Compact X-Ray Phase-Contrast Small-Animal CT Scanner: Challenges and Results

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Motivation

Phase-sensitive hard x-ray imaging can considerably improve soft-tissue contrast in biomedical samples compared to absorption-based methods [1,2,3]. Towards clinical implementation of the imaging modality, different bench top setups with polychromatic sources have been discussed and realized. As a further step, we have developed a grating-based, compact, preclinical phase-contrast small animal CT scanner with a rotating gantry, based on a three grating Talbot-Lau interferometer [4].

Experimental Setup

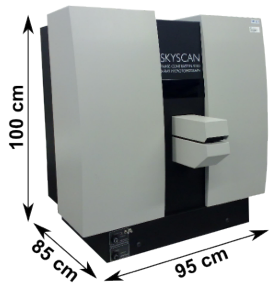

Fig 1: Picture of the developed scanner

Features:

- FOV (sample) ≈ 5 cm round
- Three-grating Talbot-Lau interferometer
- Compact rotating gantry (73 cm total length)
- Cone-beam reconstruction (absorption, phase and dark field contrast)
- Animal anesthesia and monitoring

Technical Parameters:

Detector: Hamamatsu flatpanel, 50 µm pixel, GOS scintillator
X-Ray Tube: focal spot 50 µm round, tungsten, 40 W, 50 kV
Source Grating G0 (Au): period 10 µm, depth 35 µm
Phase Grating G1 (Ni): period 3.24 µm, depth 4 µm
Analyzer Grating G2 (Au): period 4.80 µm, depth 25 µm
Distance G0-G1: 300 mm
Distance G1-G2: 145 mm
Fractional Talbot Distance: 1st
Design Energy: 23 keV

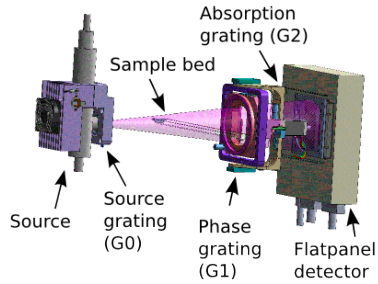

Fig 2: Schematic sketch of the rotating gantry

Stability

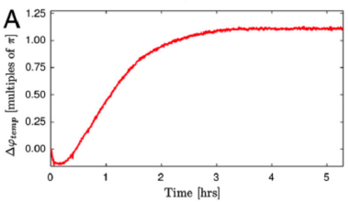

Fig 3 A: Temperature Drift [5]
Heat, generated by the x-ray source leads to the thermal expansion of G0 mounting and causes phase drift after the power is switched on.

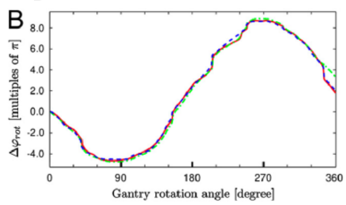

Fig 3 B: Rotation Drift [5]
The force of gravity and associated bending of support structures and play in the gears of the grating allignment motors cause a phase shift..

Phase Recovery

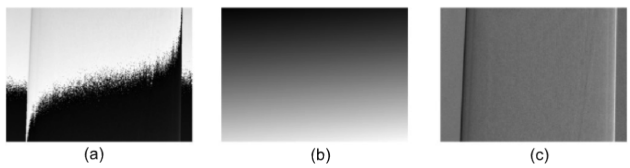

Fig 4: Phase Ramp [5]
Phase artifacts are caused by minimal changes in the grating allignment during gantry rotation. (a) DPC projection image exhibiting an artificial phase ramp. To compensate for this artifact, a plane is fitted to the phase projection image (b) and consequently subtracted. (c) Corrected projection.

Imaging Results

In vivo Mouse Projection

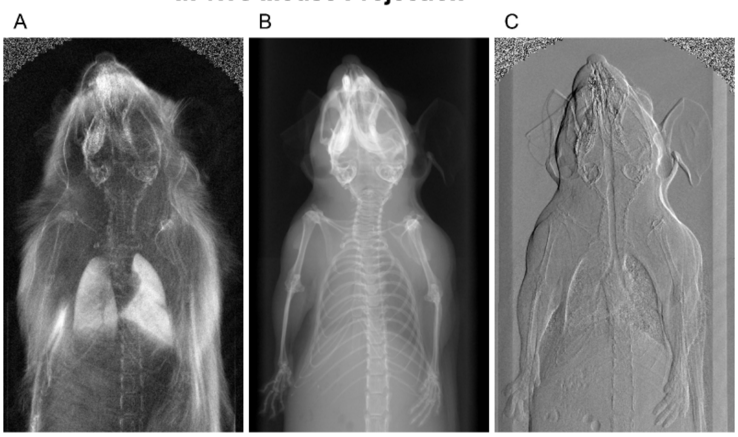

Fig 5: In Vivo X-Ray Dark Field, Absorption and Phase Contrast Projection of a Mouse
Projection image of a mouse, acquired in vivo. Animal dose is approximately 7.8 mGy. (A) Dark Field Scatter-Contrast (B) Conventional Absorption (C) Differential Phase-Contrast. X-Ray scattering on lung alveoli leads to a strong signal in the dark field. Bones have a high absorption coefficient and show a high contrast in absorption. Trachea appears distinctly in differential phase-contrast, due to the sharp edges in the tissue morphology.

Acquisition Parameters:
31 kVp, 516 µA, 10 s exposure per step, 10 phase steps

Fixated Pork Tissue

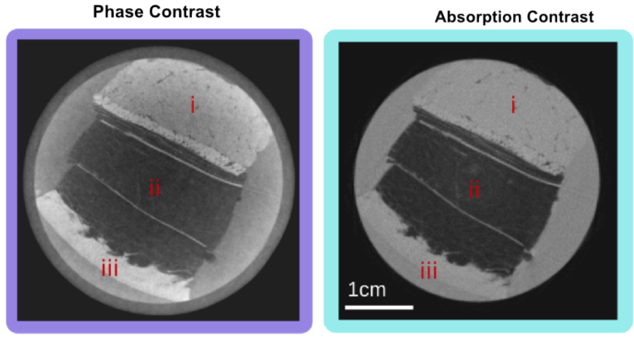

Fig 6: Phase Contrast and Absorption CT Slices of Pork Tissue [5]
Slices of a CT scan of formalin fixated pork rind. In phase contrast (left) the different tissue composites can be clearly separated: (i) muscle, (ii) subcutis, (iii) dermis/epidermis. In absorption (right), the contrast between the different tissues is strongly reduced and only the subcutis can be clearly identified.

Acquisition parameters:
40 kVp, 750 µA, 1500 projections, 5 s exposure per step, 8 phase steps

Conclusion

We have demonstrated the feasibility of phase-contrast imaging with a rotating gantry, consisting of a polychromatic source and a three-grating Talbot-Lau interferometer. It was shown that phase artifacts, caused by the gantry rotation can be corrected. A CT scan of pork rind was acquired, showing more details in phase-contrast than in conventional absorption. A mouse in vivo projection was acquired with a low dose and revealed the complementarity of the three imaging modalities.

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