IMPLEMENTATION OF A COMPUTED TOMOGRAPHY SYSTEM BASED ON A LABORATORY NANOFOCUS X-RAY SOURCE

Christian Fella[1], Jonas Dittmann[2], Dominik Müller[2], Tilman Donath[4], David Murer[4], Tomi Tuohimaa[3], Andrii Sofiienko[3], Simon Zabler[1,2] and Randolf Hanke[1,2]

1. Fraunhofer IIS, MRB, Würzburg, Germany
2. Universität Würzburg, LRM, Würzburg, Germany
3. Excillum AB, Kista, Sweden
4. DECTRIS Ltd., Baden-Dättwil, Switzerland

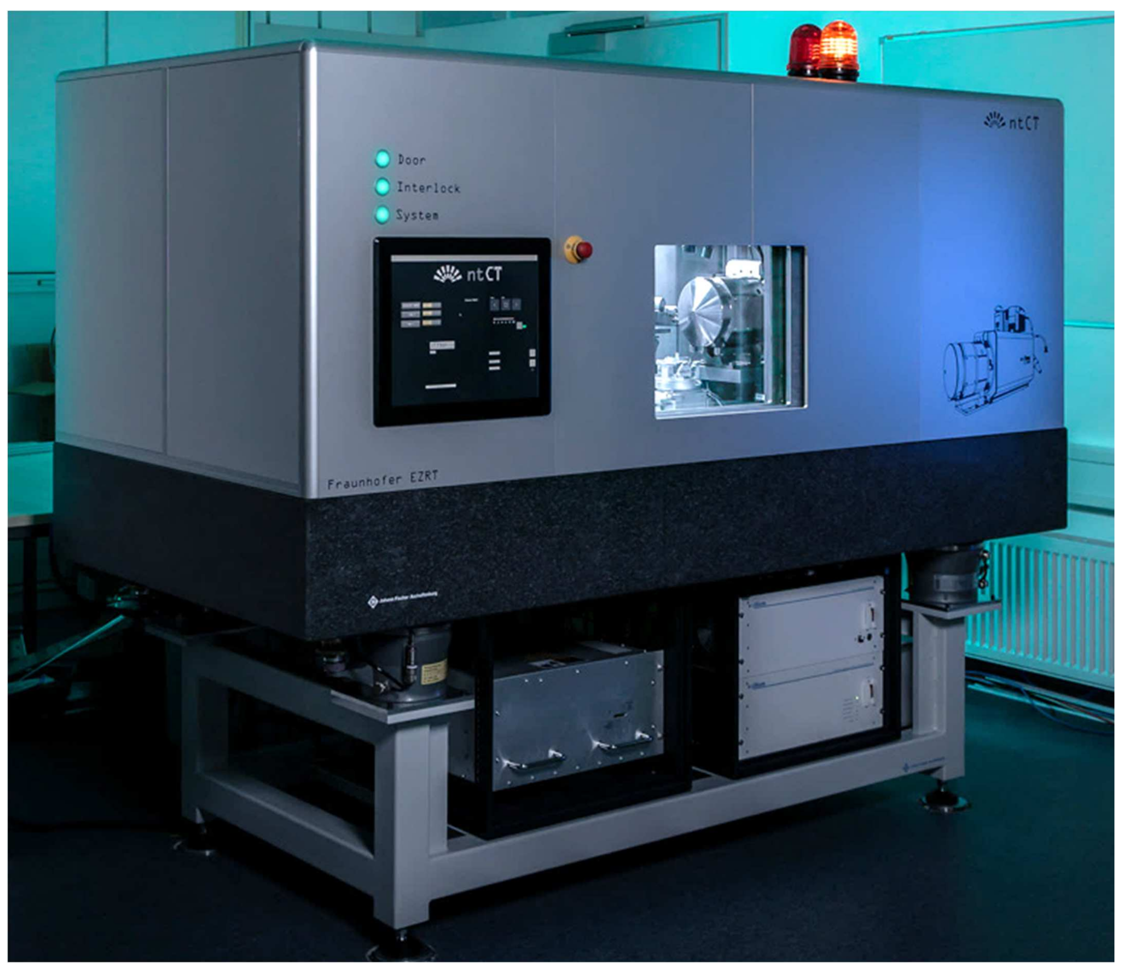
Motivation

- Resolution better than 300nm.
- Compact and simple to use, *e.g.* no alignment of optics [1, 2] and simple switching of the field of view → usage in industry possible.
- High energy to avoid beam hardening for asymmetric sample shapes (*e.g.* microchips with flat metallic layers).

