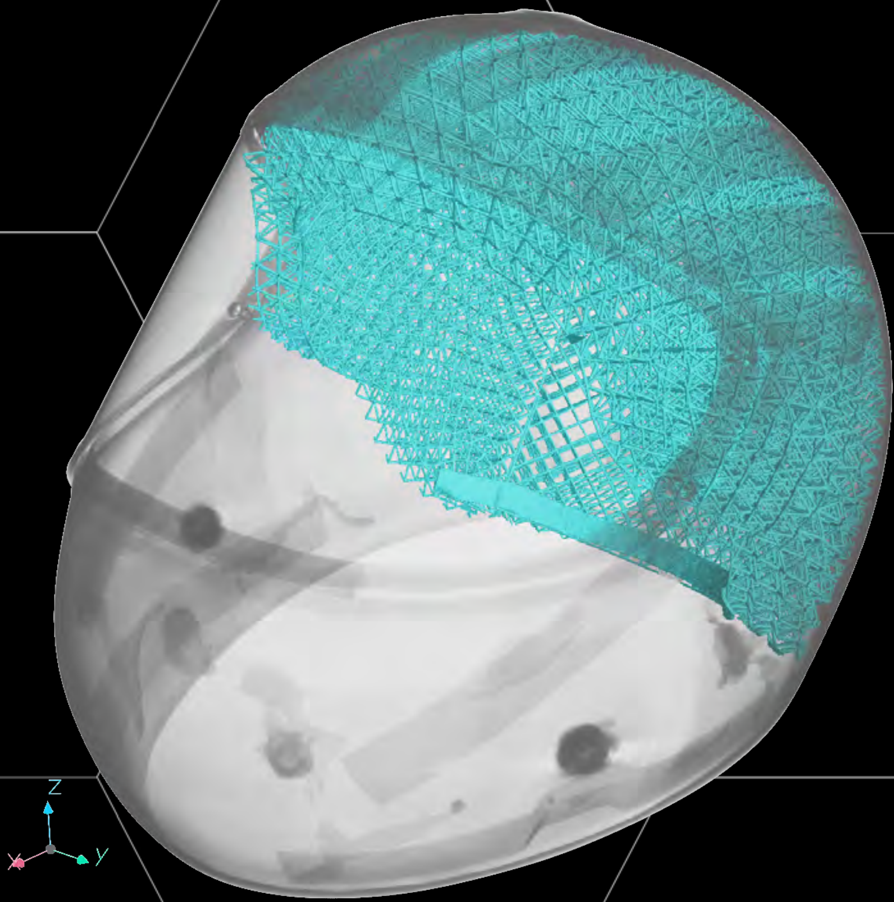
CEITEC CTLAB

BRNO UNIVERSITY OF TECHNOLOGY



CT analysis of a custom skeleton helmet on page 4.

NEWSLETTER SPRING 2022

It is a pleasure for me to present you with a new issue of the newsletter of our Laboratory of X-ray Micro and Nano Computed Tomography at CEITEC BUT. You can read about some of our recent explorations, including an inspection of a nail that might have been used in the crucifixion of Jesus Christ, an inspection of internal material quality according to ASTM E 155 and an analysis of a custom skeleton helmet. We will describe the 3D reconstruction of vascular systems of a rodent organ and share some of the latest news from our facilities and provide information about the complete portfolio of xy stages.

Enjoy reading!

Tomáš Zikmund
Head of the laboratory

CT ANALYSES

CT INSPECTION OF A NAIL THAT MIGHT HAVE BEEN USED IN THE CRUCIFIXION OF JESUS CHRIST

Figure 1: 3D render of the sample.

Our laboratory had an opportunity to inspect a forged nail found in a hidden case in the northern wall of the Church of St. Giles in Milevsko last year. This nail was hidden in the era of Hussites together with another historical artefacts in a small wooden case with the letters IR (probable meaning: Iesus Rex = Jesus the king). It is believed that the nail was part of the True Cross, i.e. the cross on which Jesus Christ was crucified.

Although the whole nail was inspected, the main region of interest was a golden cross on its surface made of 21K gold. The archaeologists had suspected whether there is a liturgical case beneath the cross

Our CT data with 33 μm voxel size didn't confirm this theory. Nevertheless, it has helped to characterize the material distribution and evaluate its condition in this valuable Christian relic.

