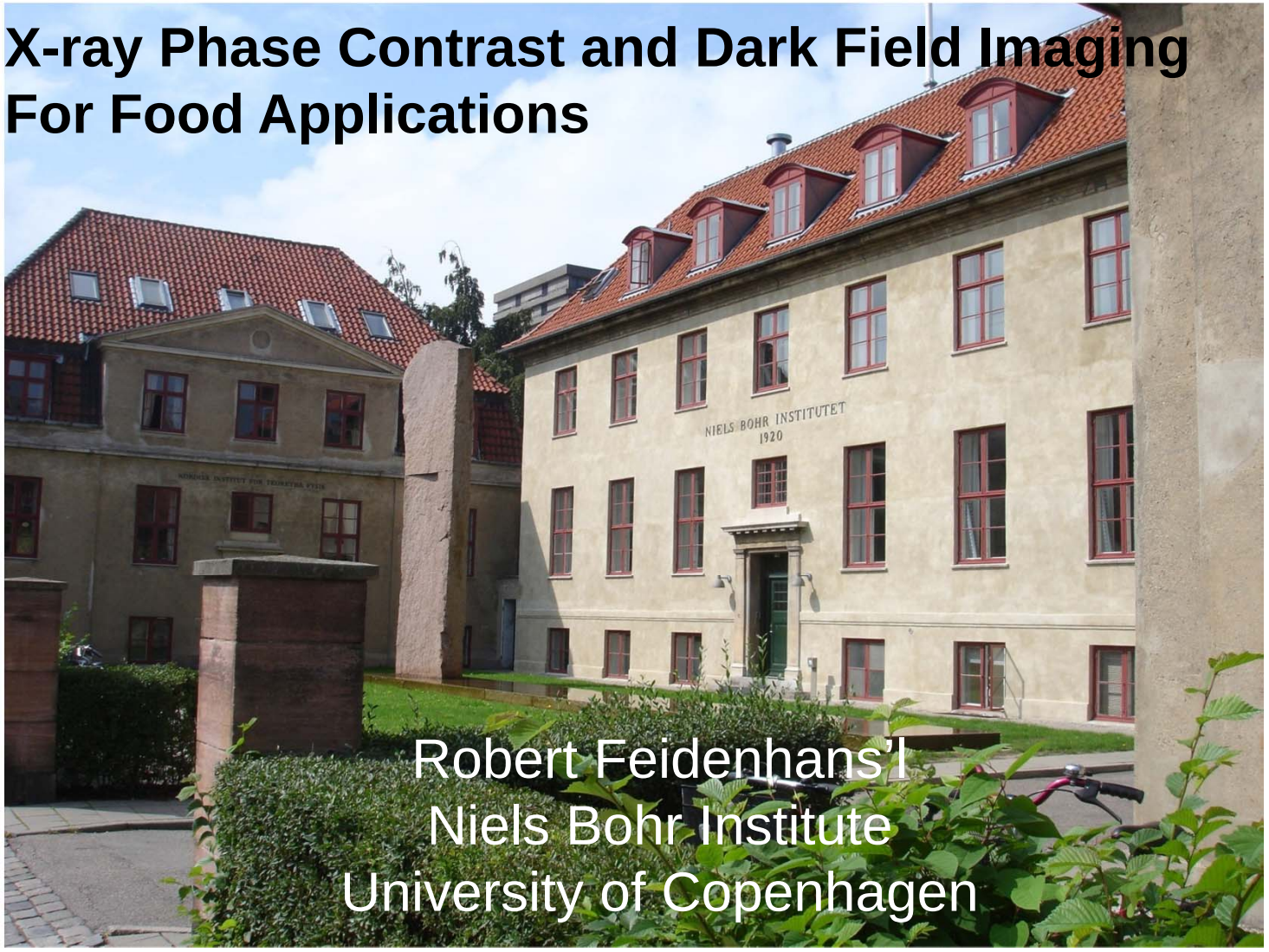
X-ray Phase Contrast and Dark Field Imaging For Food Applications



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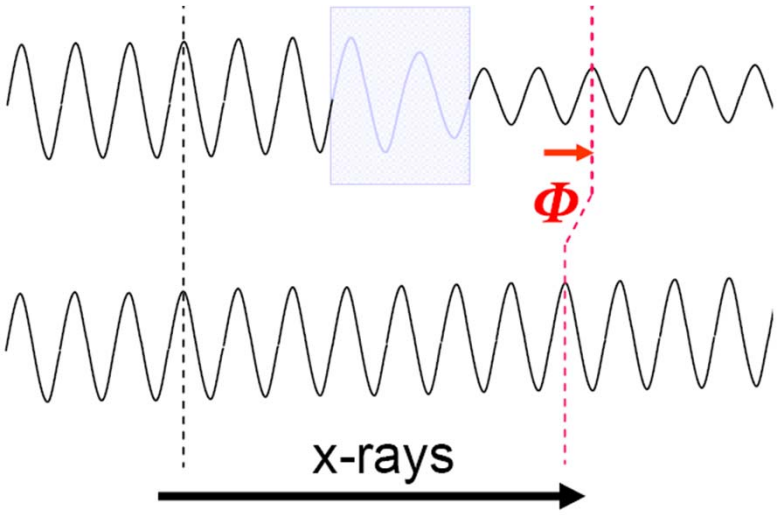
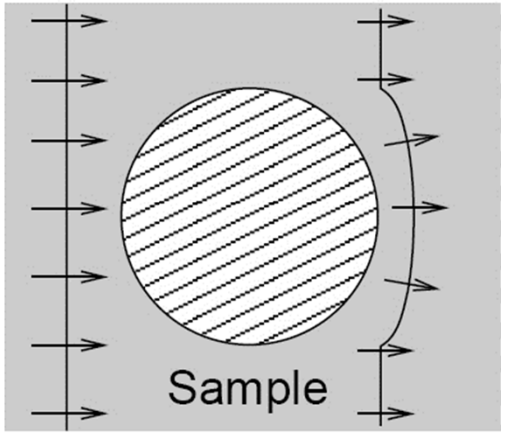
Niels Bohr Institute
University of Copenhagen

Outline

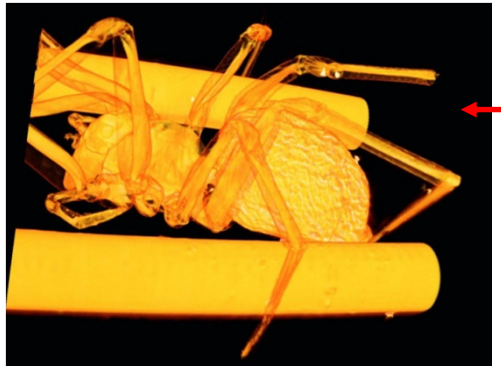
- Phase Contrast Imaging
- Motivation : Why food?
- Example : Pork, Sausages
- Detection of Foreign Bodies
- Food Quality
- Cracks and Joints
- Conclusion

