Inversion of Guided Wave Scattering for Measuring Corrosion in Pipes and Plates

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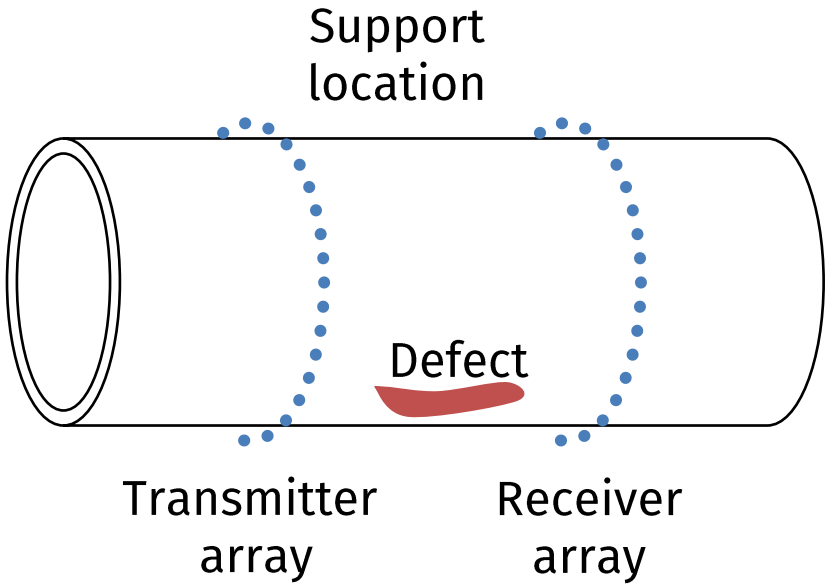
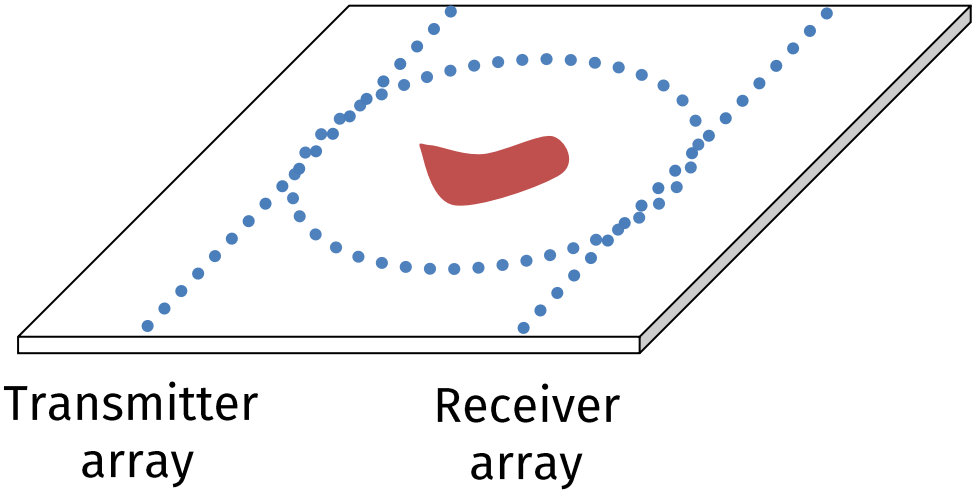
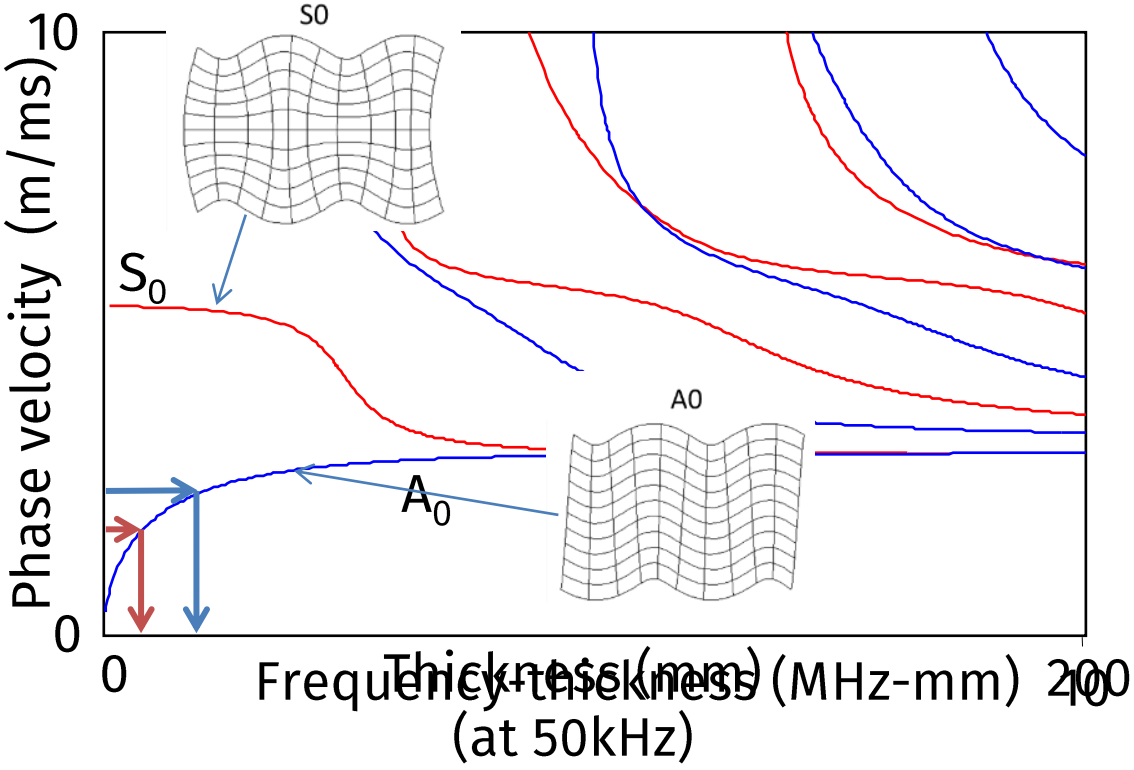
Quantitative imaging: corrosion mapping

