Forming Non-Diffracting Beams Using a 2D Matrix Phased Array Probe

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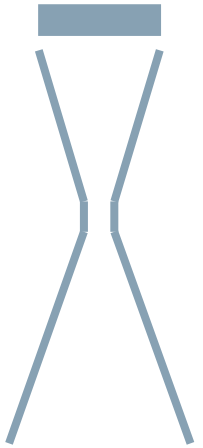
Introduction

Diffracting beams:

- diverging sound field
- amplitude drops rapidly out of the focal zone



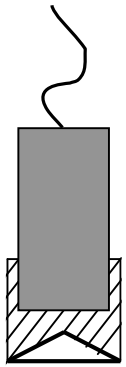
Non-diffracting beams:

- Bessel beam
- Focus a parallel beam to great depths

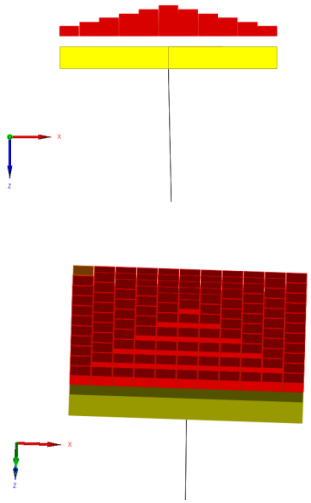
Phased Array Approach to form bessel beams

- Simulation of an physical axicon lense with adjusted time delays for a 2D matrix array

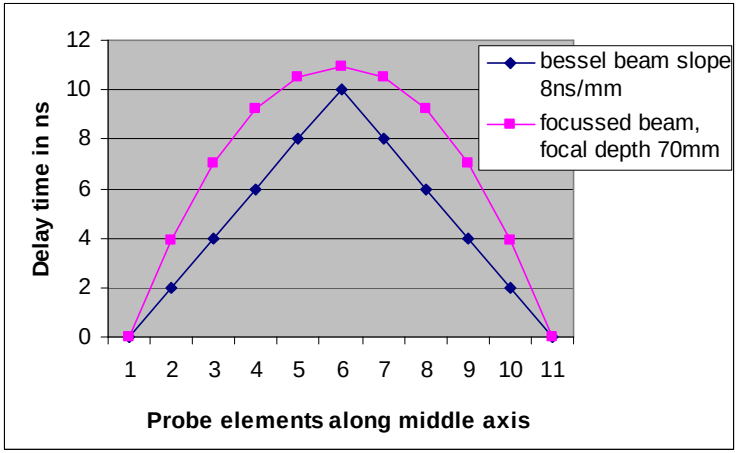
Probe with axicon lense



Time delays to form bessel beam for the matrix array



Time delays of bessel beam focussing compared to regular focussing



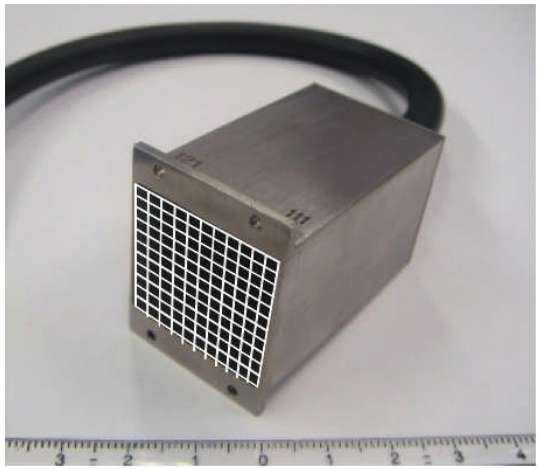
Equipment

Phased Array Equipment

Olympus Focus LT 64/128

Olympus Tomoview Software

Phased Array Probe



11 x 11 elements

10 MHz

Size of aperture: 23.1mm x 23.1mm

Element size: 2mm x 2mm

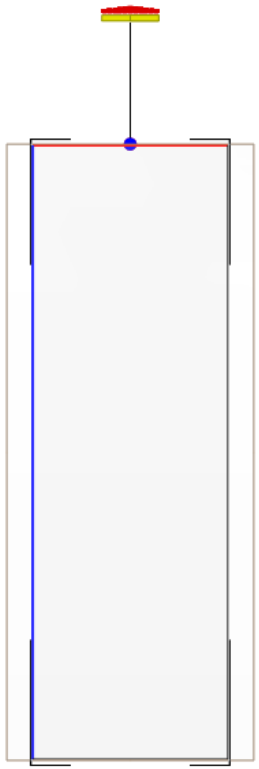
Interelement spazing: 0.1mm

Simulation setting for beam computation

Software: CIVA 10

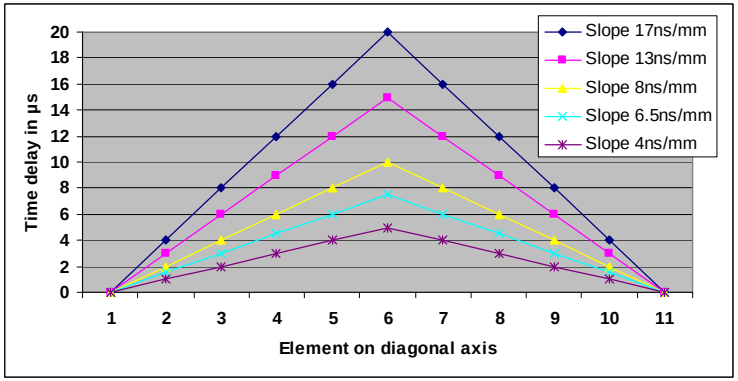
Simulation-Setting:

