Experimental Determination of the X-Ray Refractive Index of Teeth

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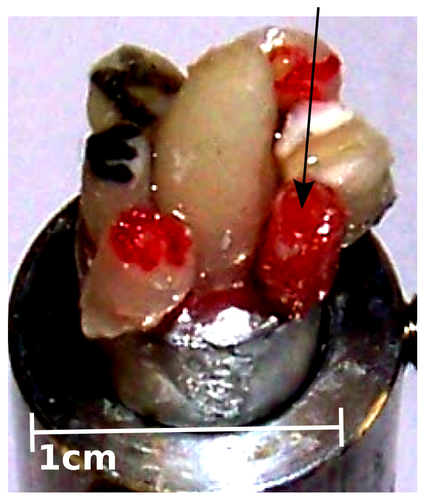
1. Motivation

X-Ray Imaging is a fundamental technique to image materials non-destructively. Recent developments have made it possible to determine the exact **X-Ray index of refraction (n=1-δ+iβ)** and open up new possibilities to better understand tissue organization in 3D using tomographic methods.
For mineralized tissues such as teeth, detailed knowledge of the spatial arrangement and packing of mineral is necessary for understanding function and pathology and also for finding new ways to fix or replicate these important load-bearing structures.
In these calcium-phosphate based (apatite) tissues, **β is up to 2-3 order smaller than δ** depending on energy and atomic number. Thus by independently measuring and validating precise values of both components of the X-Ray refractive index of apatite, important variations in the spatial arrangement and composition can be revealed [1,2]. Further, an accurate δ/β ratio is crucial for retrieving X-Ray holotomography and 3D micron/nano holo-CT. Thus accurate estimates of δ and β are needed to best quantify cutting-edge 3D SR-CT data with resolutions below the micrometer length-scale [3].

Reference material: PVC



Sample

MAIN GOAL: determination of the refractive index of tooth at different energies using x-ray grating interferometry