The Refractive Index





Phase shift



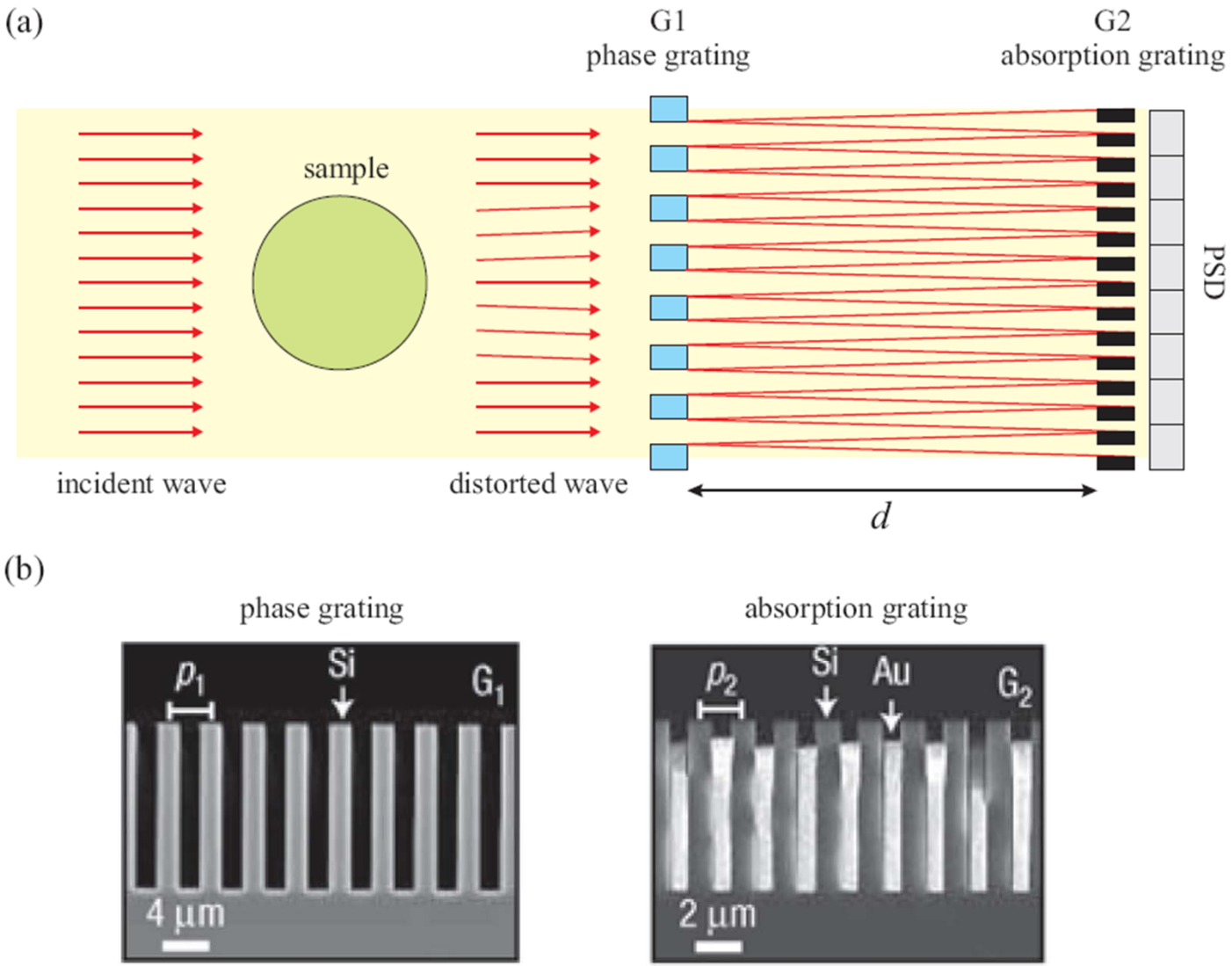
$$n = 1 - \delta + i\beta$$

$$\delta \sim 10^{-5} \sim \rho E^{-2} \sim Z E^{-2}$$

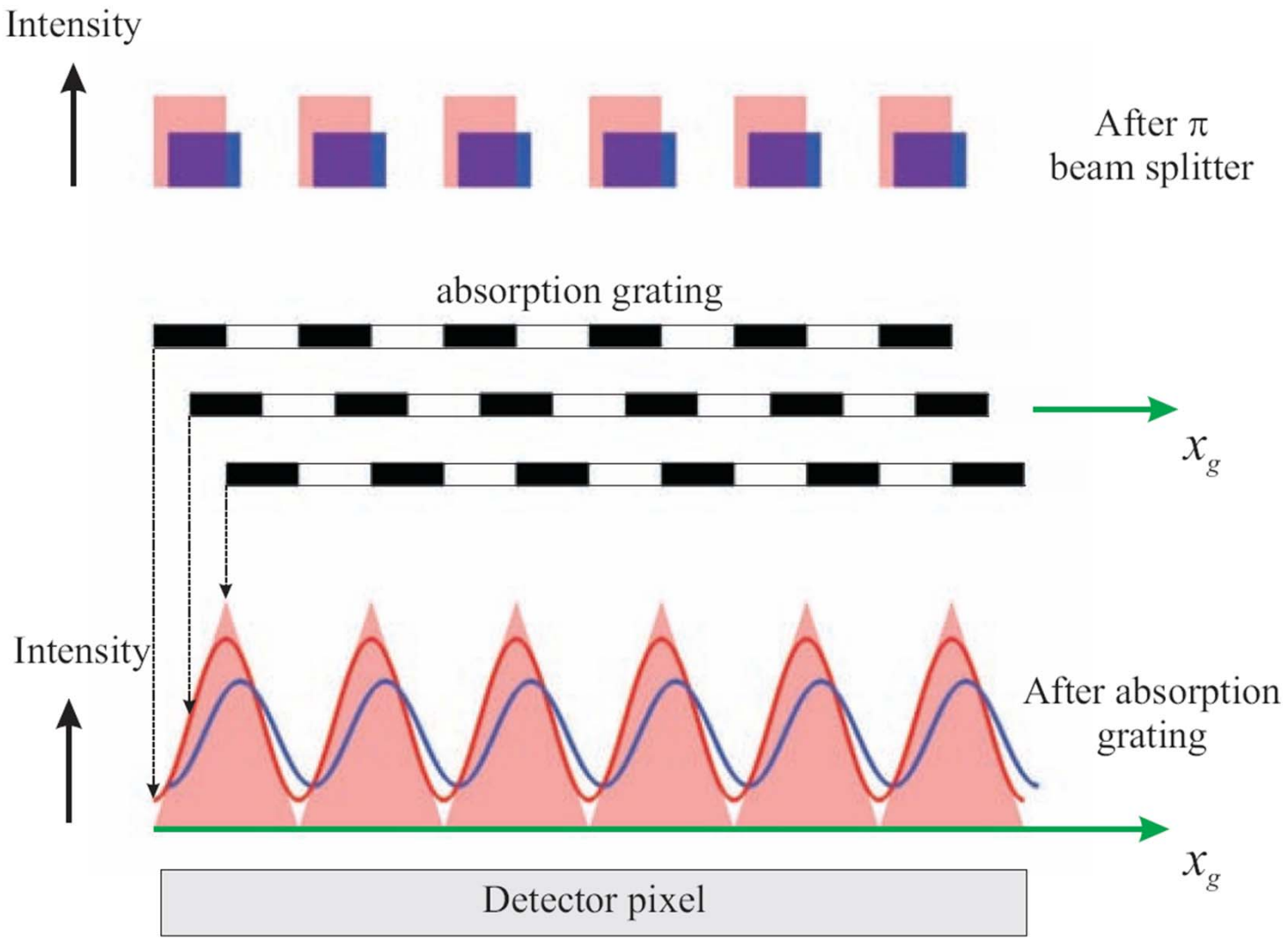
$$\beta \sim 10^{-8} \sim \mu E^{-1} \sim Z^4 E^{-4}$$