Guided wave tomography theory



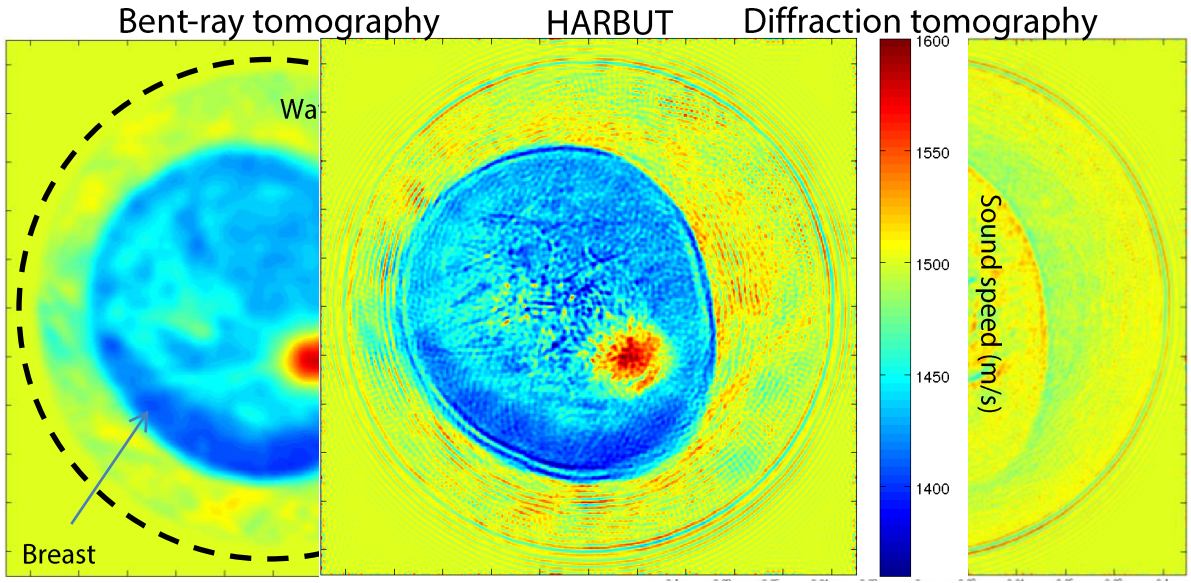


Guided wave tomography theory II



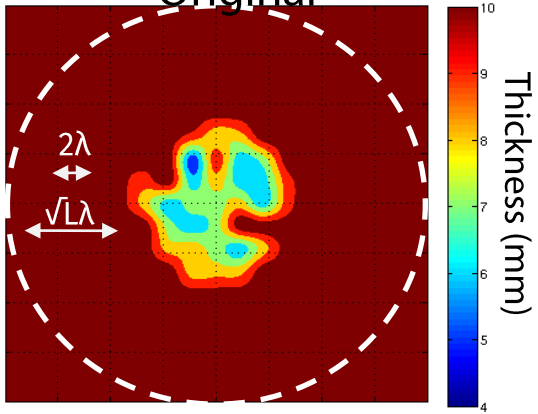
Guided wave tomography theory

HARBUT – for *in vivo* breast imaging

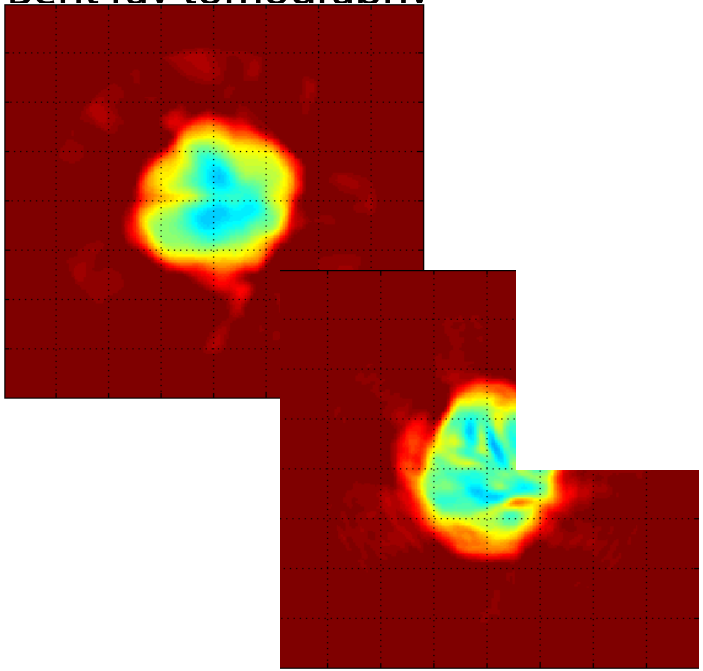


Guided wave tomography with HARBUT

Original

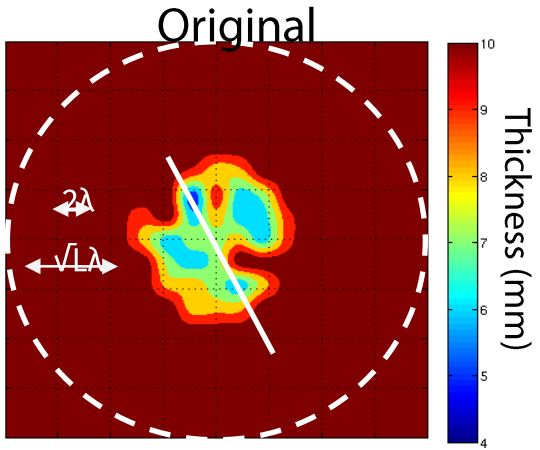


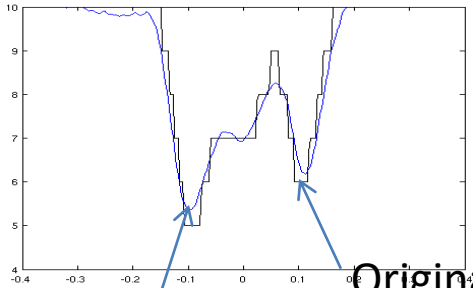
Bent ray tomography

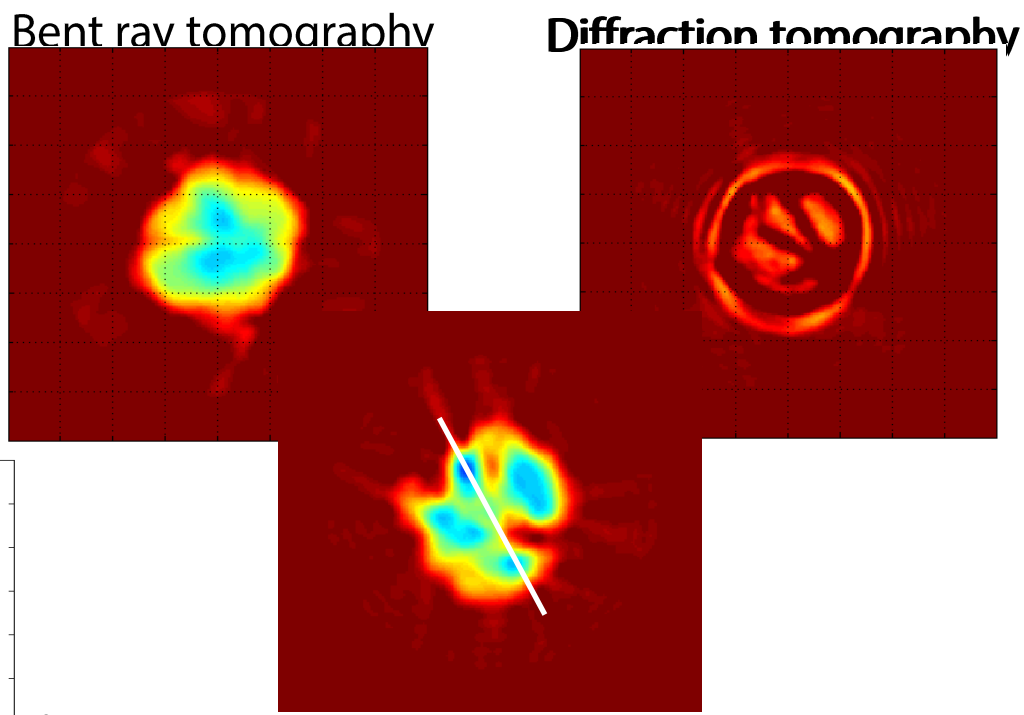


HARBUT

Guided wave tomography with HARBUT