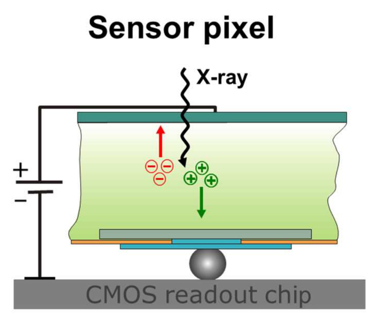
Setup

Standard projection geometry consisting of nanofocus X-ray source, sample manipulator and hybrid photon counting detector [3].

System size: 2.2m x 1.2m x 1.8m.



Picture of the prototype in our lab in Würzburg. The cabinet, made by our mechanical workshop, is mounted on an air-damped granite block. Temperature inside is stabilized with ±0.1°C. Precise mechanical stages for non-axial trajectories.



DECTRIS Eiger 450μm Si → Säntis 750μm CdTe

- 2070 x 514 pixel with 75μm pixel size.
- Hybrid photon counting, virtually zero noise.

Excillum's NanoTube

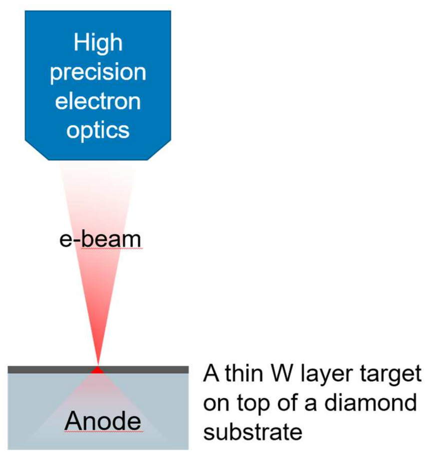
- 60kV.
- 300nm focal spot size with high spatial spot stability.

Geometry

- Source-detector distance: 300mm-650mm.

Reconstruction

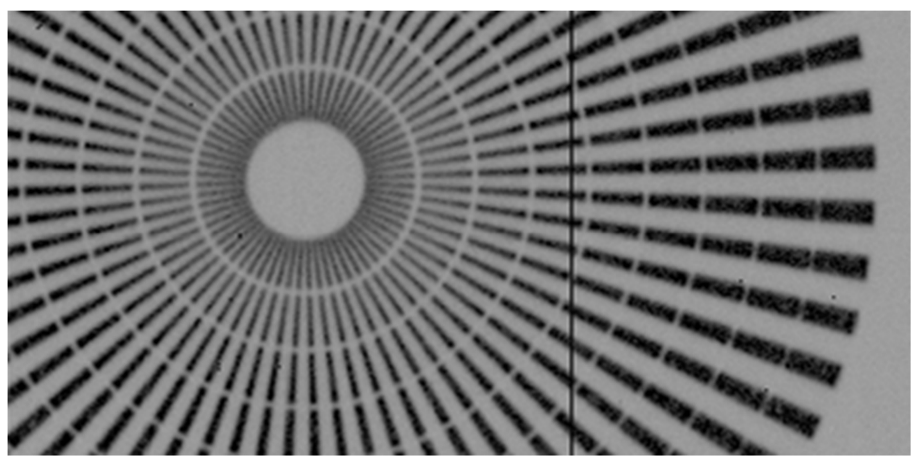
- Iterative SART & FBP.

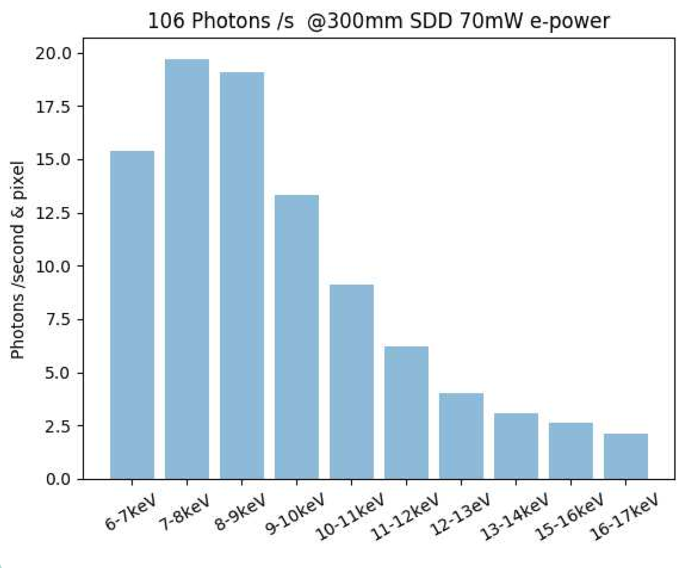


System Characteristics

Resolution test chart:

Siemens star made of tungsten.
Thickness: 1.5μm.
Smallest features: 150nm.
Pixel size: 140nm.