Absorption

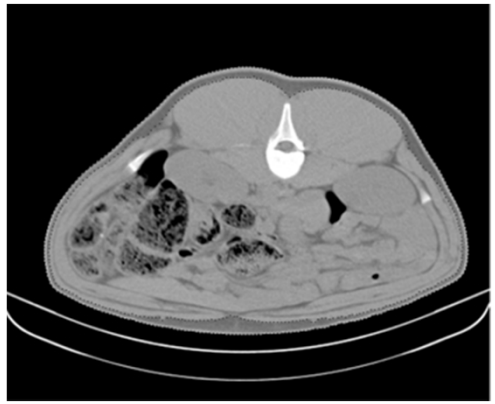
Grating Interferometry



Measuring Phase Fringes

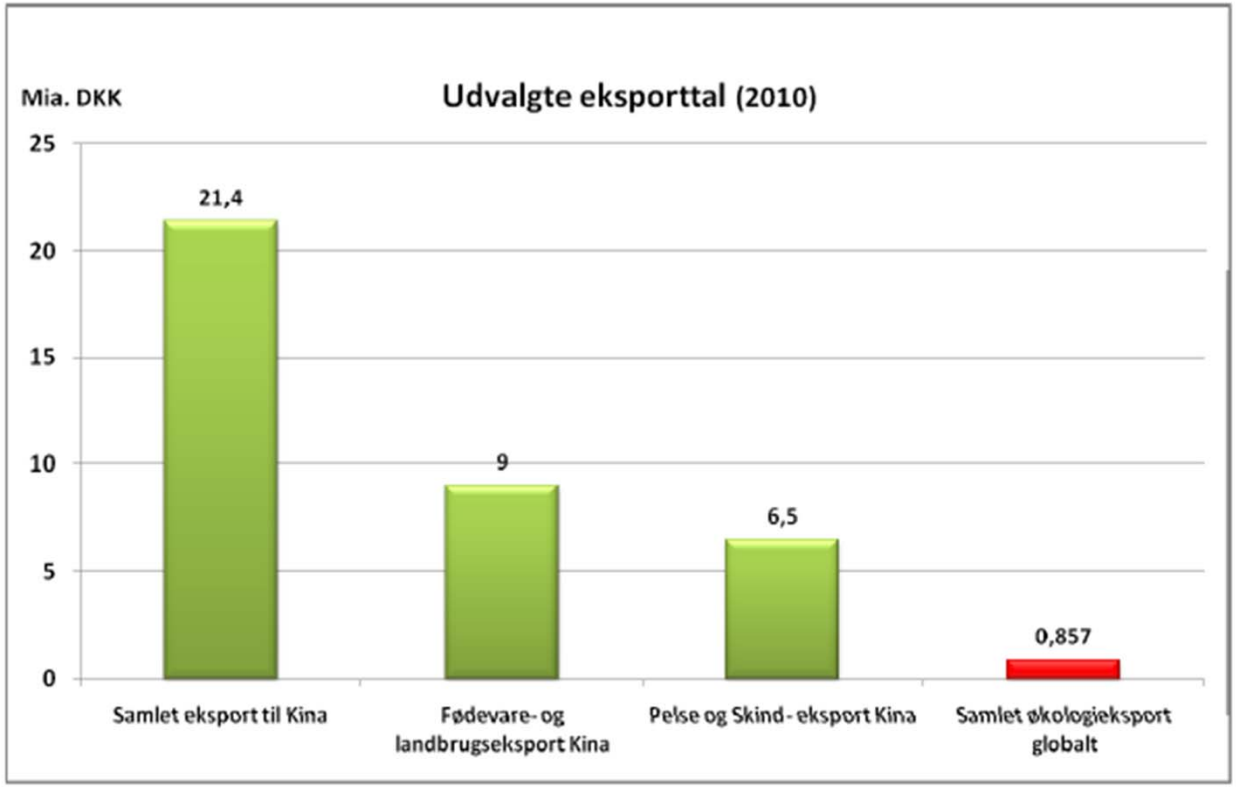


Why Food?



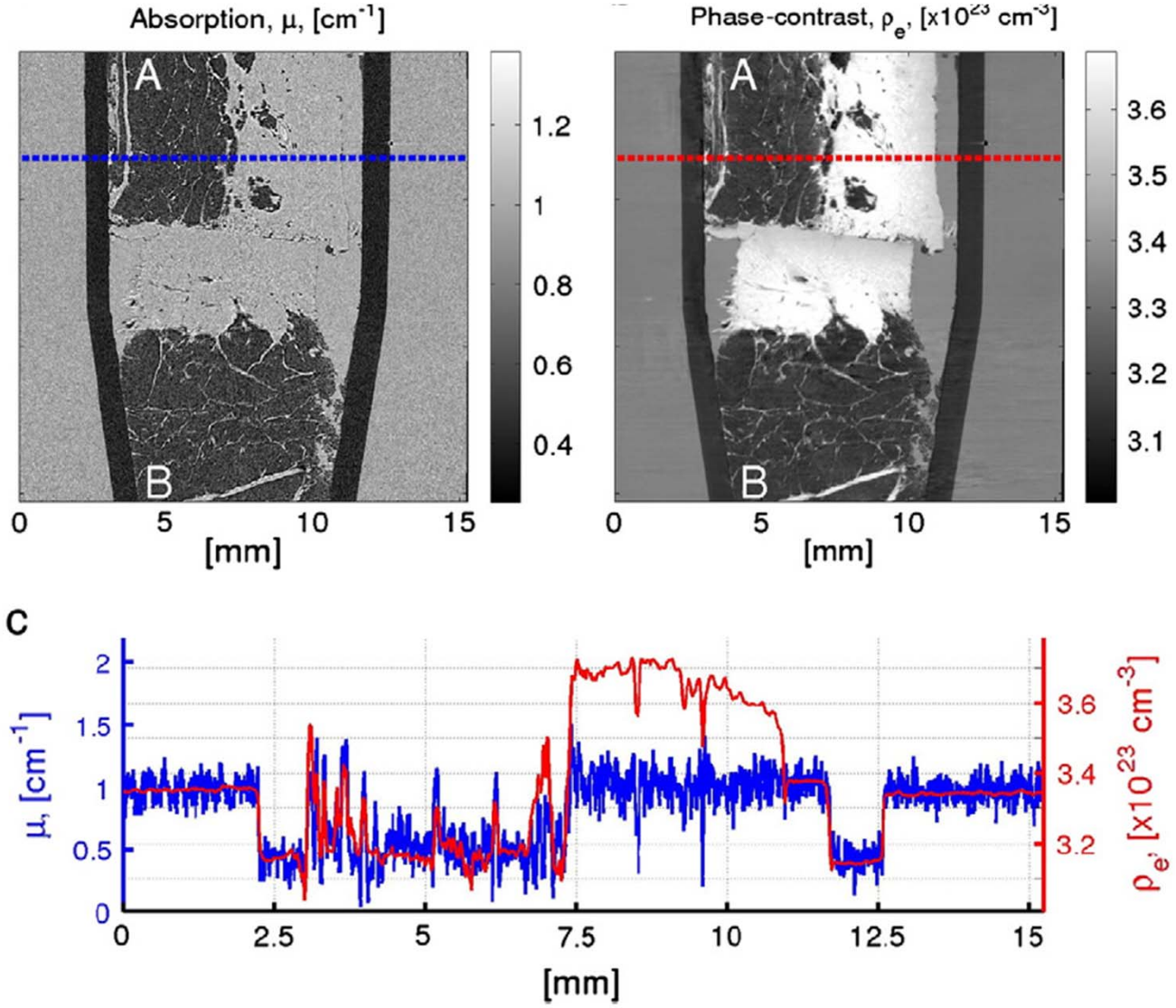
Danish Agricultural export 2010 : 13 Bio €