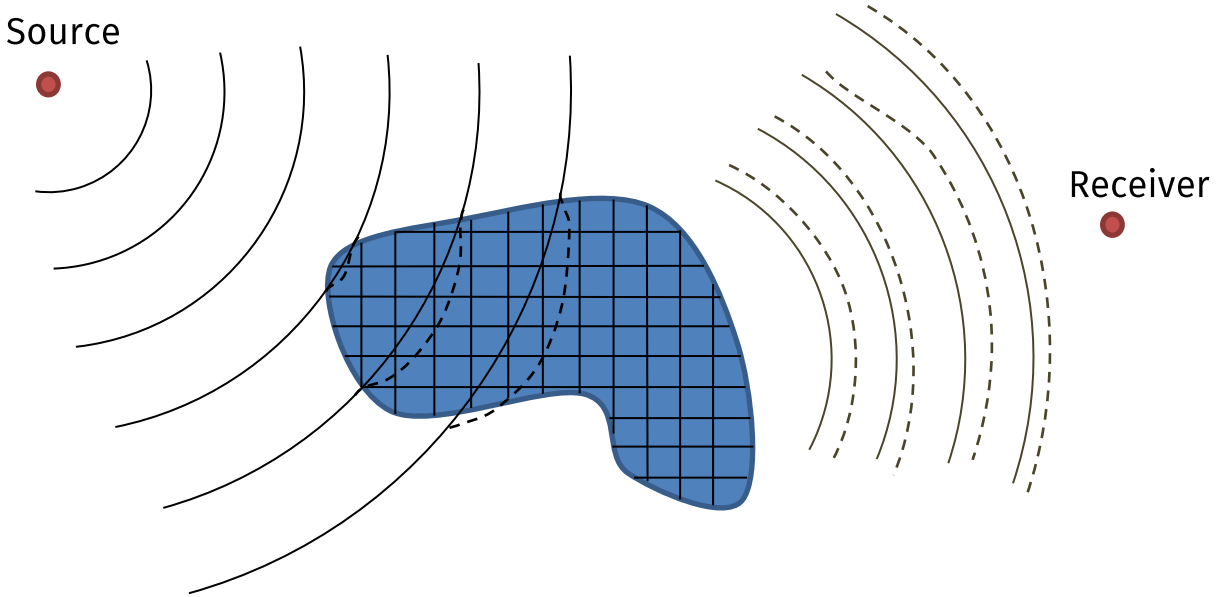




Huthwaite & Simonetti, 'High-resolution Guided Wave Tomography' Wave Motion 2013

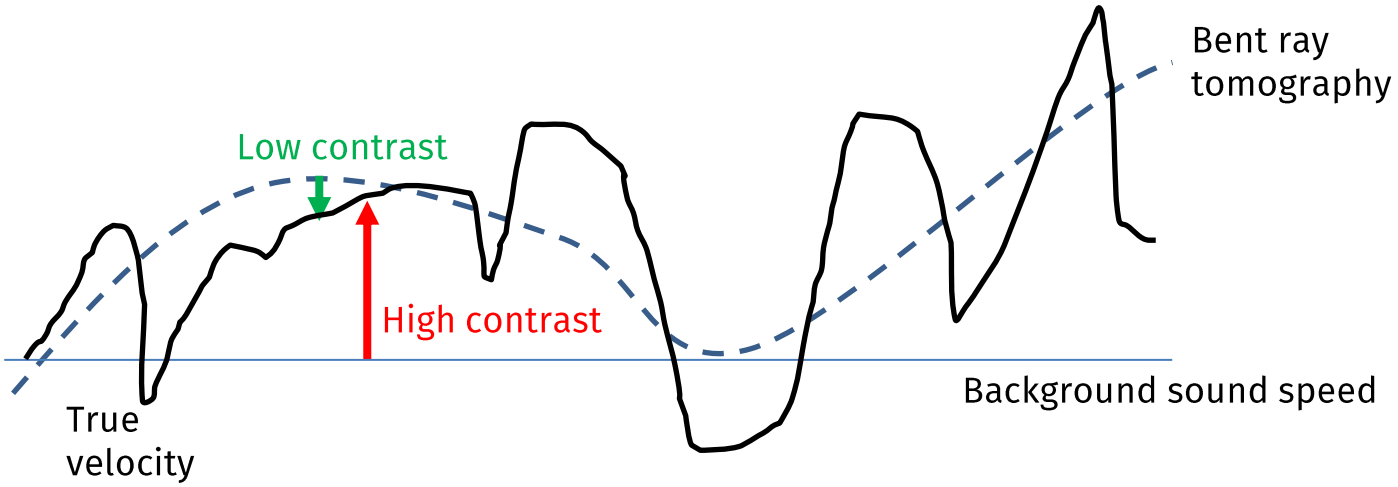
HARBUT

Hybrid Algorithm for Robust Breast Ultrasound Tomography



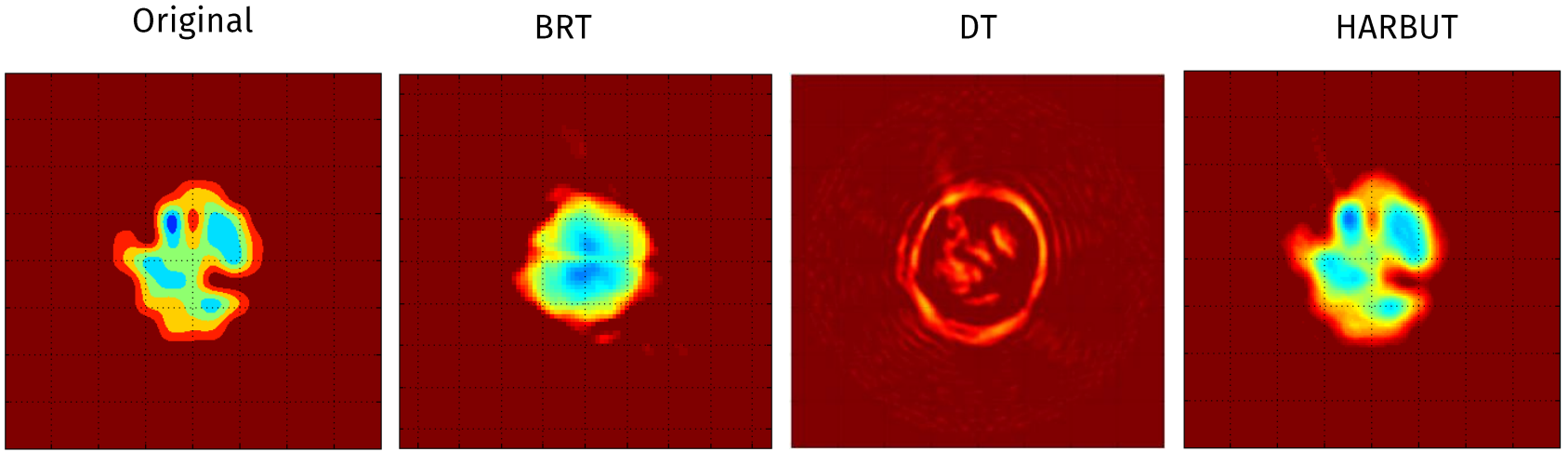
HARBUT principle

Hybrid Algorithm for Robust Breast Ultrasound Tomography



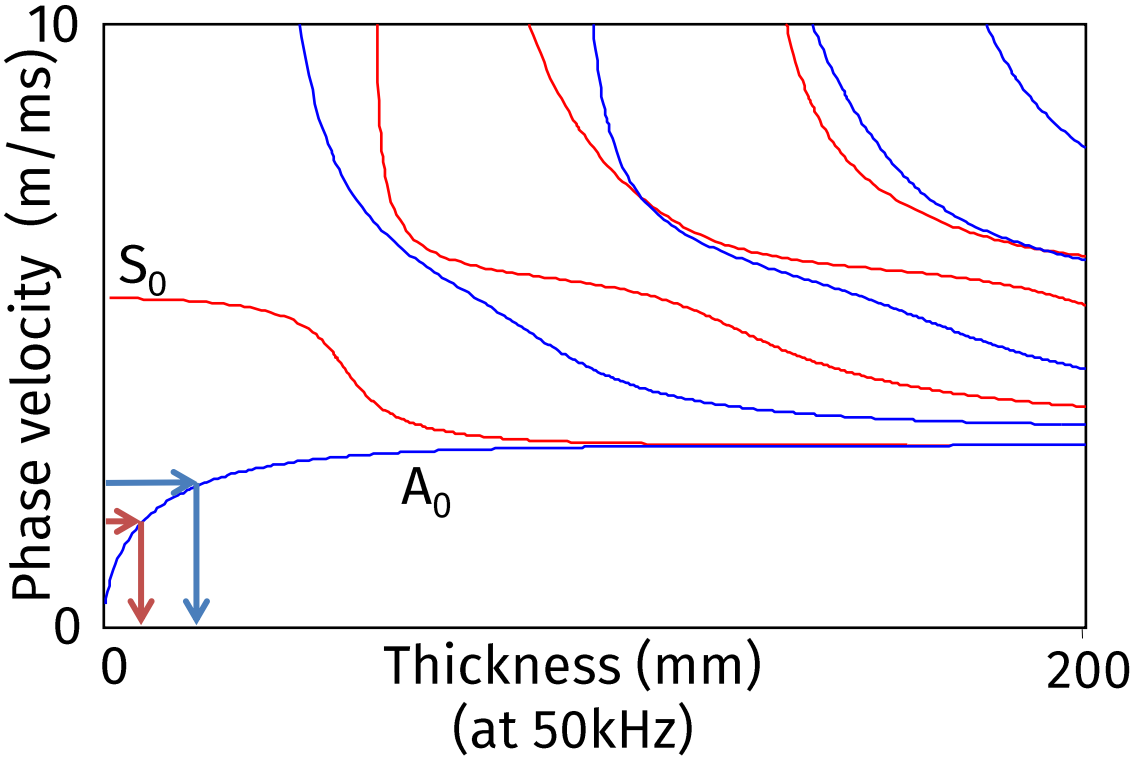
HARBUT

- Higher resolution than ray tomography (BRT)
- More widely applicable than diffraction tomography (DT)

