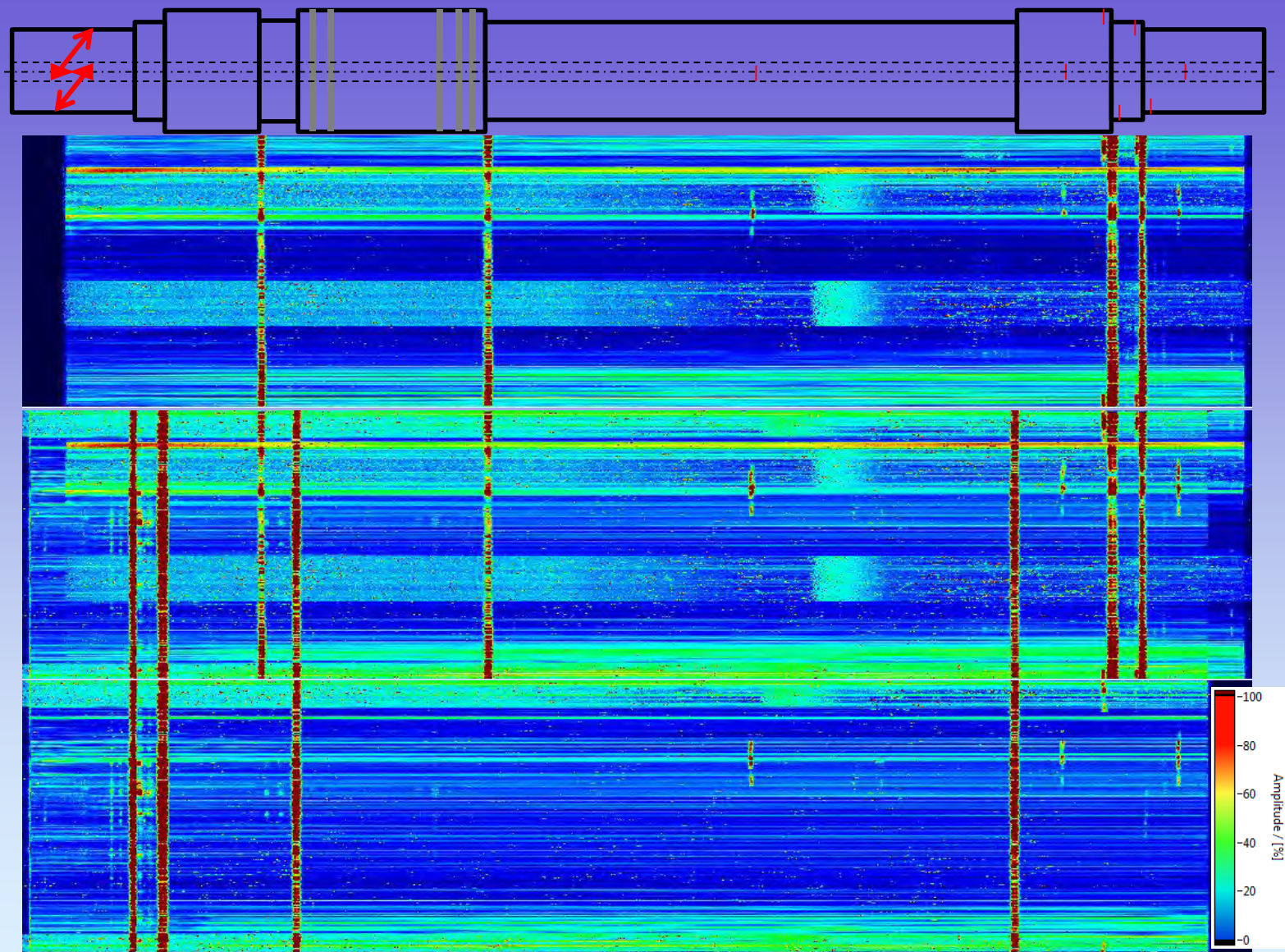




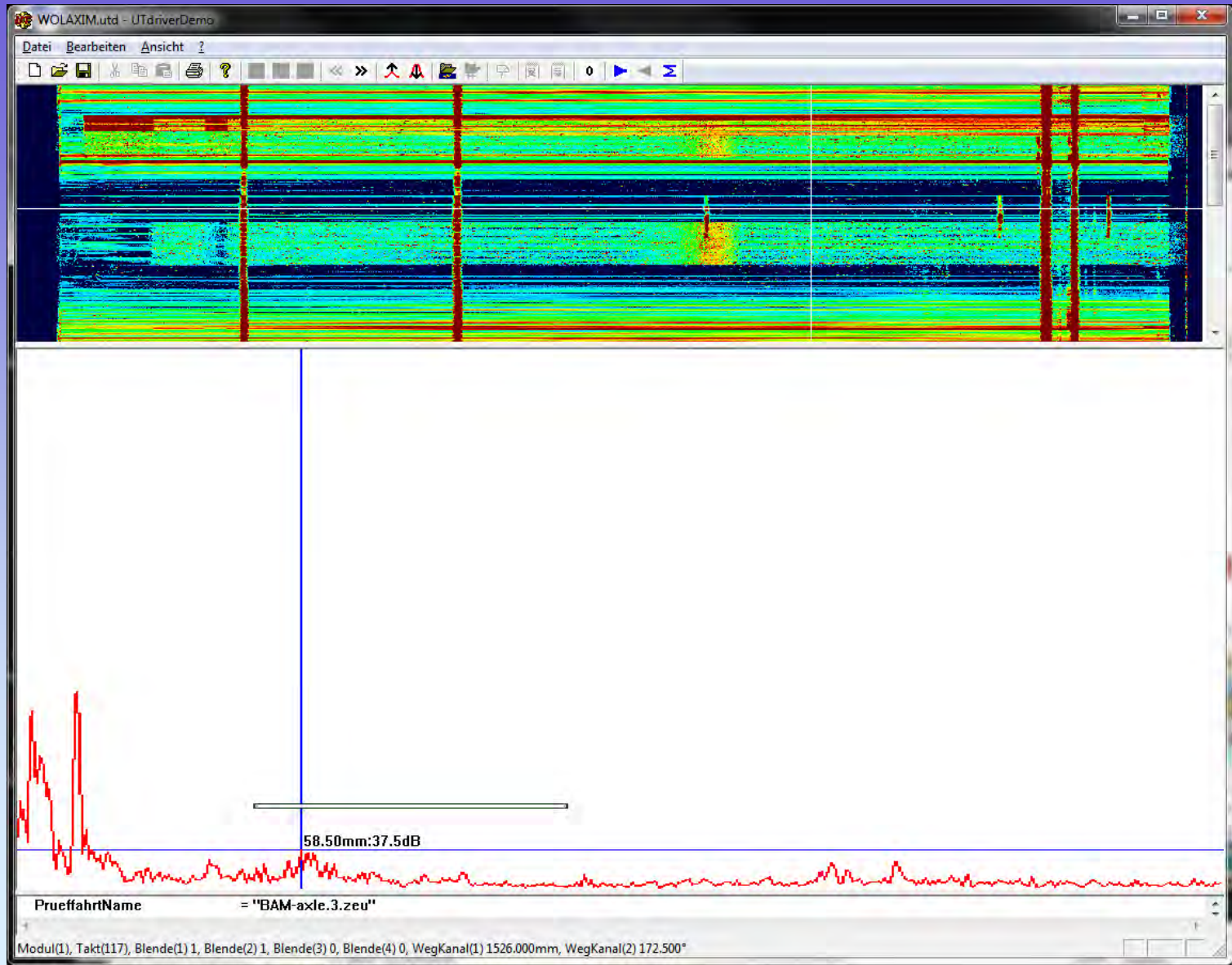


Comparison of the C-scans of the first test (top) and the second test with the probe 90° rotated (bottom), 2mm deep saw cuts