Globale behov og nicher…



Pork fat

Synchrotron Radiation ESRF ID19

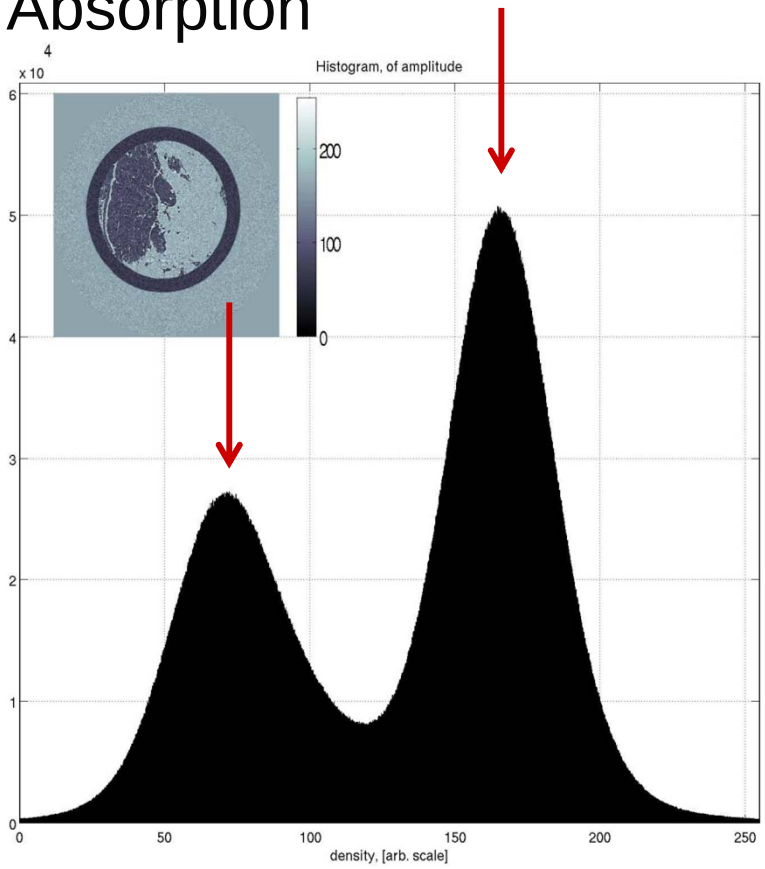


*Torben H. Jensen et al. Meat Science **88**, 379 (2010)*

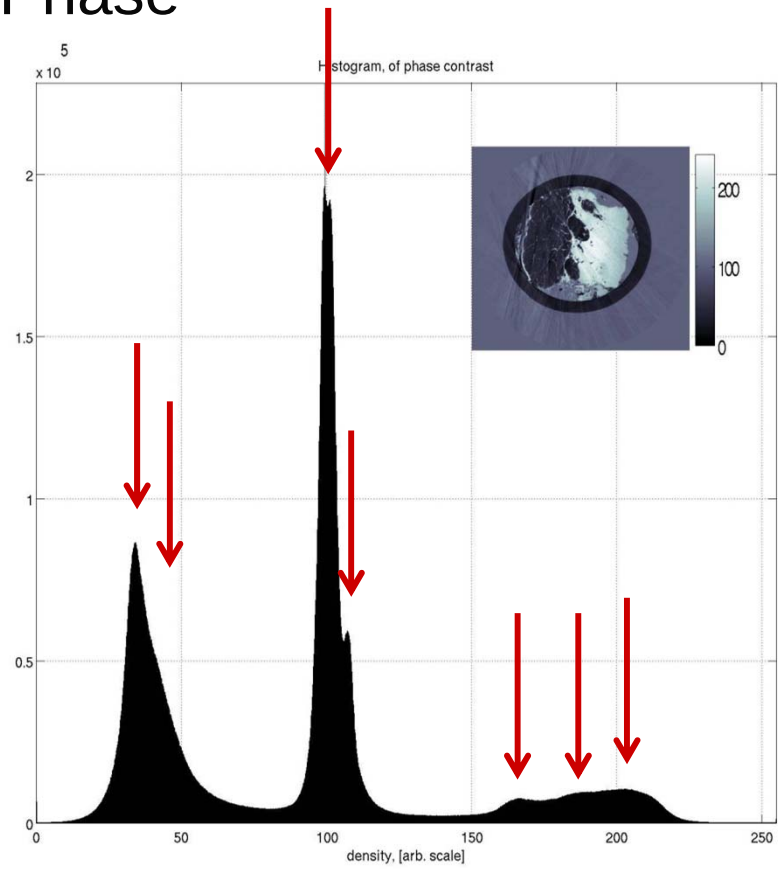
Histograms

Sensitivity ~ 3 mg/cm³

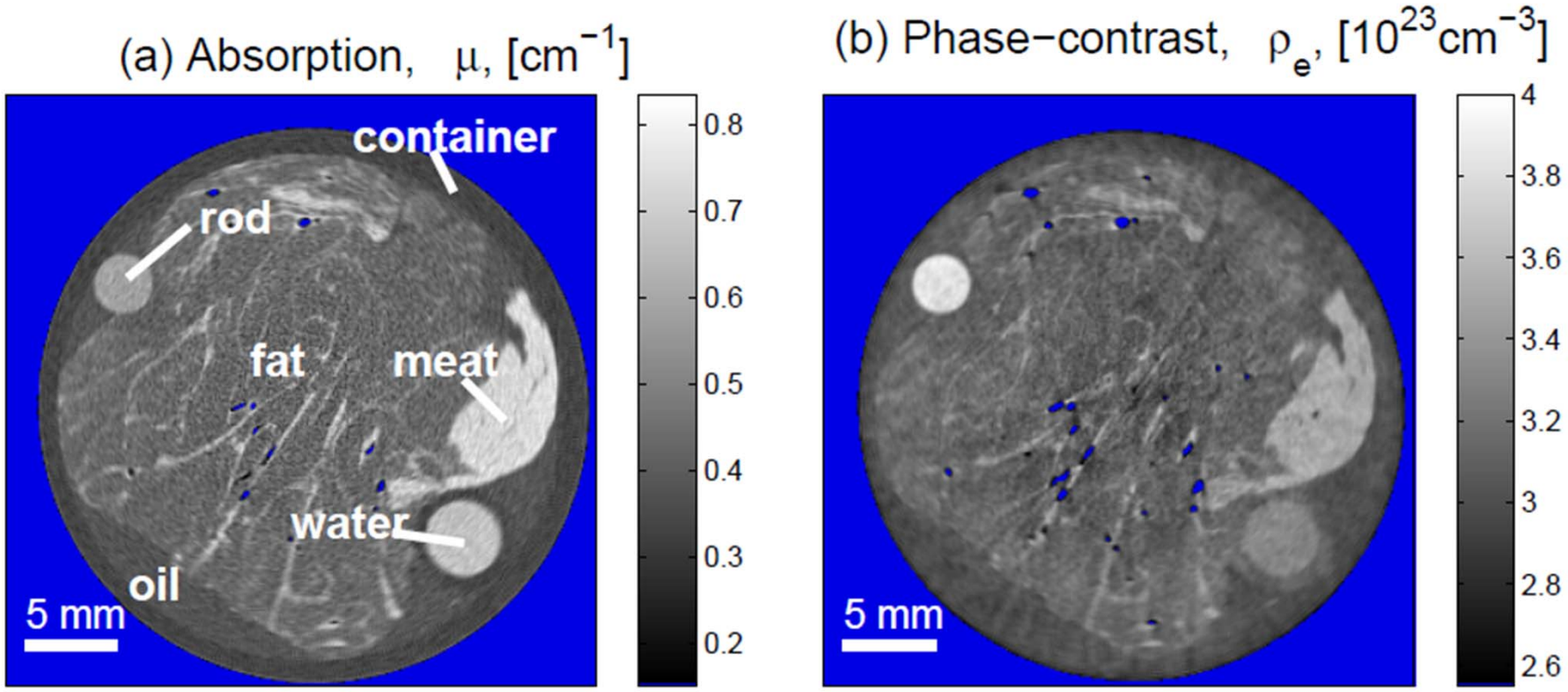
