EVALUATION OF THE ABSORBED DOSE IN X-RAY MICROTOMOGRAPHY

Amelie De Muynck[*1], Stijn Bonte[1], Jelle Dhaene[1], Manuel Dierick[1], Matthieu Boone[1], Klaus Bacher[2] & Luc Van Hoorebeke[1]

[1]UGCT – Dept. Physics and Astronomy, Ghent University, Proeftuinstraat 86/N12, B-9000 Gent, Belgium
[2]Department of Basic Medical Sciences, Division of Medical Physics-Gent, Ghent University, Ghent, Belgium

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Summary: During an X-ray CT scan a sample receives a radiation dose which can affect the sample's properties. This research aims at validating the accuracy of absorbed dose simulations to be able to predict the dose a sample will receive during an X-ray micro-CT scan. Both Monte Carlo simulations, with BEAMnrc and Geant4, and simulations with the in-house developed Setup Optimiser are compared with measurements performed with an ionisation chamber.

1. INTRODUCTION

A drawback of X-ray imaging is the deposition of a radiation dose in the object being imaged. For medical applications, it is important to quantify this dose, because it can be harmful to the patients' health. In comparison to medical scanners, micro-CT scanners can vary the acquisition geometry (i.e. magnification) and can consist of a wide variety of components (particularly sources). Unlike for medical CT systems, no standard protocols are determined for typical micro-CT setups, massively increasing the amount of different settings that are used.
Next to the lack of standardised acquisitions, micro-CT scans have a much higher resolution, for which the object is typically installed closer to the focal spot and the scan can take a substantial amount of time. This gives rise to a higher dose deposited in the scanned object. Furthermore, micro-CT can be used in a large number of research domains, and the objects under investigation can vary strongly in size and composition.

Due to the differences between micro-CT and medical CT, it is impossible to use the standardised dosimetry calculations and measurements of medical scans for laboratory-based micro-CT applications. An exception of course are small animal micro-CT scanners, which can be seen as mini medical CT scanners in which the animals, mostly rodents, are scanned alive and receive a radiation dose during the scan. In many studies, the absorbed dose for small animal CT scanning has been investigated using both experimental measurements and simulations. In contrast, for practically all other micro-CT scan applications very little information is available in literature about dose deposition in the samples. For some scans, for example of non-living samples such as metal objects, the dose is less important, because the absorbed dose will not affect the sample. However, some samples are radiation sensitive, such as minerals of which the colour can change due to radiation or plants which need to be examined several times during their lifetime. These two examples prove that it can be important to know the exact absorbed dose (or at least an estimate) that the sample under investigation will obtain during the total scan time.

2. EXPERIMENTAL METHOD

The experiments were performed at HECTOR (see figure 1) [1], one of the scanners at the 'Centre for X-ray Tomography' of Ghent University (UGCT; www.ugct.ugent.be). UGCT is a research facility specialised in high resolution X-ray computed tomography, where several home built modular micro- and nano-CT scanners are in use.
The aim of this study is to examine the absorbed dose in lab-based micro-CT. The dose is measured using an ionisation chamber during different scan protocols. These measurements are also compared to different simulation

* e-mail: amelie.demuynck@ugent.be

methods. First, two Monte Carlo based simulation tools, BEAMnrc and Geant4 were investigated. Next to Monte Carlo simulations, which take in general the most computing time, the dose is estimated with the in-house developed set-up optimiser [2]. This GPU-based tool accurately predicts attenuation of polychromatic beams through slabs of specified materials.

3. RESULTS

The results describe the accuracy of different kind of simulations for dose estimation prior to scanning. The Monte Carlo simulations give the most accurate results, but are also the most time-consuming. The results of the in-house developed set-up optimiser provide an upper and a lower limit of the absorbed dose in a certain sample.

References

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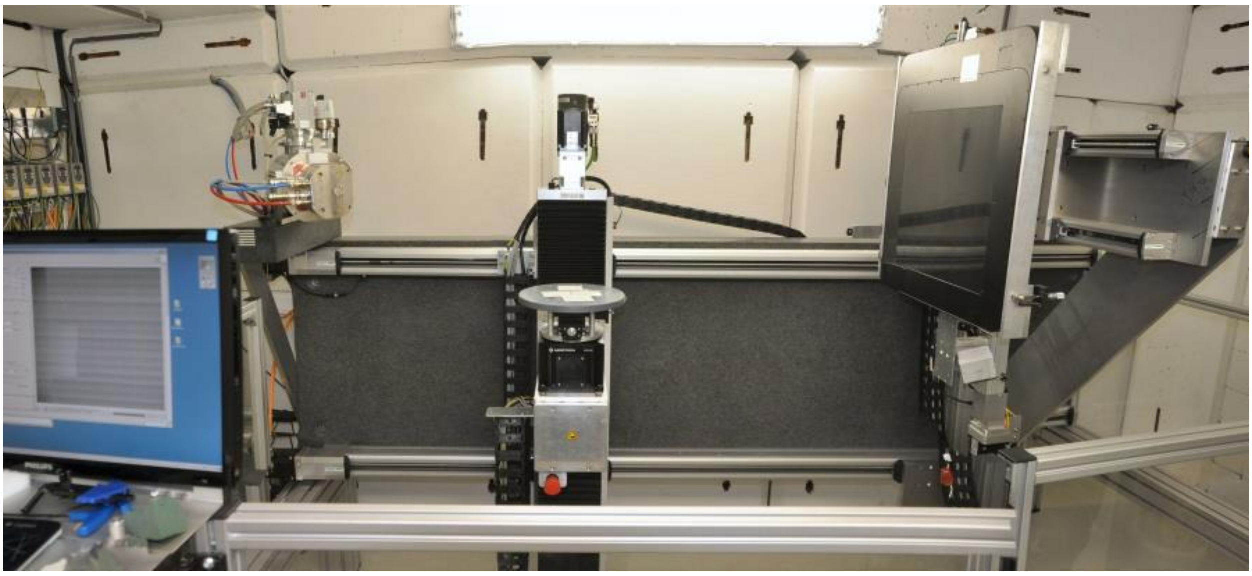

Figure 1: the HECTOR scanner at the 'Centre for X-ray Tomography' of Ghent University (UGCT; www.ugct.ugent.be)