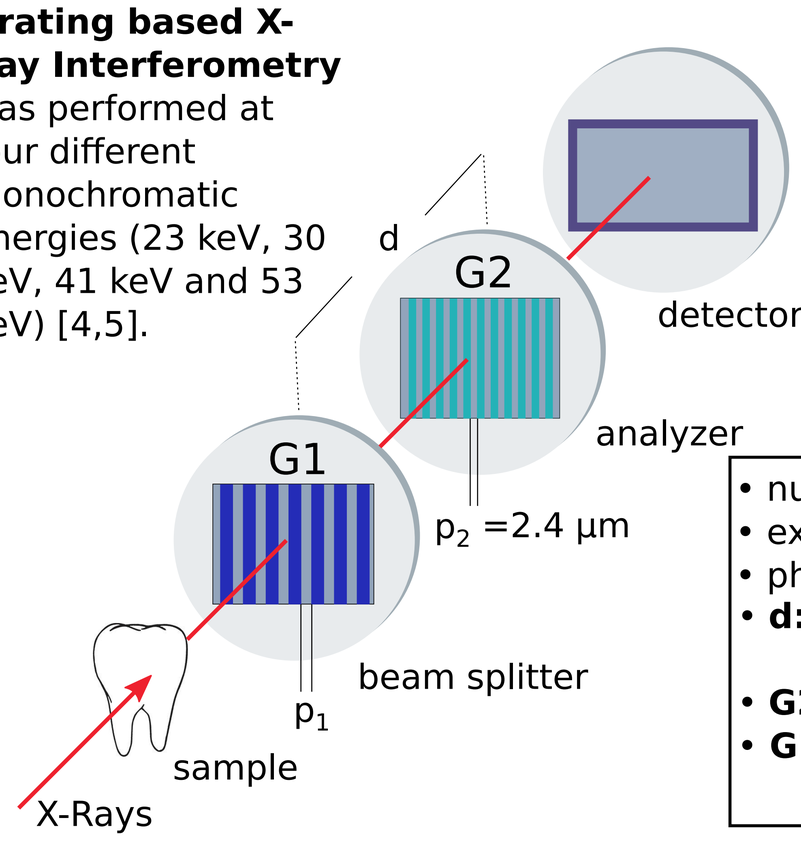
2. Synchrotron Radiation

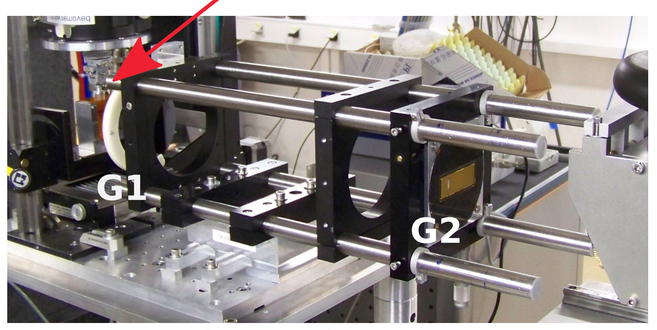
The experiment was performed at the imaging beamline ID19 of the **European Synchrotron Radiation Facility** in France.

Advantages of Synchrotron Radiation:
1. **intense source** of X-Rays with a **wide energy range**
2. **monochromaticity** (no beam hardening effect, quantitative analysis possible)
3. **small source size** at a distance of 150 m from the detector (parallel beam, coherence)

3. X-Ray Grating Interferometer

Grating based X-Ray Interferometry was performed at four different monochromatic energies (23 keV, 30 keV, 41 keV and 53 keV) [4,5].