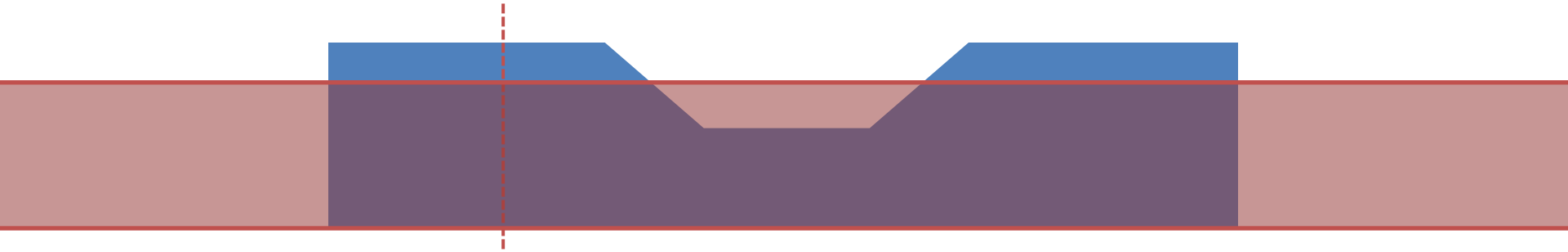


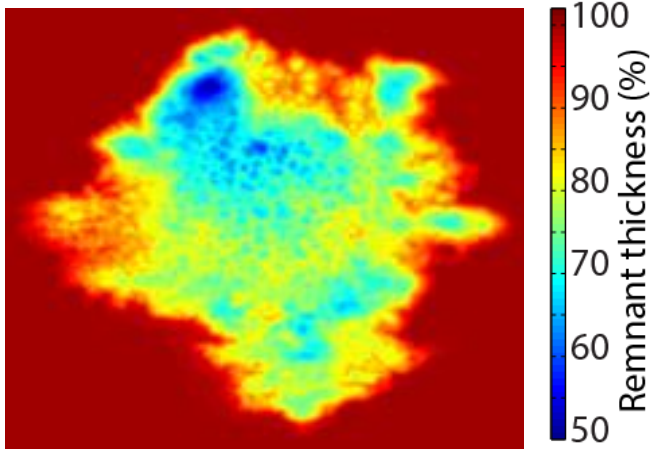
More complex scattering…

Guided wave tomography theory II



Guided wave tomography theory III

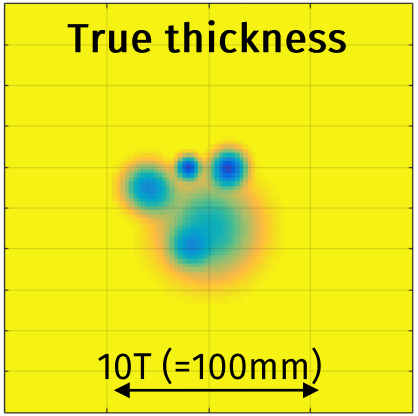


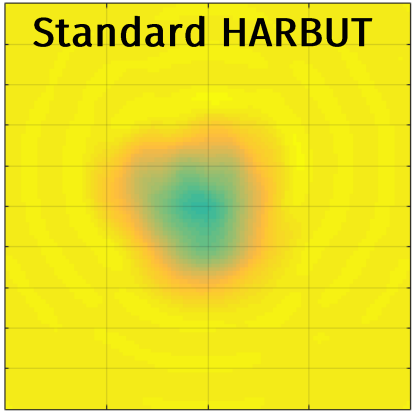


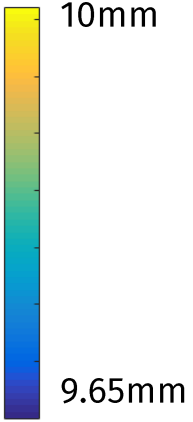
Utilising the FE method

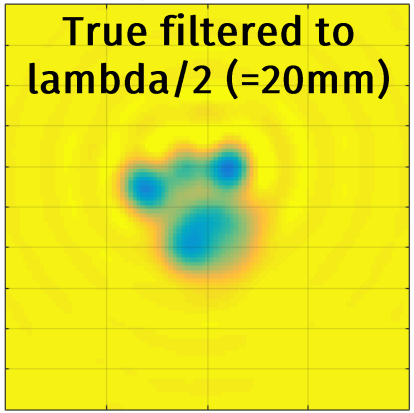
- Capable of simulating complex wave interactions
- Can help inspection design
- Potential in ‘full-waveform inversion’-type techniques