Material	Titanium (c_Long = 6100m/s, c_Trans = 3120m/s, density = 4,53 g/cm^3)
Material geometry	100mm x 100mm x 250mm
Coupling	Water
Water distance	50mm
Beam computation	0-250mm in Titanium



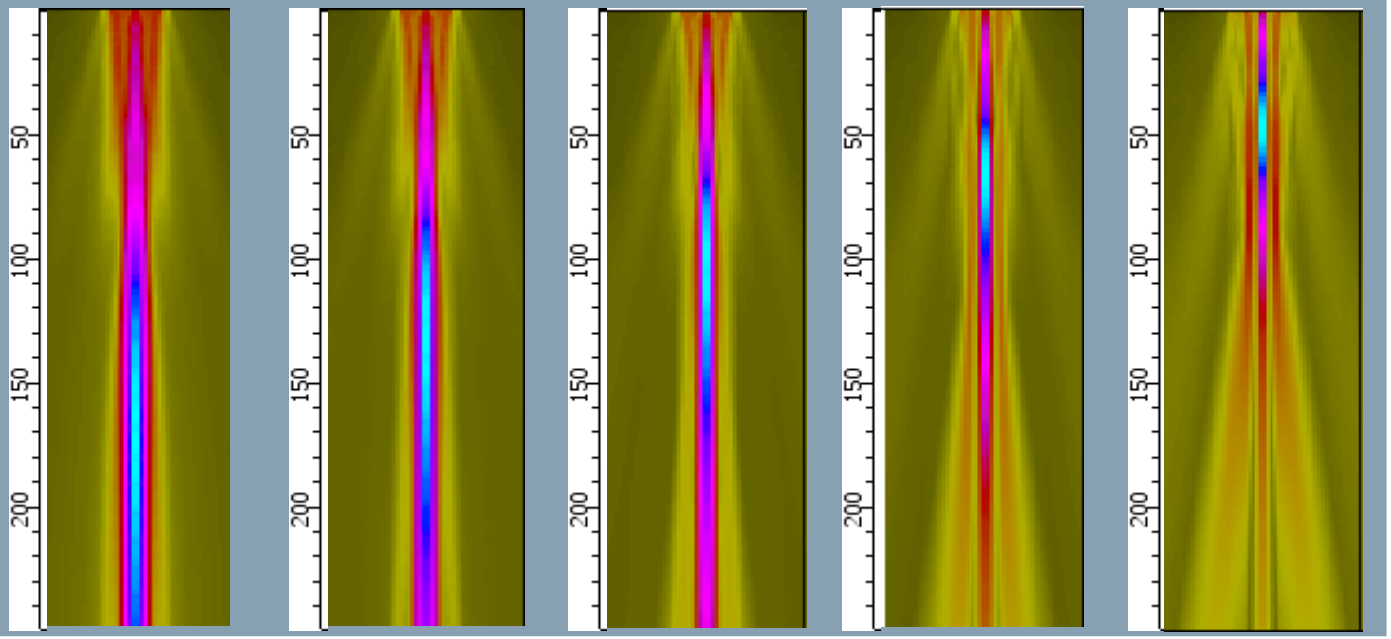