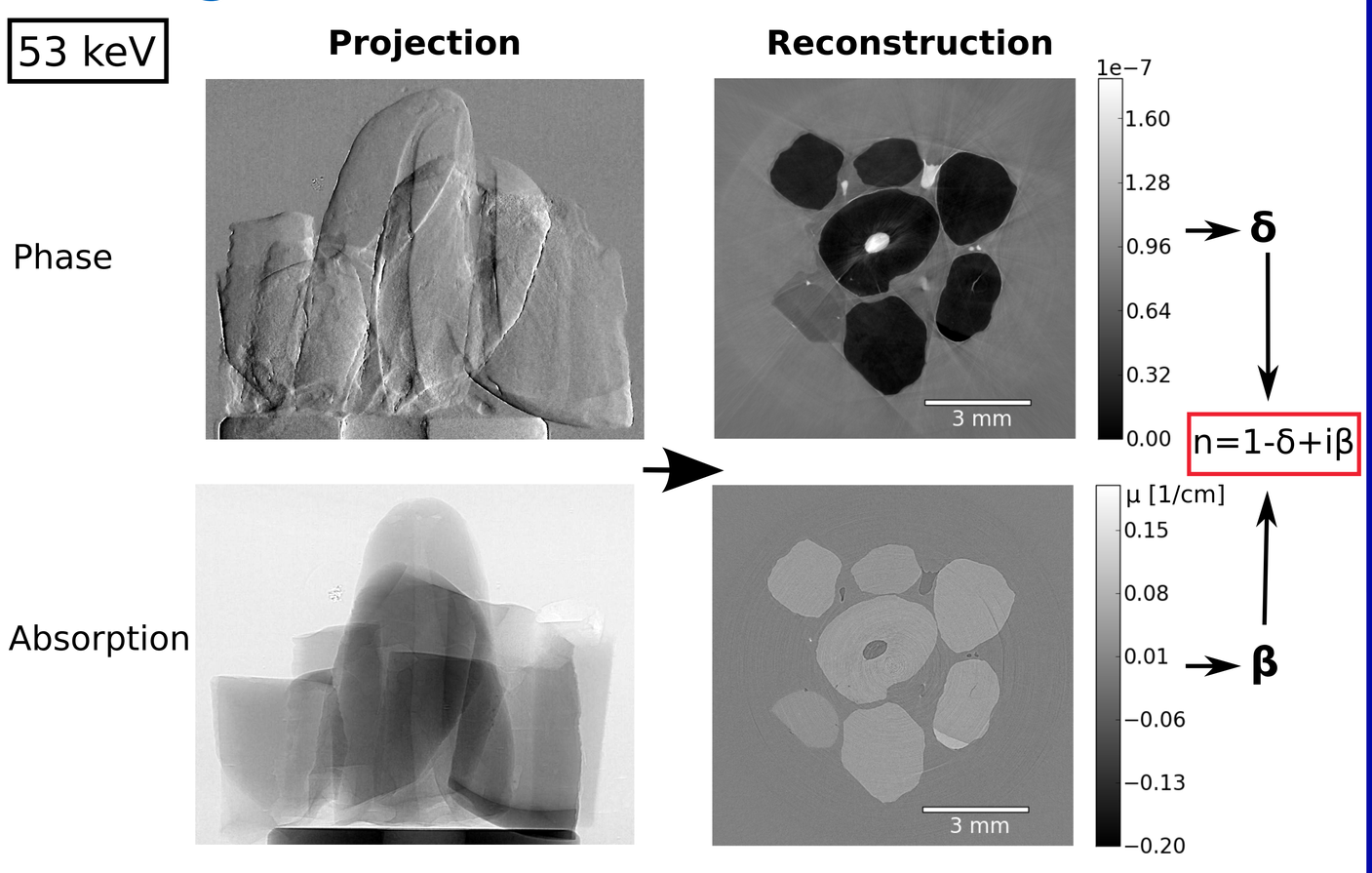


Experimental setup at ID 19

- number of projections: 800 over 180°
- exposure time: 2 s, for 23 keV 6 s
- phase stepping scan: 1 period in 4 steps
- **d:** 53 keV: 37 cm, 41 keV: 28 cm, 30 keV: 20 cm, 23 keV: 26 cm
- **G2:** grating period: p_2= 2.4 µm, Au
- **G1:** 53/41/ 30 keV: p_1= 2.4 µm; 23 keV: p_1= 4.78 µm, Si

4. Image Reconstruction

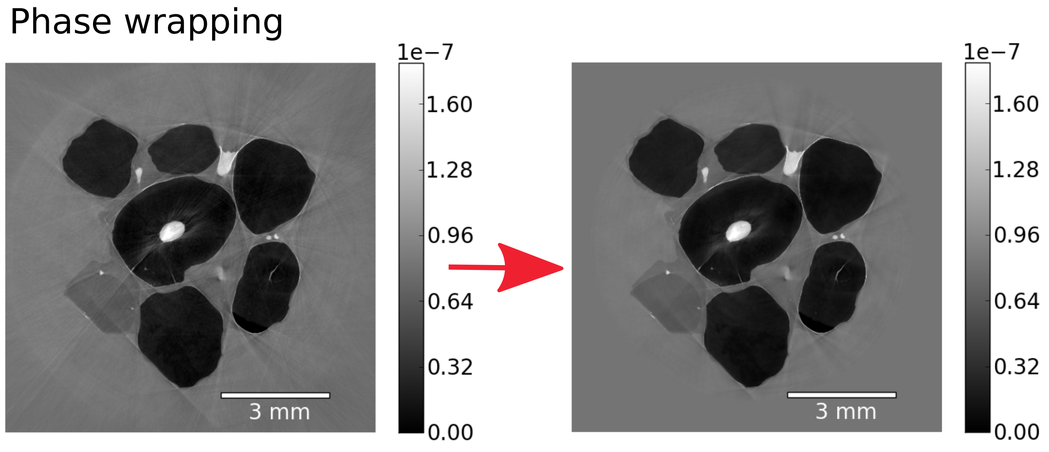
53 keV



5. Image Processing

Removing artifacts

Phase wrapping



Filtered back projection — Iterative reconstruction

6. Future Steps

After the processing of the sinograms, the quantitative analysis of the δ and β values for the different energies will be done. Furthermore a close look to the values will identify if a δ or β gradient exists inside one tooth.

References

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Acknowledgements

The author greatfully acknowledges the ESRF for a 6 month hosting. Special thanks to the E17 group of TU Munich for fruitful discussions and a lot of support.

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