Guided wave tomography resolution

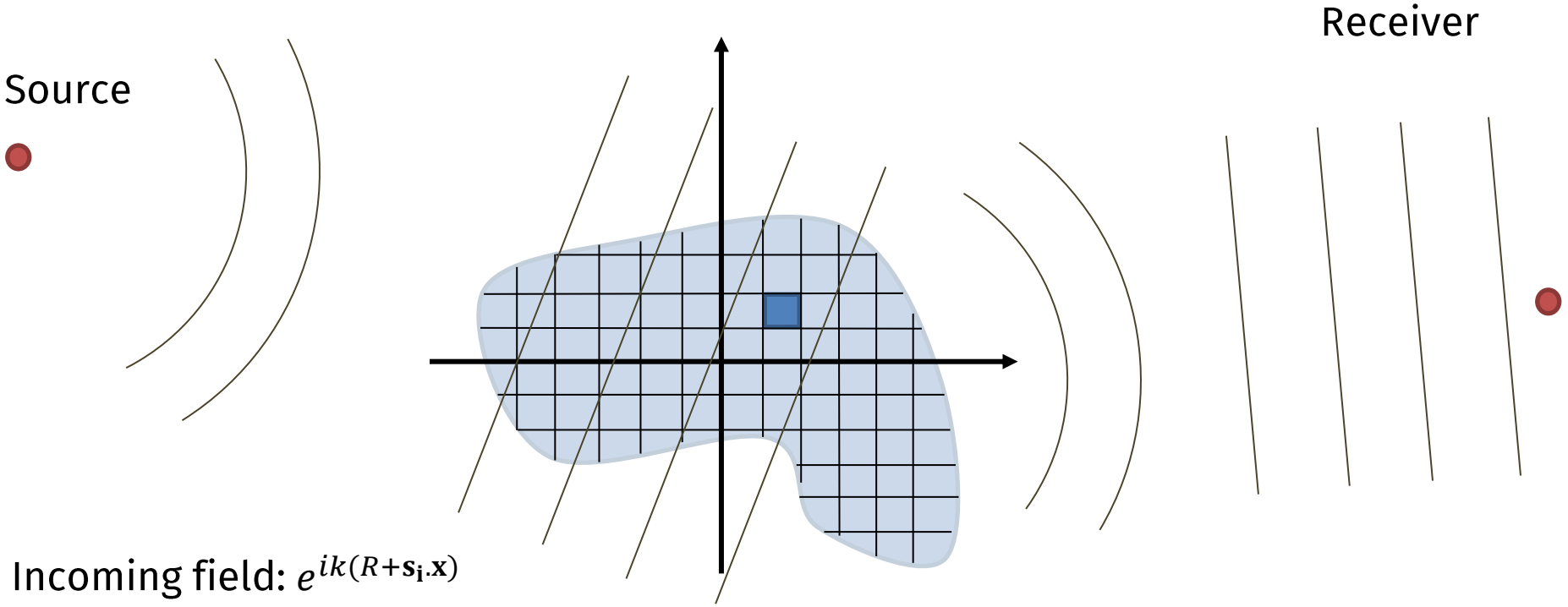








Why?