Simulation of different slopes

The slope of the time delays can be varied



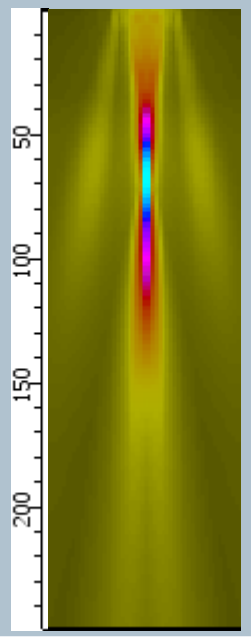
Bessel beams

4 ns/mm **6.5 ns/mm** **8 ns/mm** **13 ns/mm** **17 ns/mm**

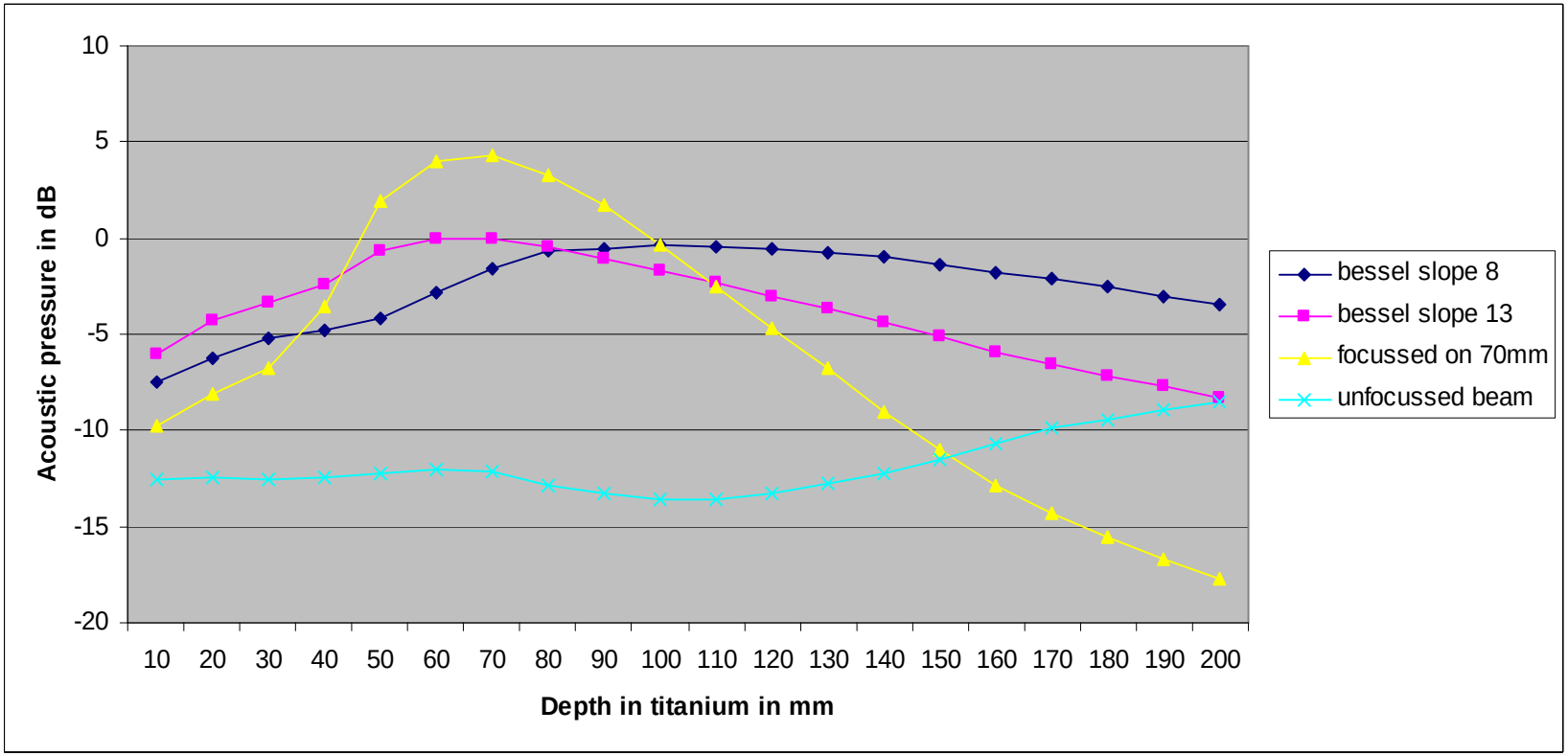