Absorption



Phase

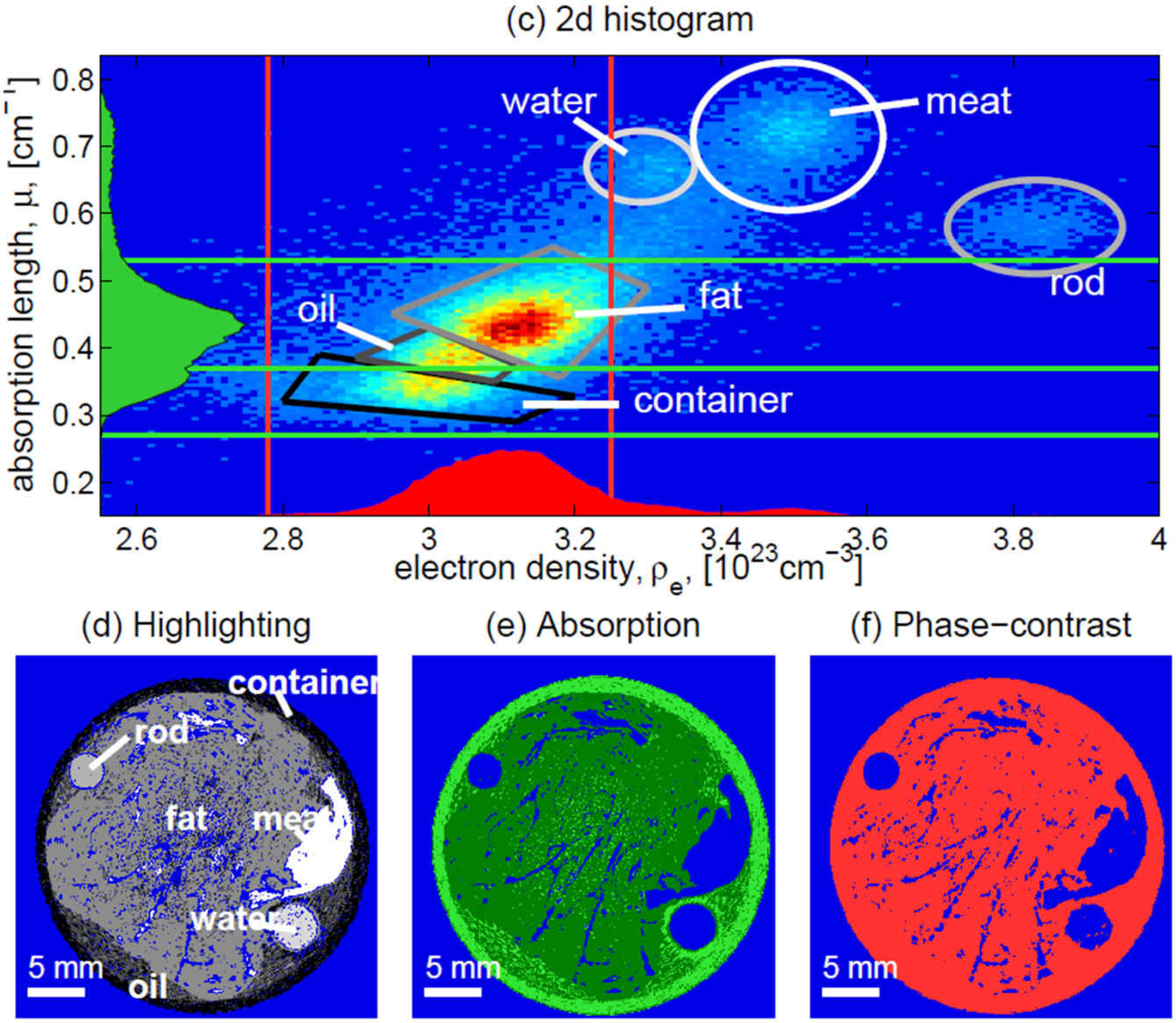


Can we do better : example pork

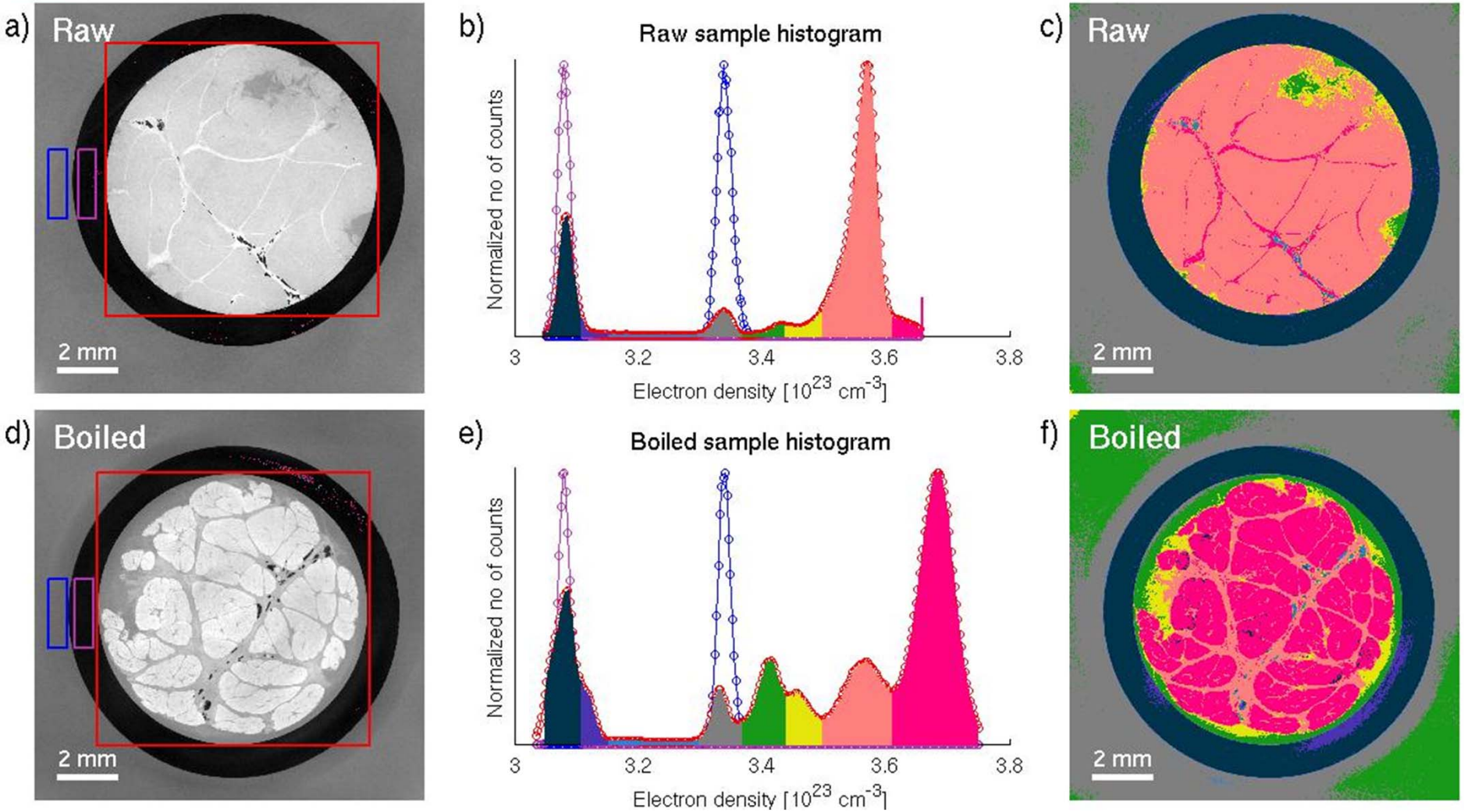


Data taken at TUM

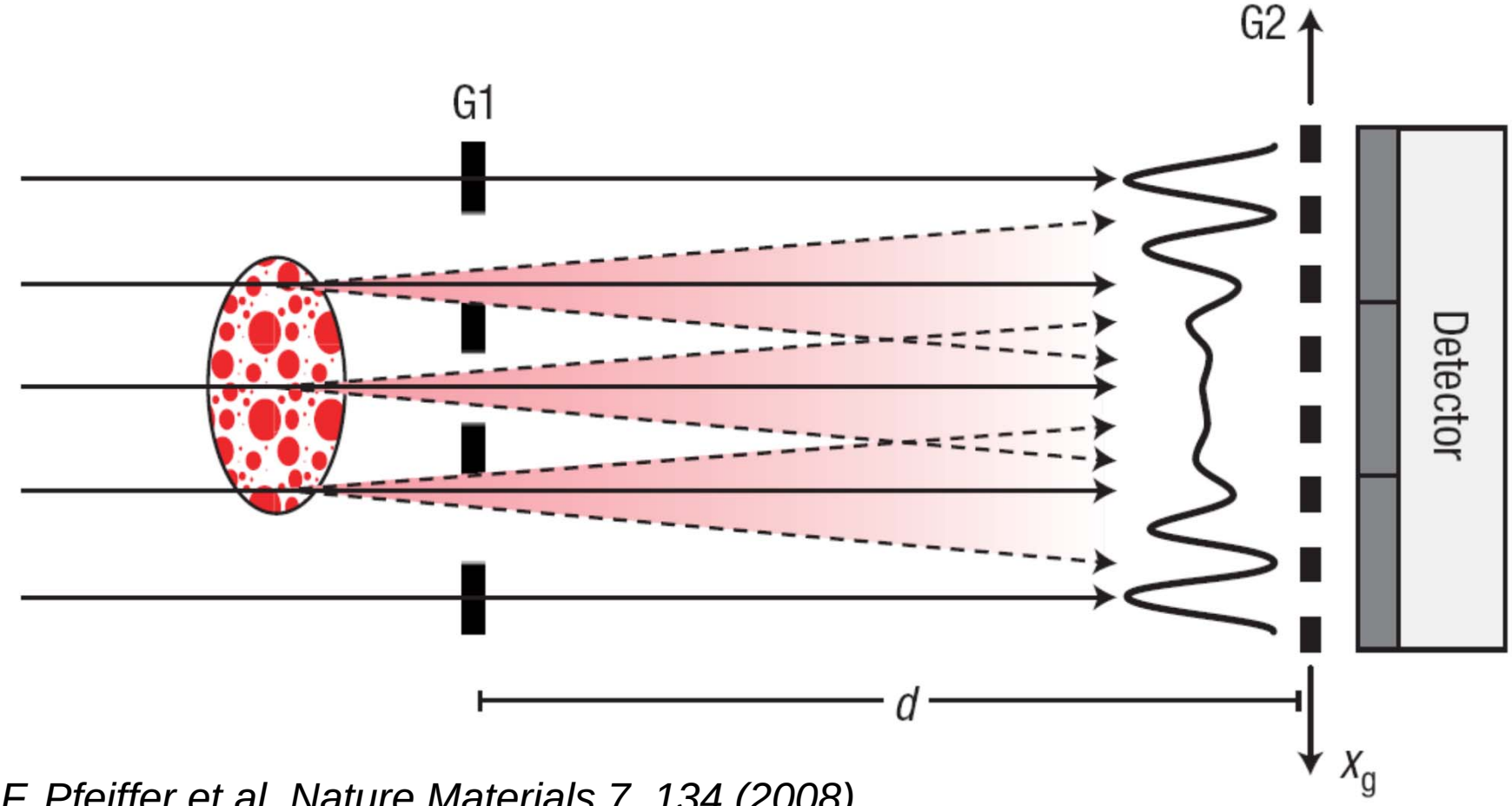
Multivariate segmentation



Phase contrast Meat @ TOMCAT