Counts per second and pixel for different energies for the Si 450μm detector.

The electron beam spot size was set to 380nm, the target electron power to 70mW.

Source-detector distance: 300mm, corresponding to a solid angle of 6.25E-8sr.

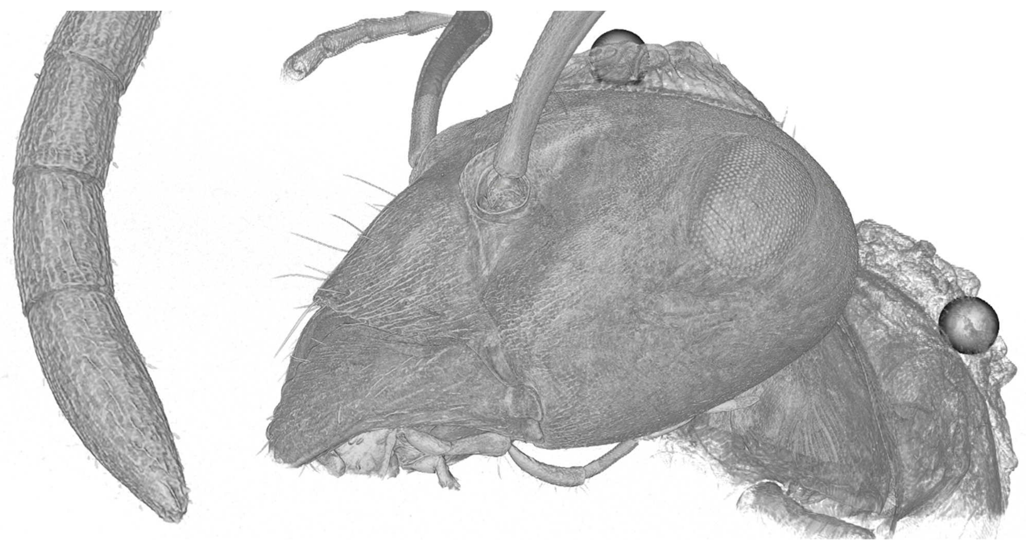
The decay of the counts represents the DQE of Si. CdTe will make high energy photons usable.

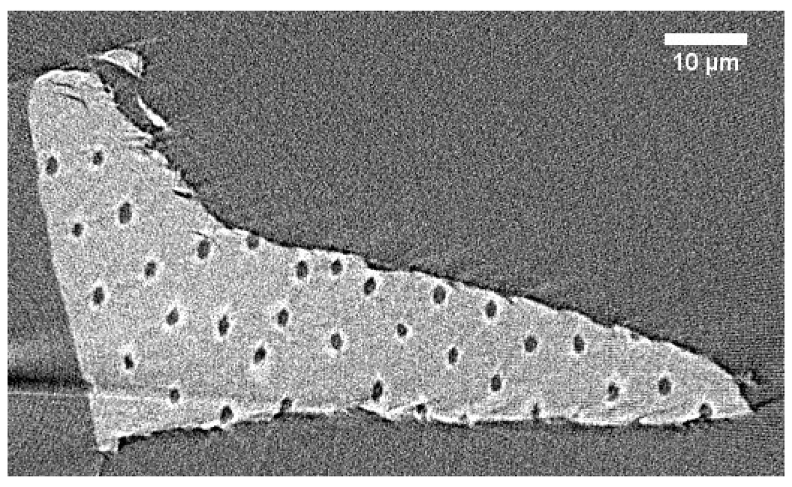
Results

3D rendering of an ant with glued markers.

200μm markers were used for automatic geometry finding and wobble correction.