Compared to

Focus 70mm

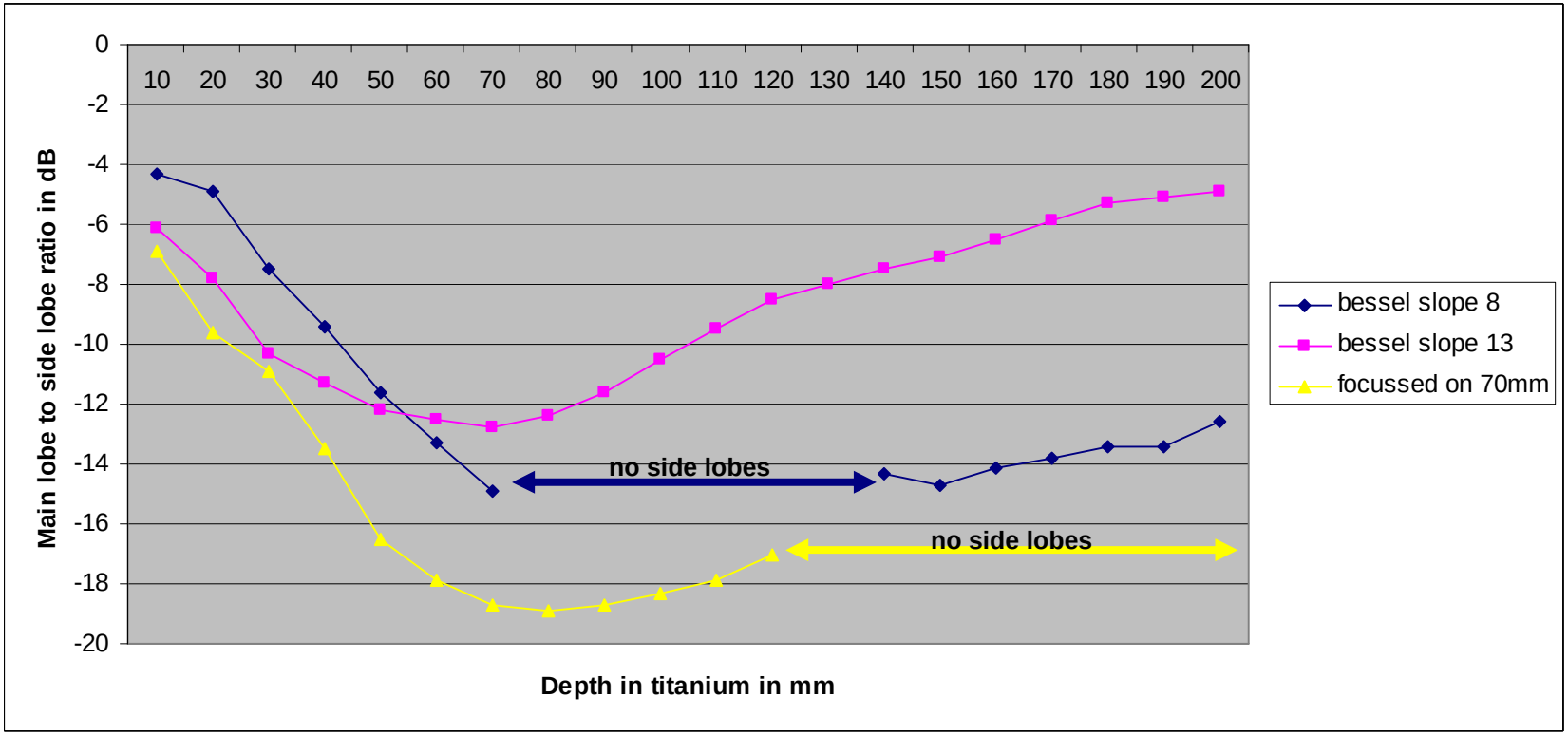


Acoustic pressure



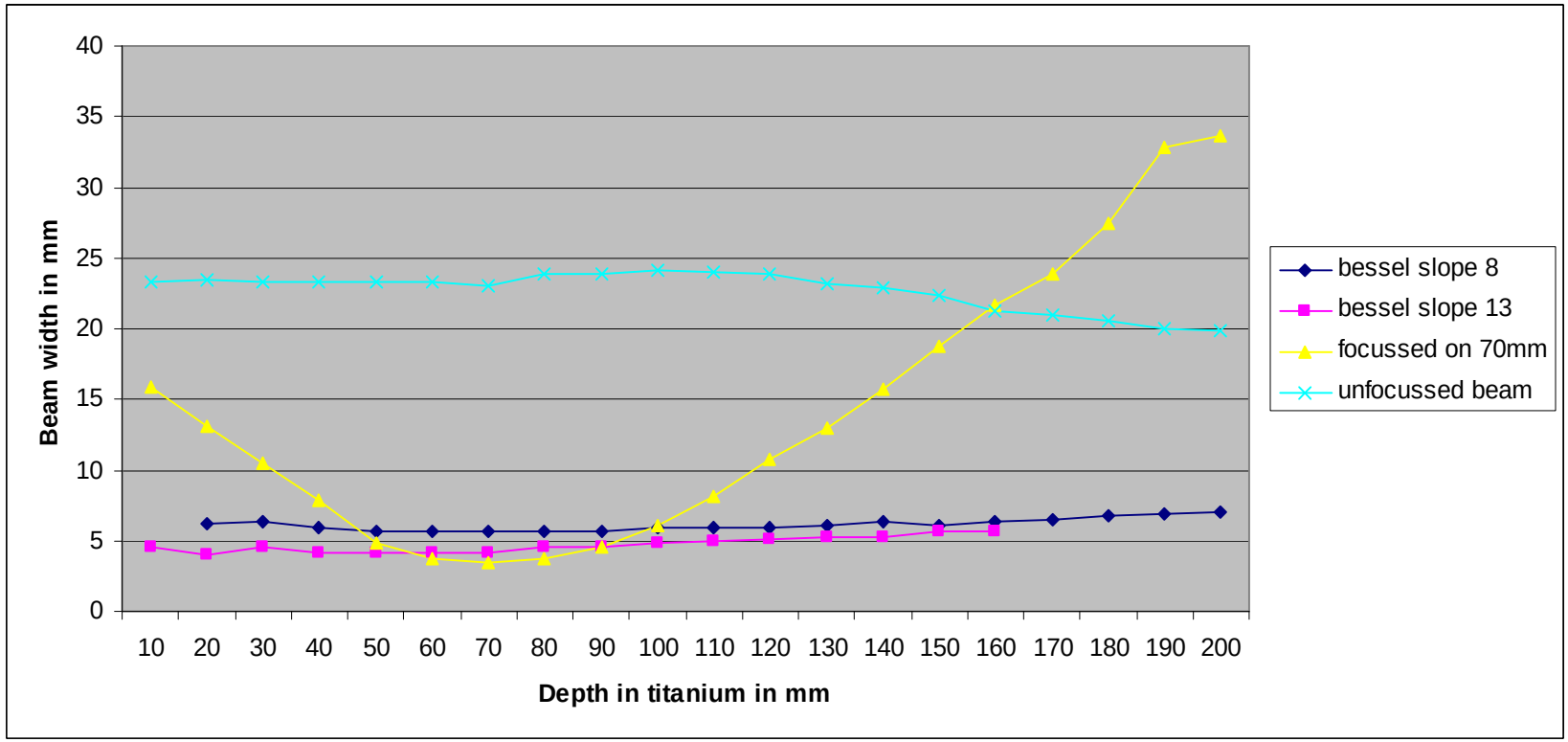
Bessel beams have about 4 dB less acoustic pressure compared to the focal spot of a focussed transducer