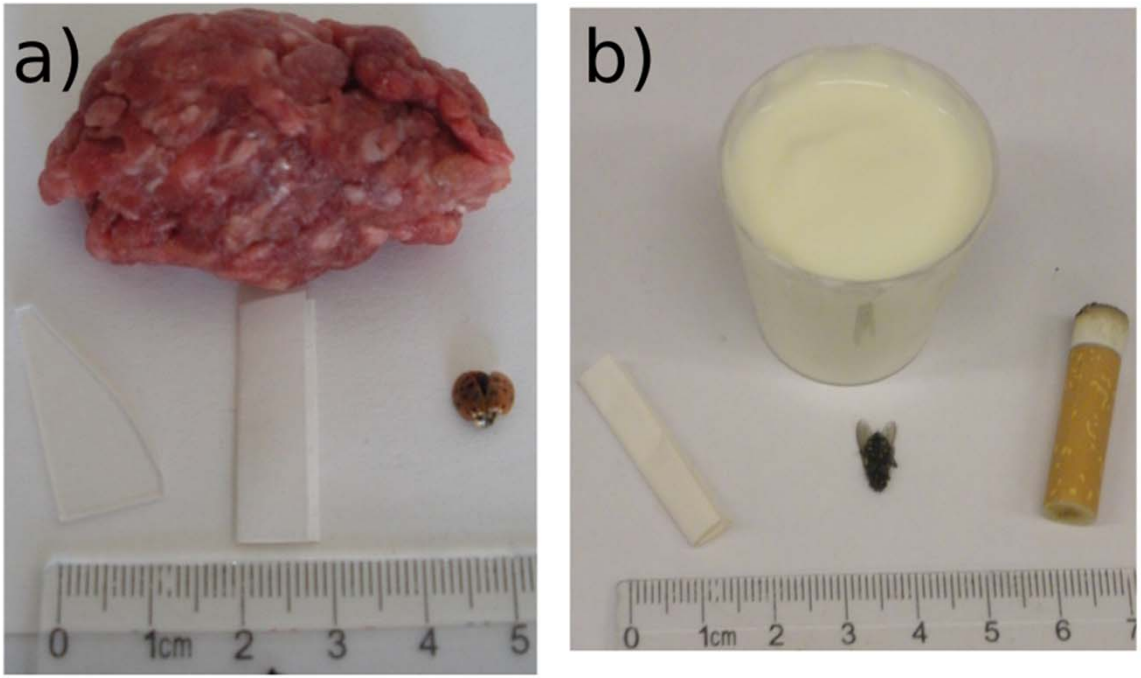


Dark Field Imaging



F. Pfeiffer et al. Nature Materials 7, 134 (2008)

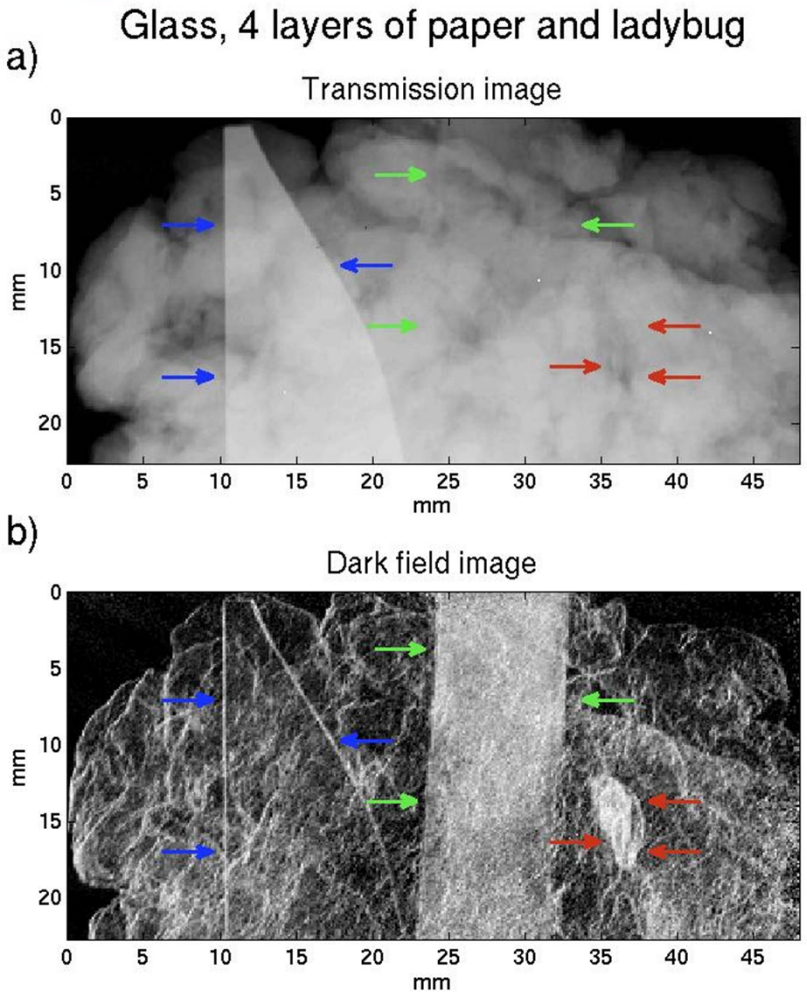
Detection of Foreign Bodies

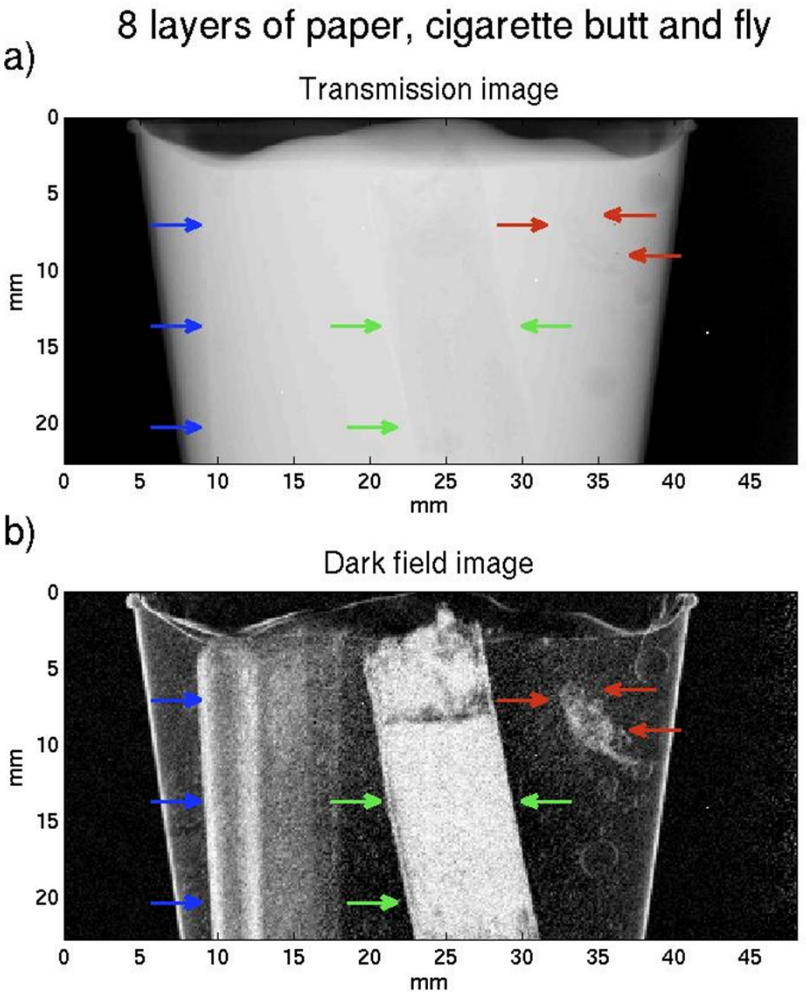


Mikkel Schou Nielsen at al. Food Control 30,531 (2013)