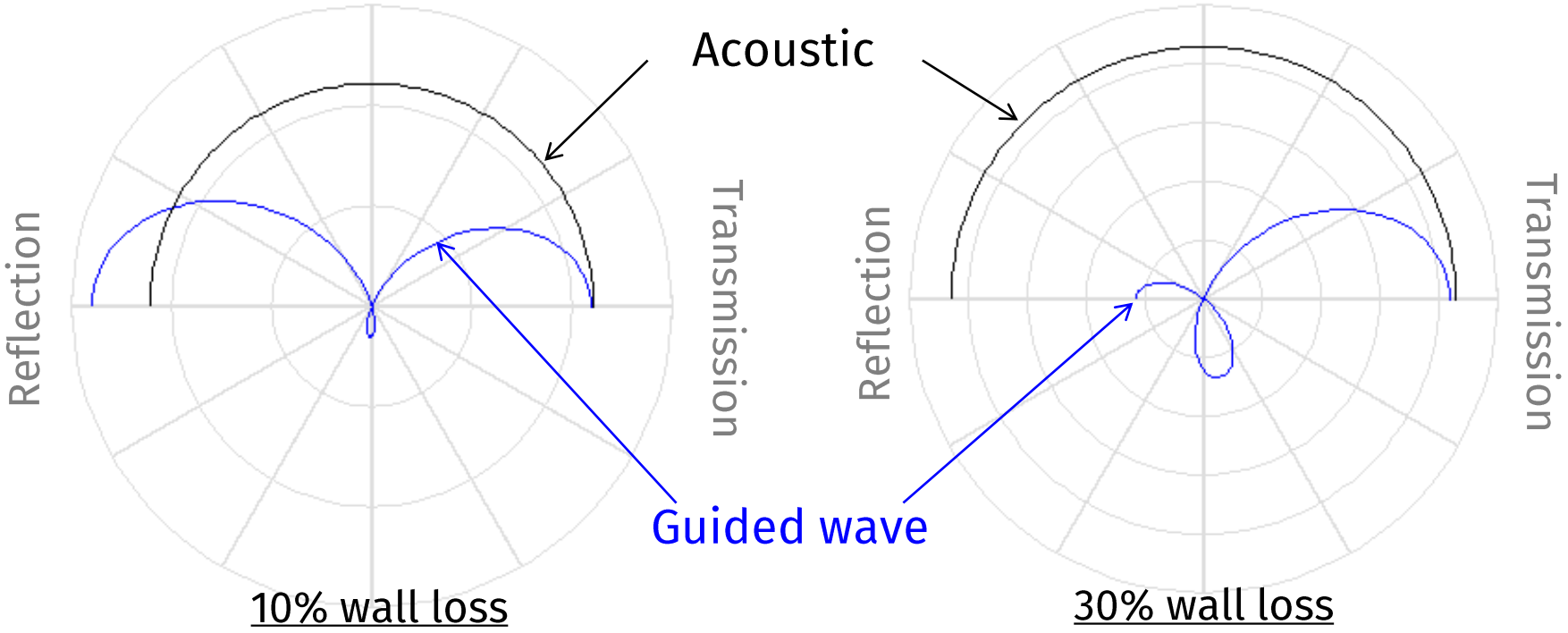


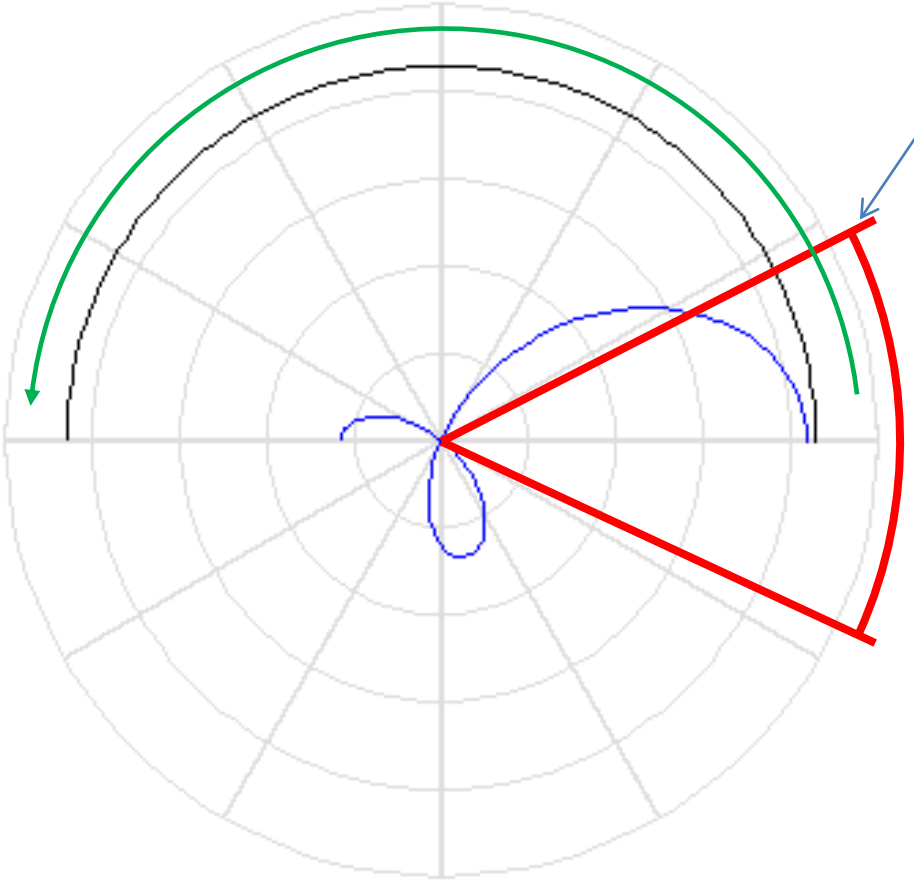
Incoming field: $e^{ik(R+\mathbf{s_i}.\mathbf{x})}$

Scattering potential: ρ ← Assumed non-directional

Outgoing field: $e^{ik(R-\mathbf{s_r}.\mathbf{x})}$

Guided wave scattering





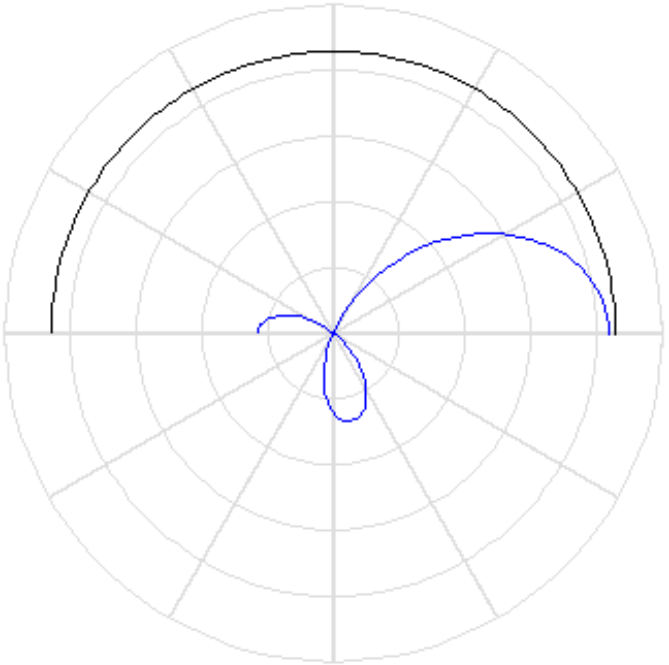
Resolution limit around 2λ

High spatial frequency components

Low spatial frequency components

Good matching

Improved scattering model



$$\rho(\theta, h) = \sum_{n=1}^{N} \sum_{m=0}^{M} C_{mn} \cos m\theta \; h^n$$