Main lobe to side lobe ratio



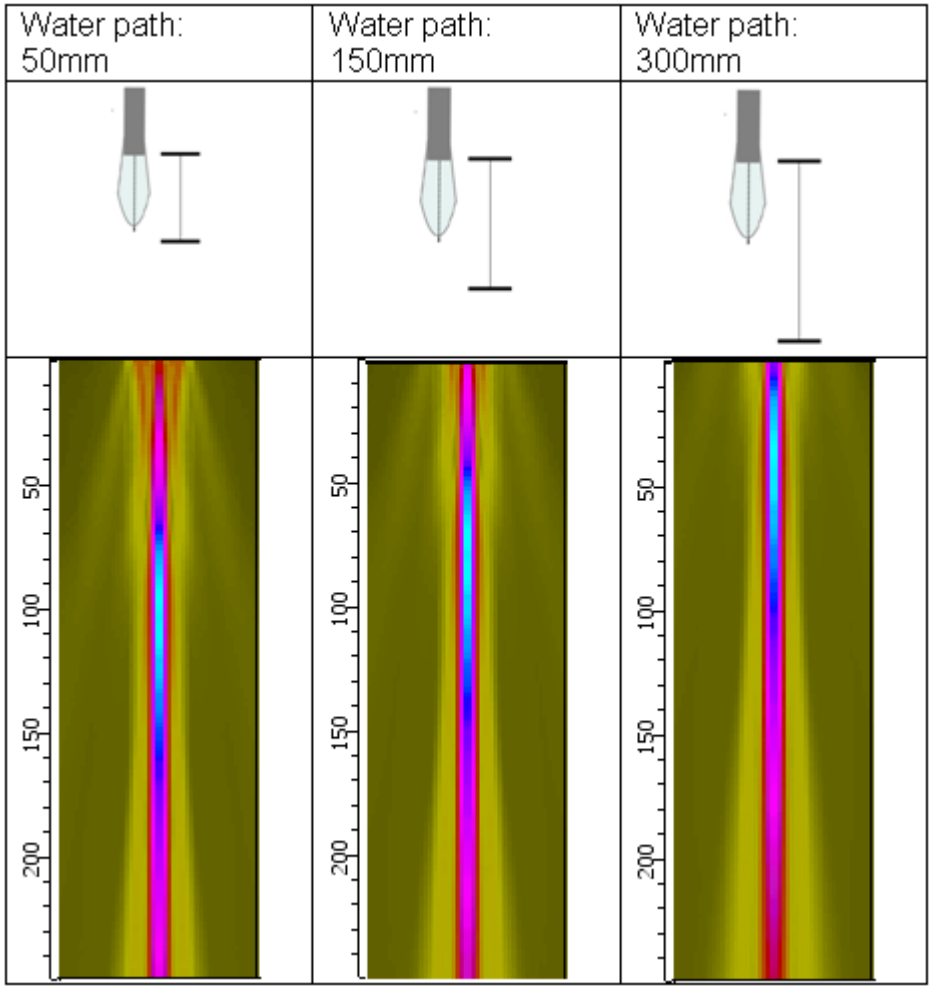
The effect of the side lobes is only a little worse than for the focussed beam. The beam with a slope of 8ns/mm is for greater depth a lot better than the beam with a slope of 13ns/mm

Beam width



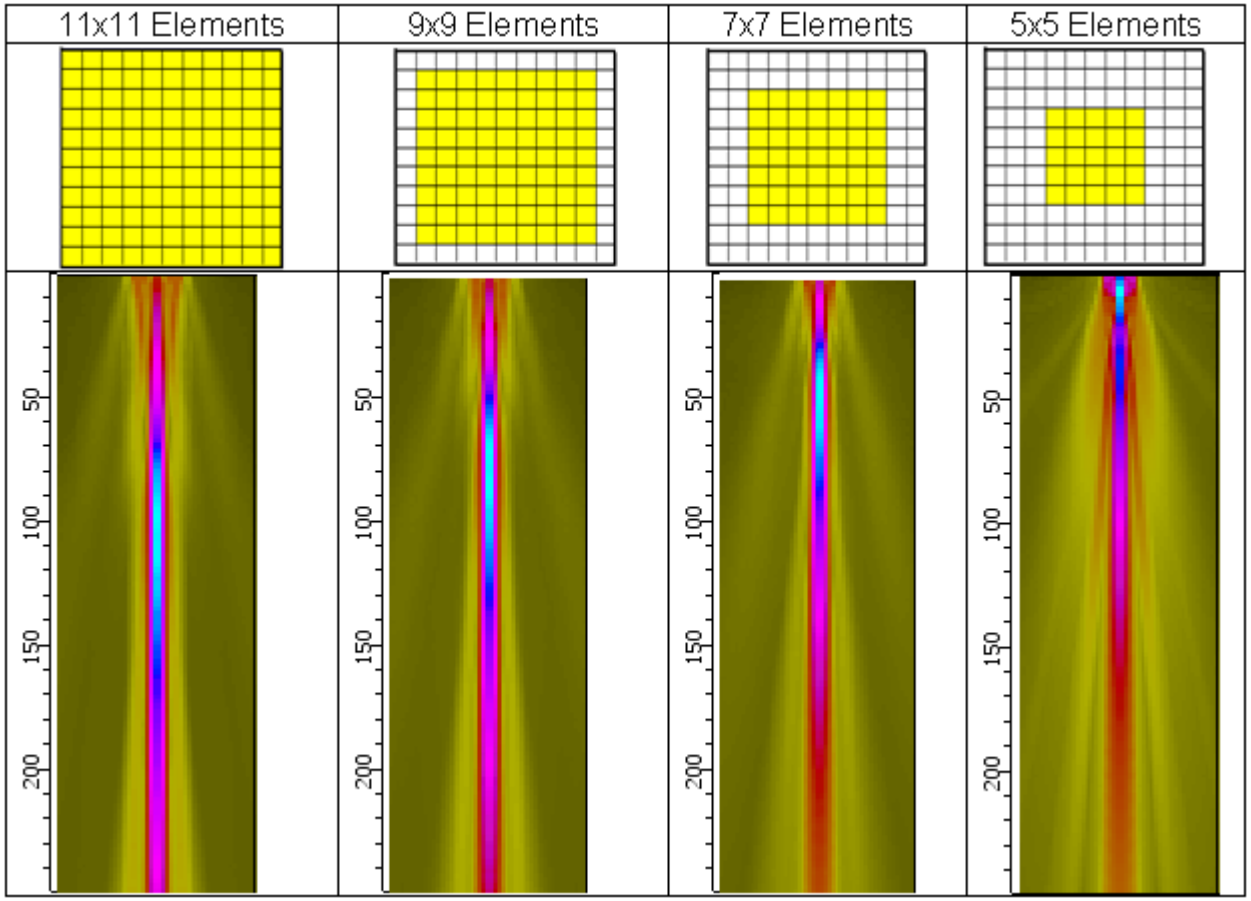
→ Bessel beams have a small beam width in great material depth