Foreign body detection

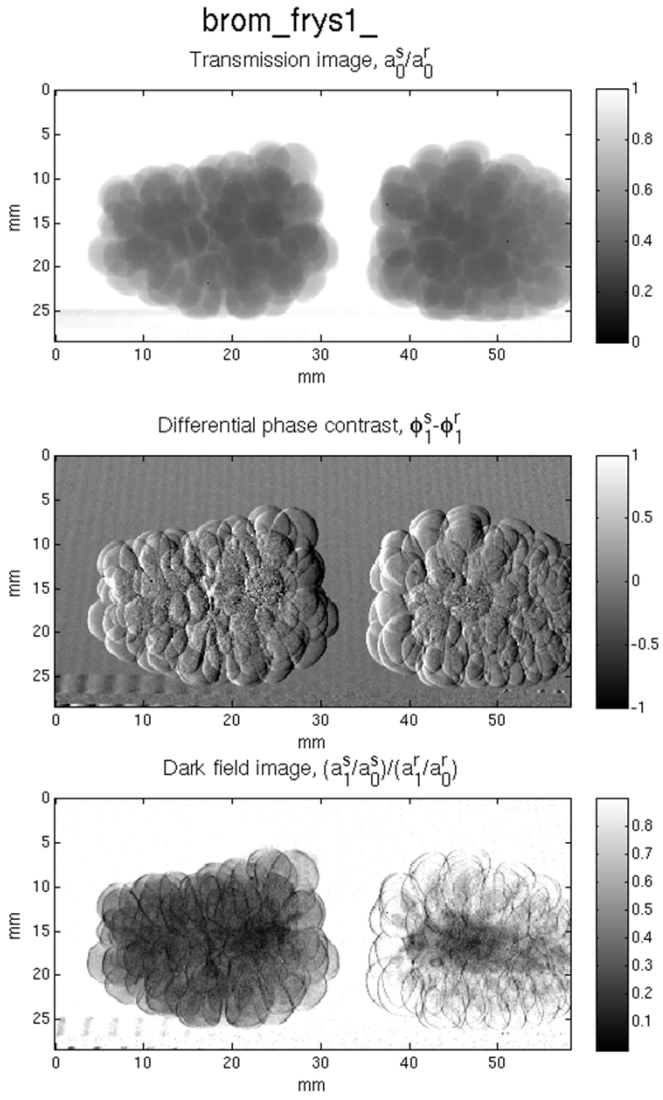
Transmission and Dark-field images

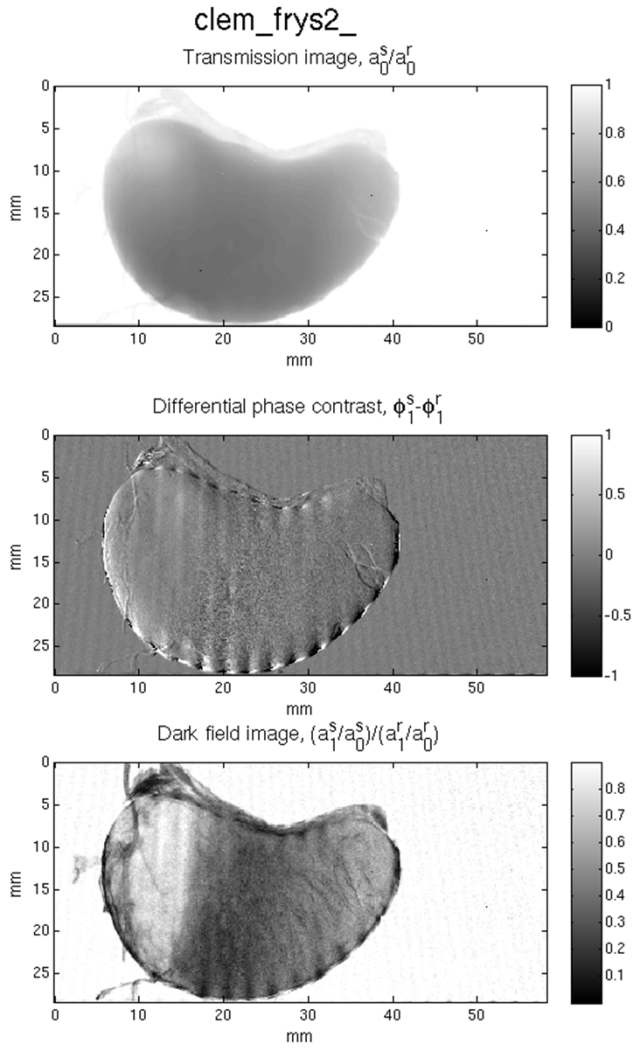




Mikkel Schou Nielsen at al. Food Control 30,531 (2013)

Frozen Fruits?

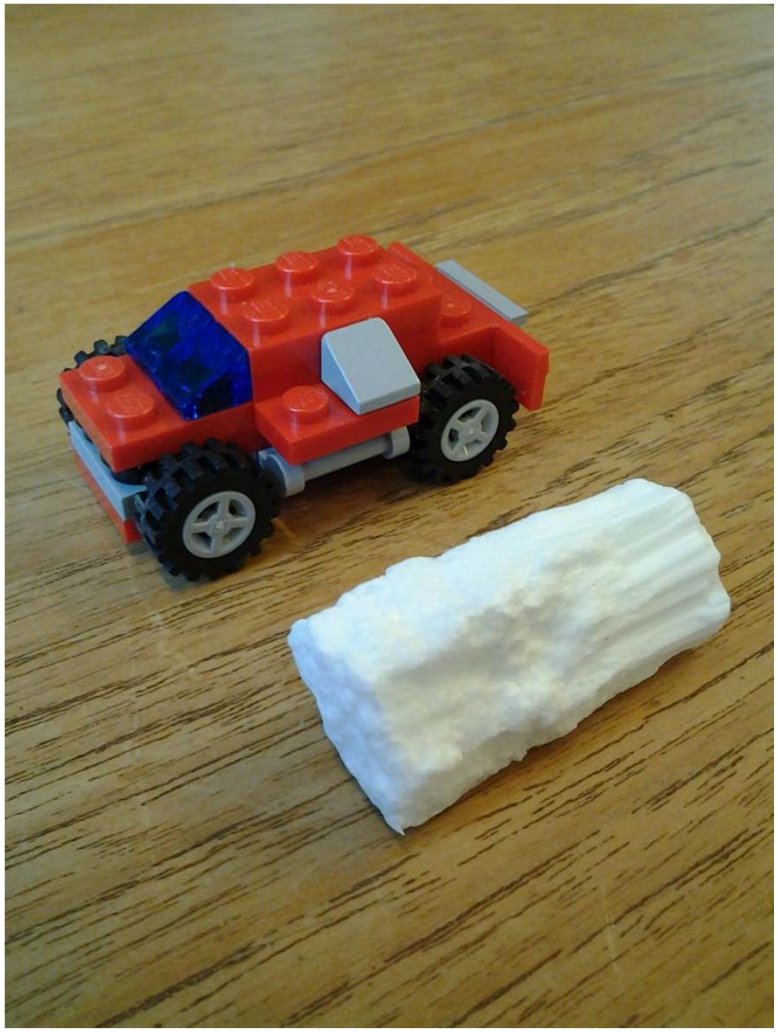




Can we see sub pixel joints and cracks ?