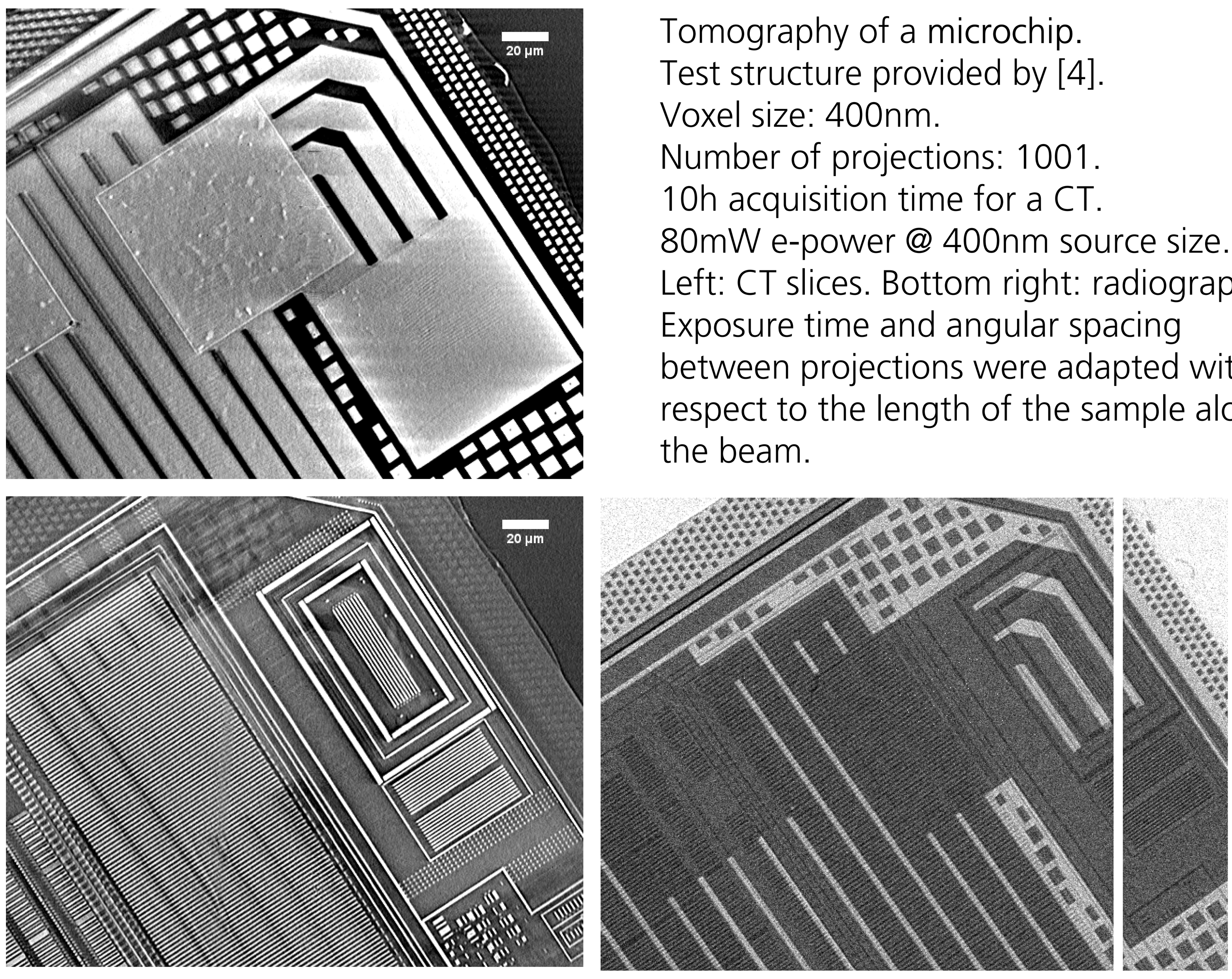
For smaller samples, markers with a diameter of 20μm are used.





Tomography slice of a human dentin. Dentinal tubules with a diameter of 1-2μm are clearly visible.

Voxel size: 184nm.
1401 projections.
Exposure time: 50s per image.
20h acquisition time for a CT.
70mW e-power @ 320nm source size.



Tomography of a microchip.
Test structure provided by [4].
Voxel size: 400nm.
Number of projections: 1001.
10h acquisition time for a CT.
80mW e-power @ 400nm source size.
Left: CT slices. Bottom right: radiograph.
Exposure time and angular spacing between projections were adapted with respect to the length of the sample along the beam.

Outlook

- Improved compensation of residual drifts by smaller tracers.
- Full automation of measurements and reconstruction.
- Implementation of non-axial trajectories for tomography, usable also for asymmetric sample shapes (*e.g.* MEMS).
- Dual-energy CT by using both energy thresholds of the CdTe Detector.

References

[1] A. Tkachuk *et al.,* Z. Kristallogr. 222 (2007).

[2] C. Fella *et al.,* Review of Scientific Instruments 88 (2017).

[3] C. Brönnimann and P. Trüb, Synchrotron Light Sources and Free-Electron Lasers, Springer (2015).

[4] B. Yan, L. Li, X. Xi, Y. Han, National Digital Switching System Engineering and Technological R&D Center, Zheng Zhou, Henan, China.

IN COOPERATION WITH

Julius-Maximilians-UNIVERSITÄT WÜRZBURG

excillum REDEFINING THE X-RAY TUBE

DECTRIS

Fraunhofer IIS

christian.fella@iis.fraunhofer.de