Varying the water path



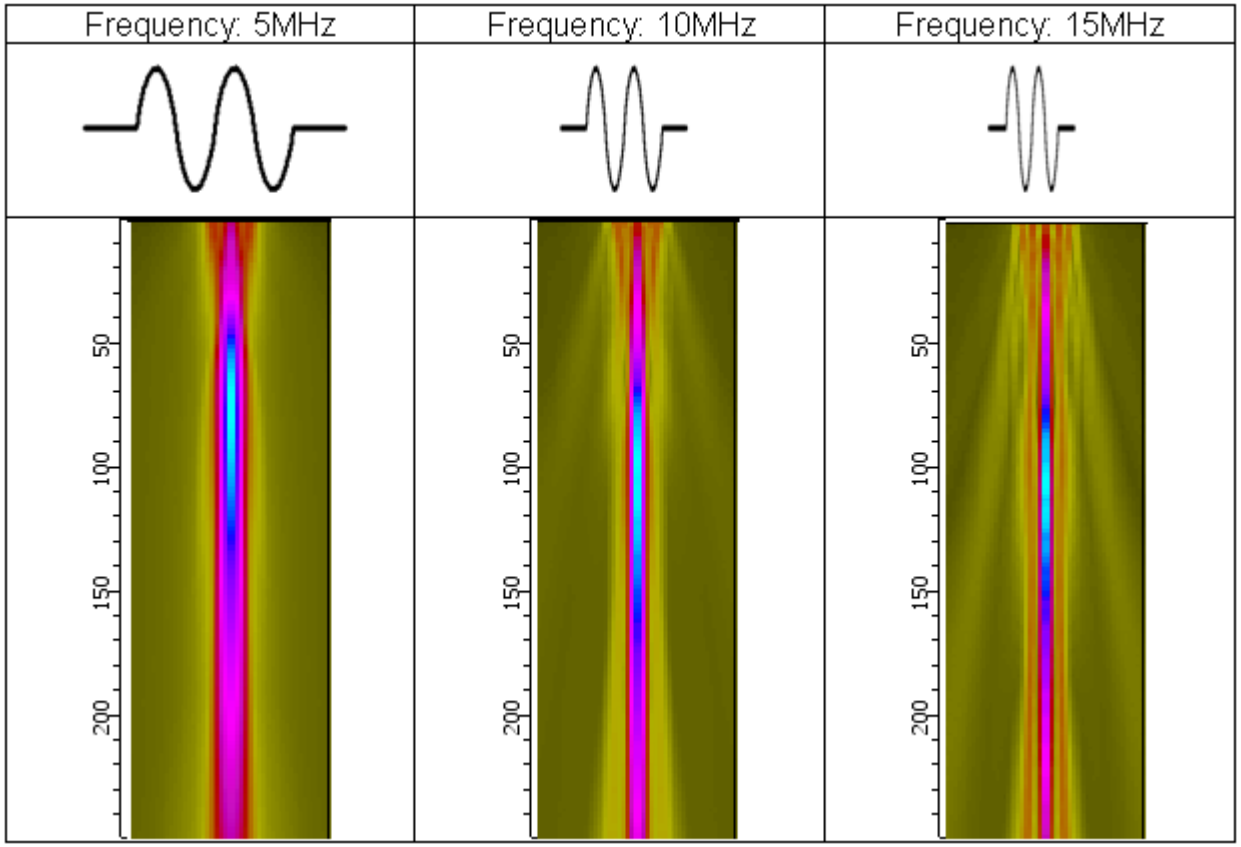
By increasing the water path, the effect of the side lobes can be decreased and a near surface inspection is possible