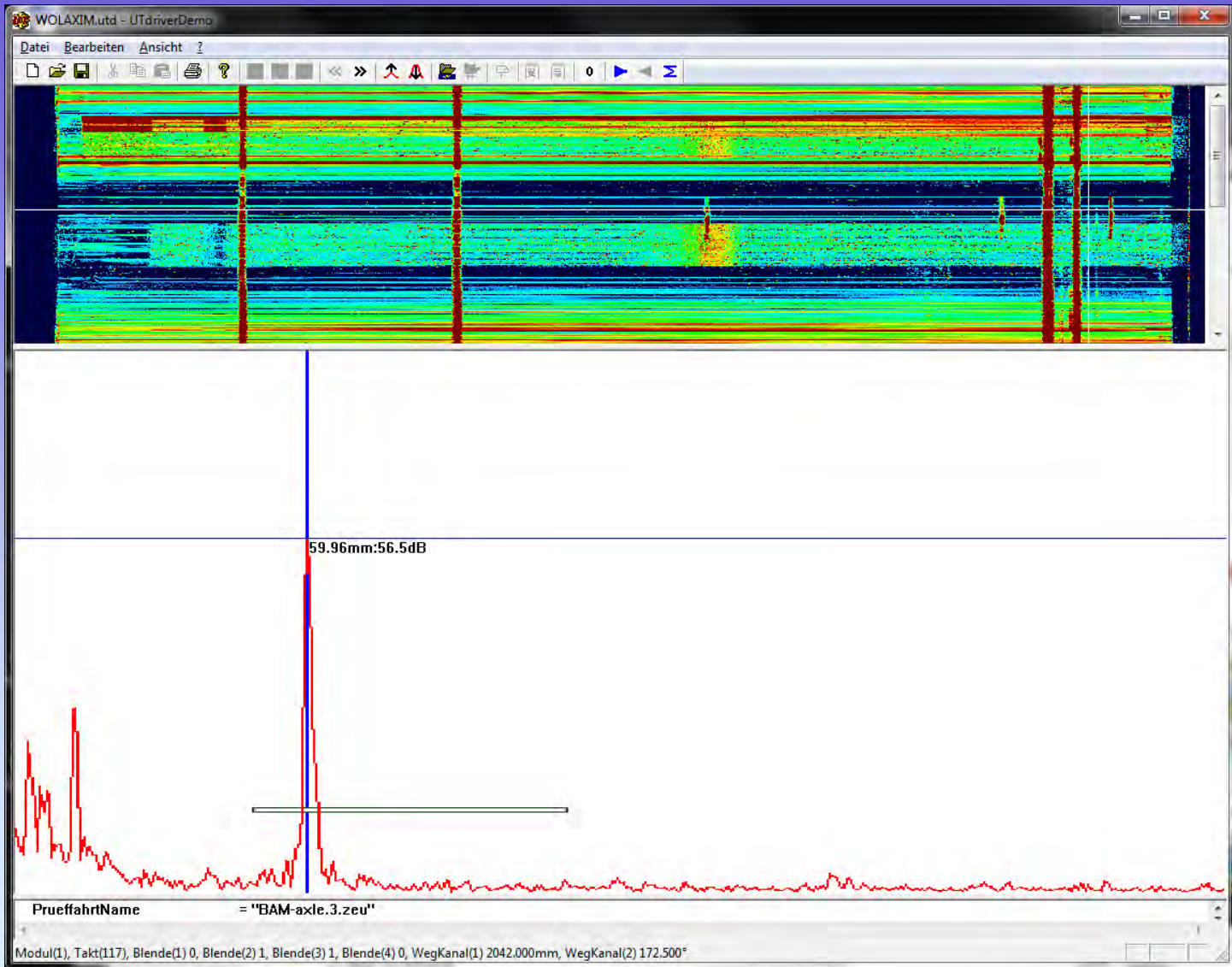




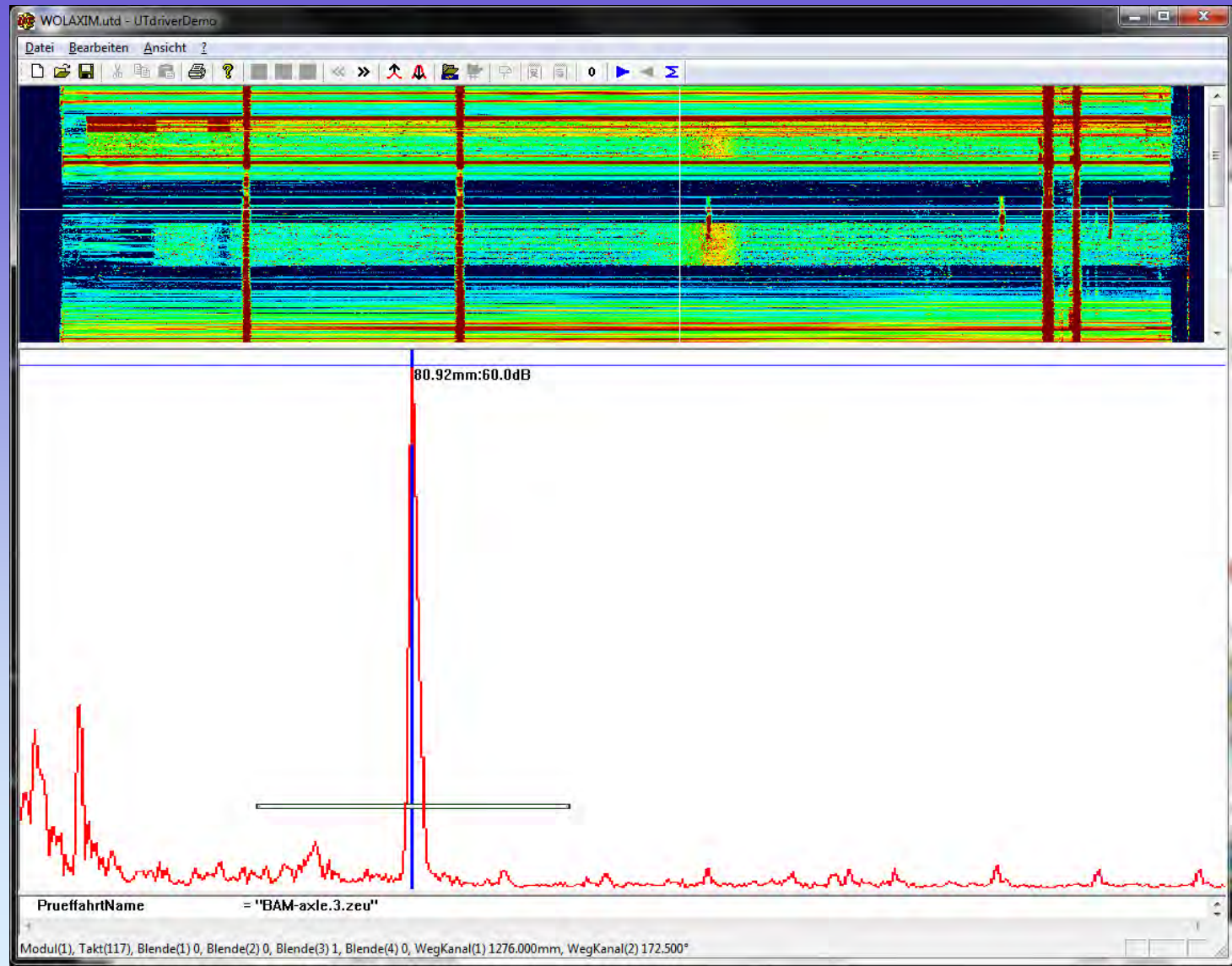
Comparison of the C-scans of cone 1 (top), cone 2 (bottom), and the fusion of both (middle)







A-scan of an element group without interference, reflection of the test flaw in the journal



A-scan of an element group without interference, reflection of the test flaw in the shaft

- Fast UT-inspection system based on an electronically rotated Phased Array system (measurement time of 60 seconds / axles)
- Resolution of  $1.5^\circ$  circumferential direction and 2mm in axial direction (resulting in 1000 x 240 A-scans)
- Signal-to-noise ratio of better than 17.5 dB
- In the shaft region about 22.5 dB for 2mm deep notches
- Further optimization is possible