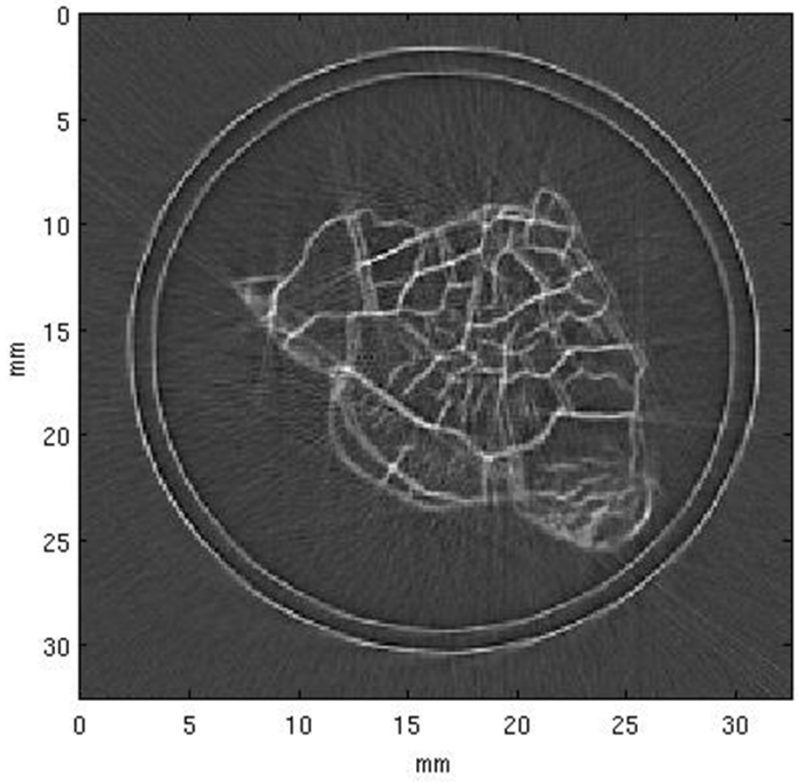
Legocar

Stearin: quick-frozen in liquid nitrogen to create cracks

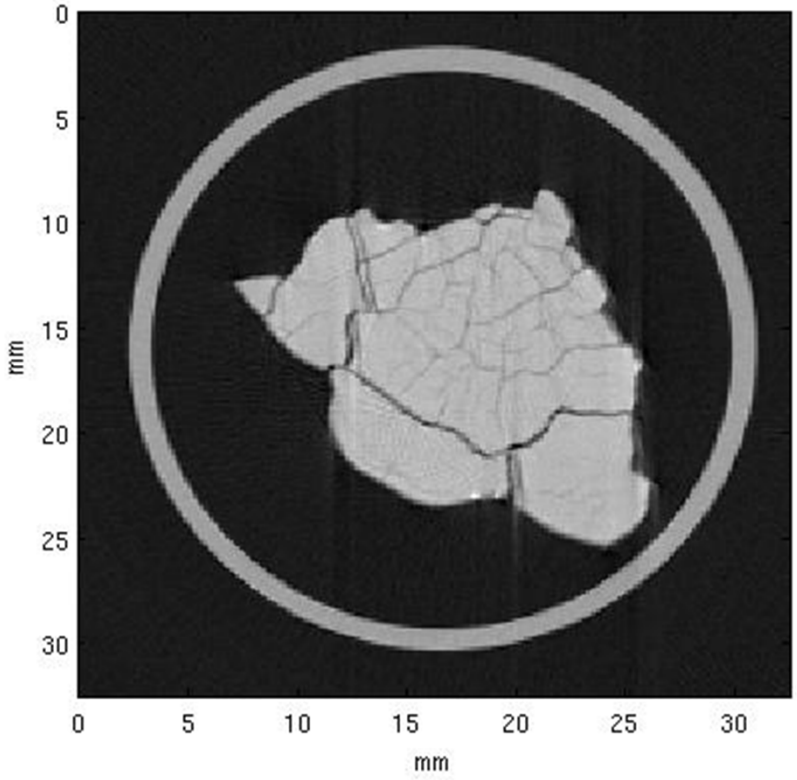


Stearin sample

Dark field

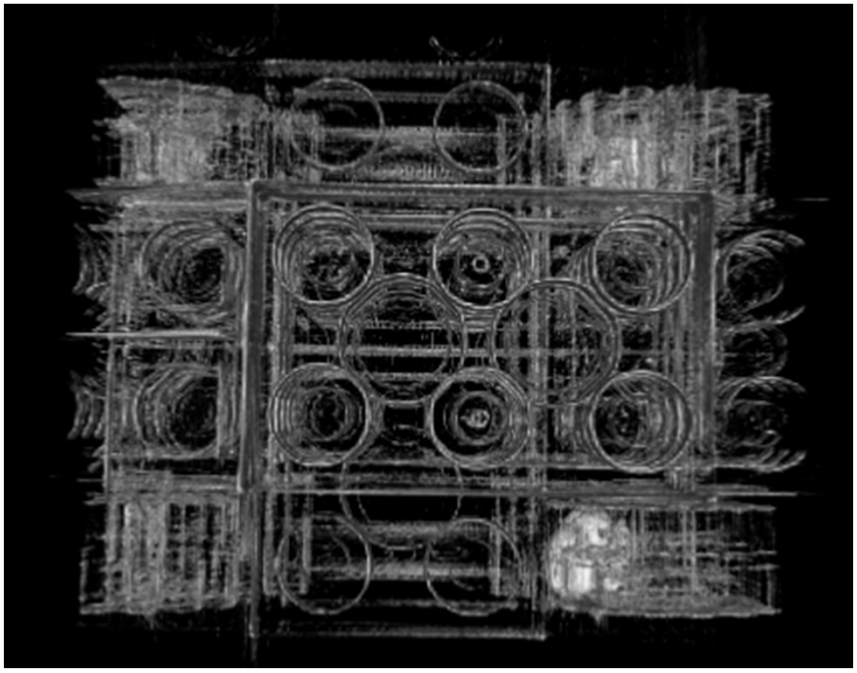


Absorption

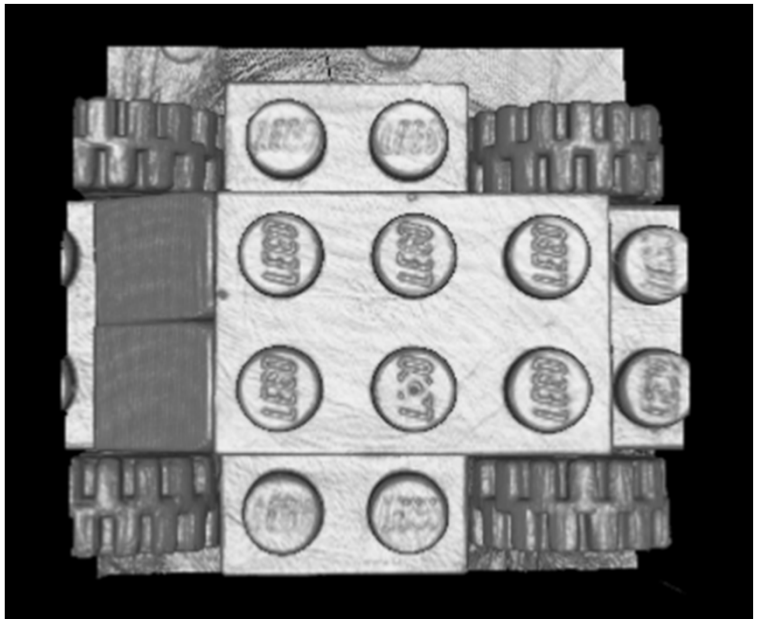


Legocar in 3D

Dark field



Absorption



Conclusions and Outlook

Phase contrast works for food
Better contrast possible
Excellent results at Synchrotrons

Implementation at lab sources
Quantification

More applications: Fish, pork, sweets, spring rolls, bakery,…

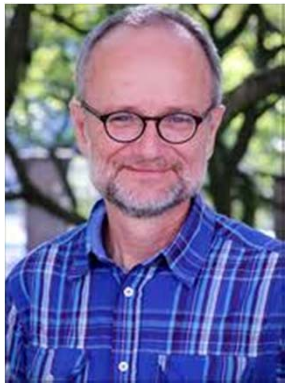
Conveyer belt solutions?
Image recognition and image processing?

MAX IV (X-ray) and ESS (neutrons) in Lund very soon

The NEXIM team

Computerpower, NBI

DMRI
Practical Experience



X-ray Technology,
NBI, TUM, Lund

Food Science Life

Tulip
Danish Crown
Arla
Lantmännen/Schulstad
Daloon
Tican
Toms
Bisserup Havbrug
Foss
InnospeXion

Image recognition IMM DTU

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Jürgen Mohr	KIT
Christian David	PSI

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DANSCATT

NEXIM

CIA CIT

Test Objects