Varying the aperture



With fewer elements, the length of the high acoustic pressure zone is decreased

Varying the frequency

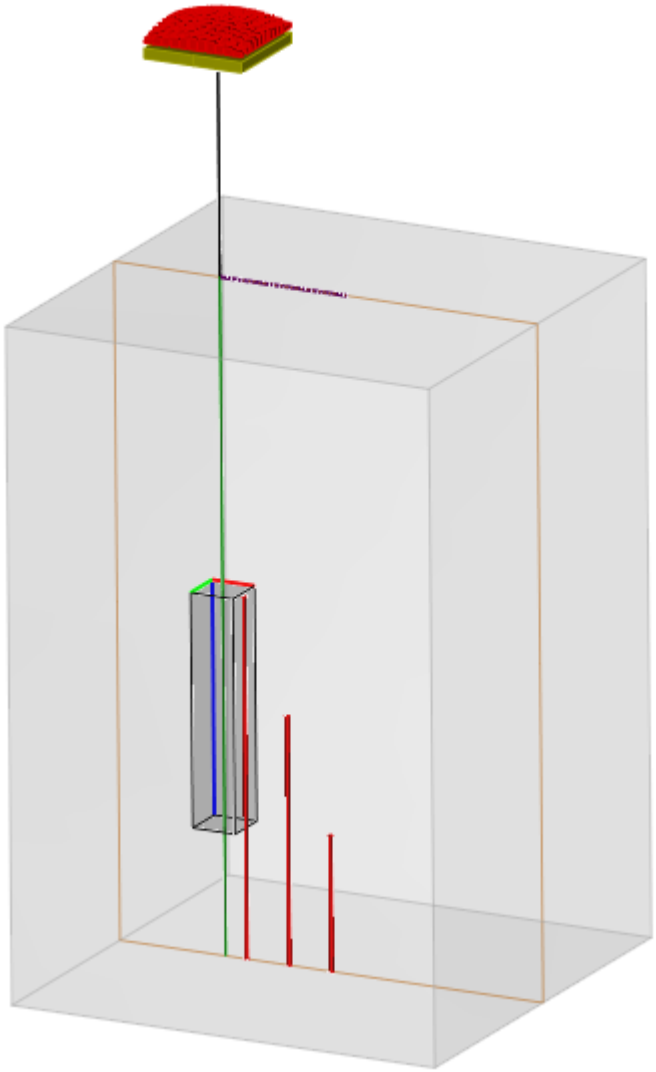


With higher frequencies the beam width is decreased and the effect of the side lobes is increased

Simulation setting for defect response

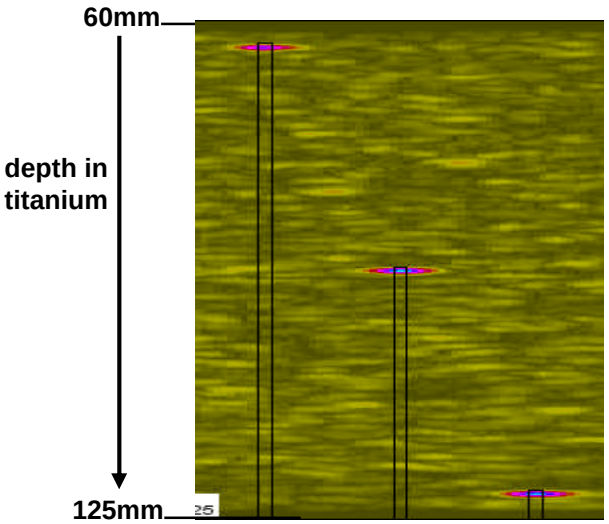
Simulation setting:

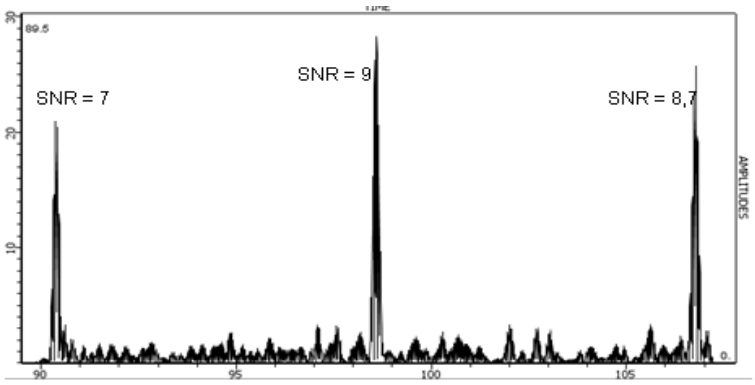
Material Material geometry	Titanium (c_Long = 6100m/s, c_Trans = 3120m/s, density = 4,53 g/cm^3) 100mm x 100mm x 150mm
Noise Density Amplitude	Structural Noise 0,3 points/mm^3 measured 1,1 S.I.
Coupling Water path	Water 50mm
Flaws Depth from surface	Flat bottom hole, Ø 1mm 70mm, 95mm, 120mm