Scattering angle

Coefficients

Wall loss as fraction of T

Determine coefficients

- Run many finite element simulations
  - Different defect widths and depths
  - Extract scattered field
- Find coefficients to match scattered data
  - Fixed for particular operating point (frequency-thickness, material properties)

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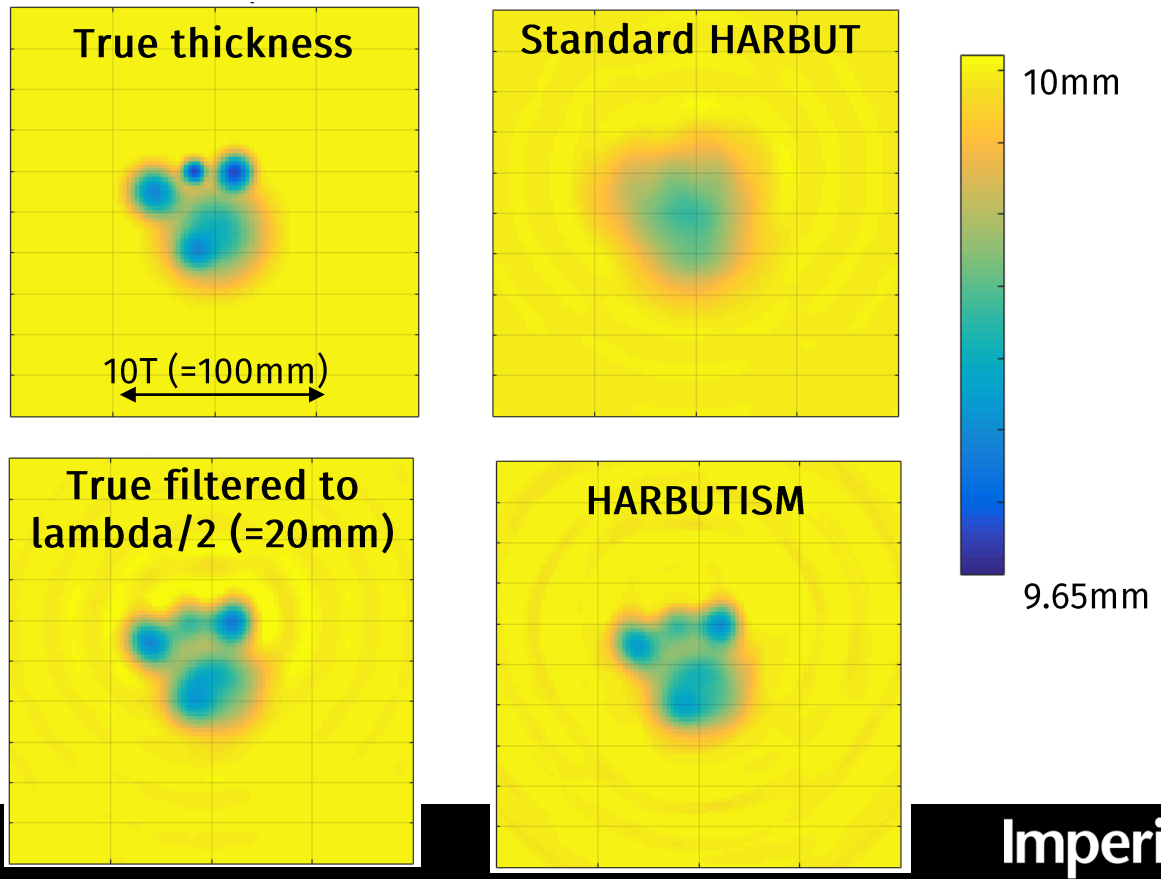
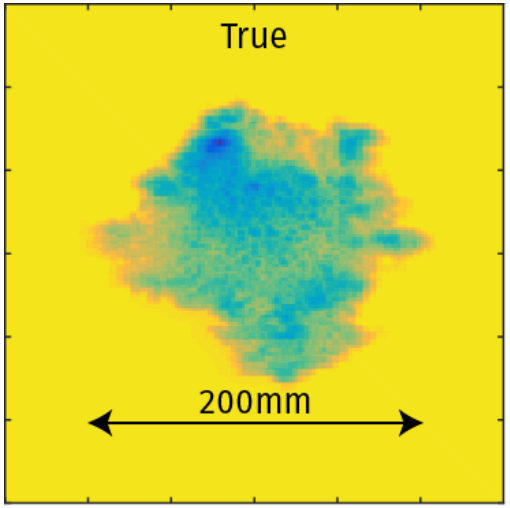
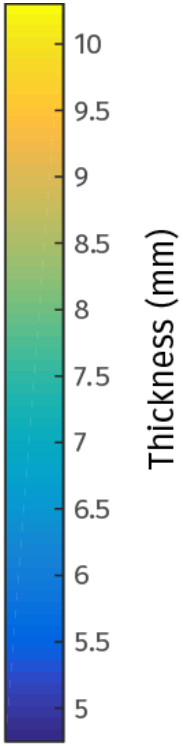
Imaging

- Perform a velocity inversion using HARBUT
- Remap spatial frequency components to fit improved scattering model (HARBUTISM)

Improved scattering model

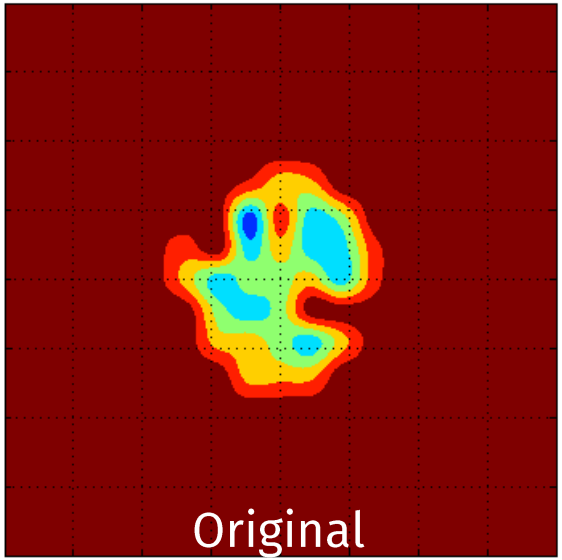


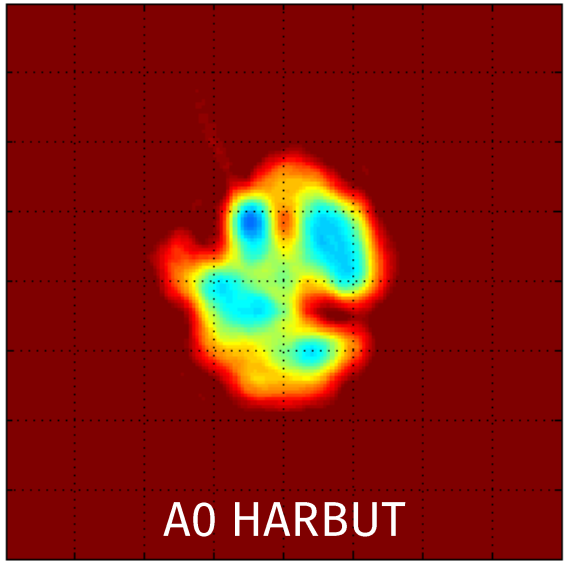

True
200mm

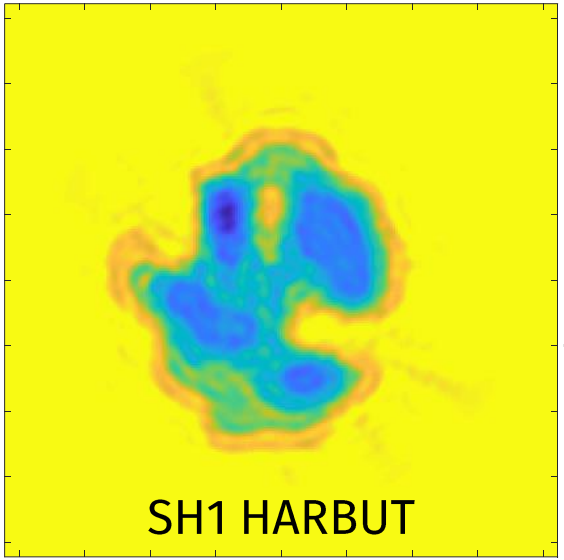

10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
Thickness (mm)

Another approach: SH1 tomography

- Use higher order mode with higher frequency -> shorter wavelength -> higher resolution







(Thanks to A. Zimmermann)

[Zimmerman, Huthwaite, Pavlakovic, High-resolution thickness maps of corrosion using SH1 guided wave tomography, Proc. Roy. Soc. 2021]

Conclusions

- Demonstrated corrosion mapping through tomography approaches
- HARBUT achieved high resolution
- HARBUTISM improved this further
- SH1 Tomography with higher frequency achieves desired resolution