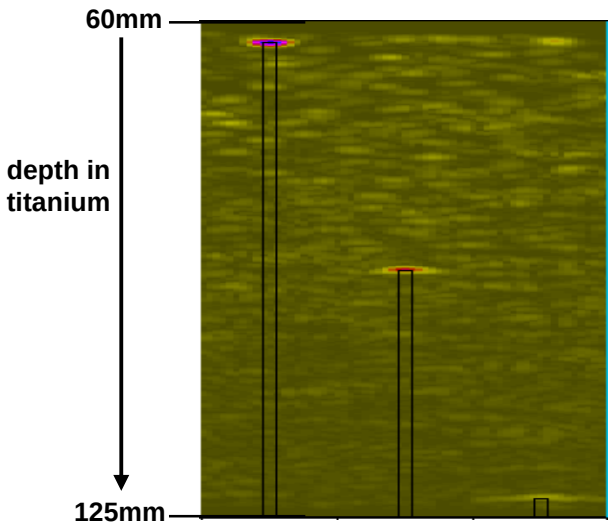
Simulation Defect Response

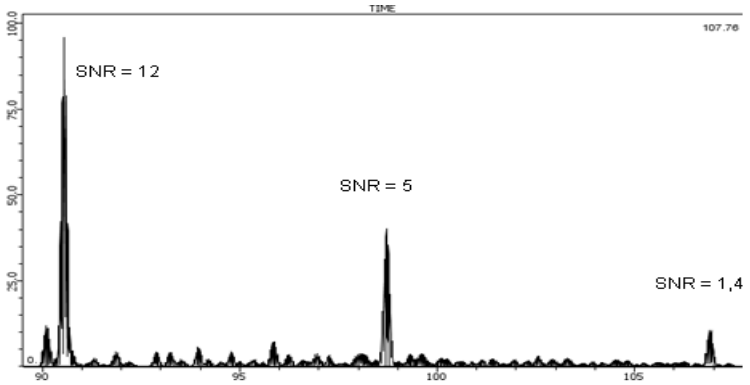
Bessel beam





Focussed beam (70mm)





Experimental results

Experimental setup:

#2 FBHs in Nickel base alloys

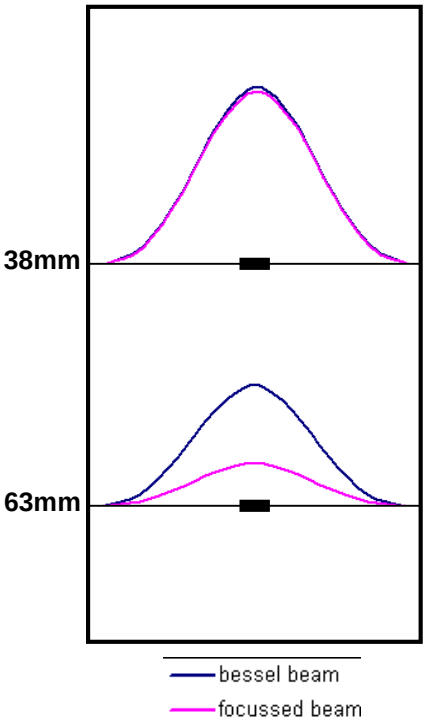
Depth of FBHs:

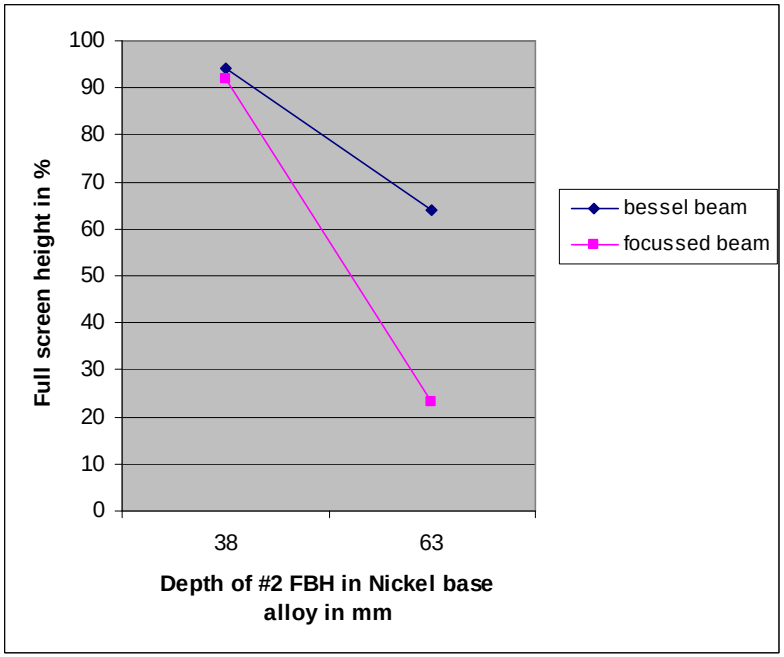
38mm, 63mm

Water path: 75mm

Beam 1: Bessel beam

Beam 2: Focus 40mm





Conclusion

- Fast and sensitive inspection of great material depths, even if the material is noisy
- As the non-diffracting beam is formed by phased array, the inspection can be changed to high resolution in short time. With the same equipment a focussed beam can be produced easily.

Prospect:

- Bessel beams have a self-reconstructing ability, especially if they are produced with such a big aperture as with the matrix array.
- With the self-reconstructing ability flaws which are hidden by other flaws could be detected.