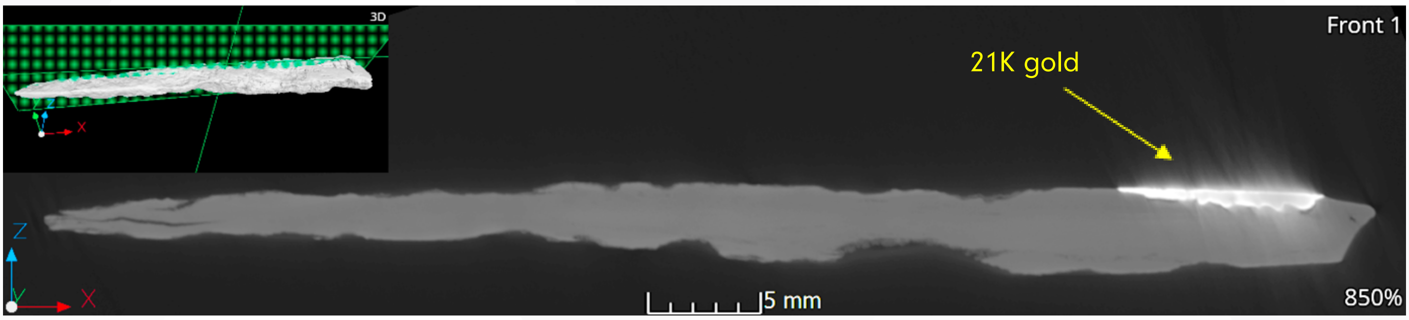


Figure 2: Tomographic cross-section; the position is shown by the green plane in the 3D render.

INSPECTION OF INTERNAL MATERIAL QUALITY ACCORDING TO ASTM E 155

While analyzing the plastic or aluminium industrial components, we often encounter the requirement to inspect the internal material quality using X-ray images. For this purpose, we own the ASTM E 155 standard, which classifies the samples by the internal defects of the given material into eight categories based on the reference X-ray images.

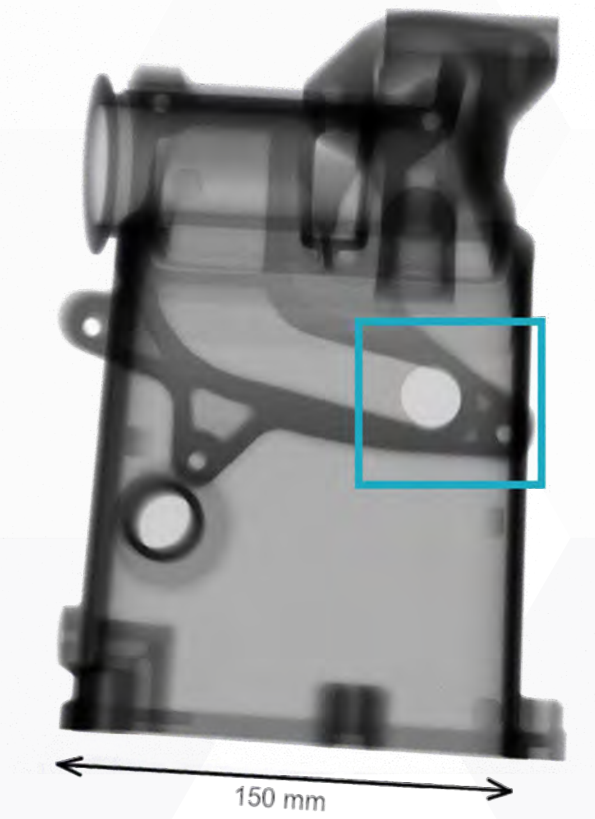


Figure 3: X-ray image of an aluminum case.

A complete CT scan is not needed for this type of analysis. We only use X-ray images showing the area of interest. This type of scanning is less time consuming, even though more images are needed when the sample shape is more structured and needs to be scanned from multiple angles. This analysis is a less costly method of evaluation compared to CT analysis.

The final X-ray images are compared with the reference images from the standard and each area of interest is classified into the category depending on the size and shape of the internal defects. The categories (size and shape of defects) into which the sample may or may not be classified are usually predefined for most samples. Thus, samples are often classified as OK and NOK regarding these requirements. The result of the analysis always contains a code representing the type of the given defect (porosity, shrinkage, inclusion) and how often it occurs. In addition, the requirements can be set for each area separately and it can happen that the sample complies with the requirements only partially.

One of the important parts of the evaluation process in our laboratory is the contrast adjustment of the X-ray images. This adjustment is performed before classifying into the categories in order to detect internal defects that might be overlooked using the conventional X-ray image.

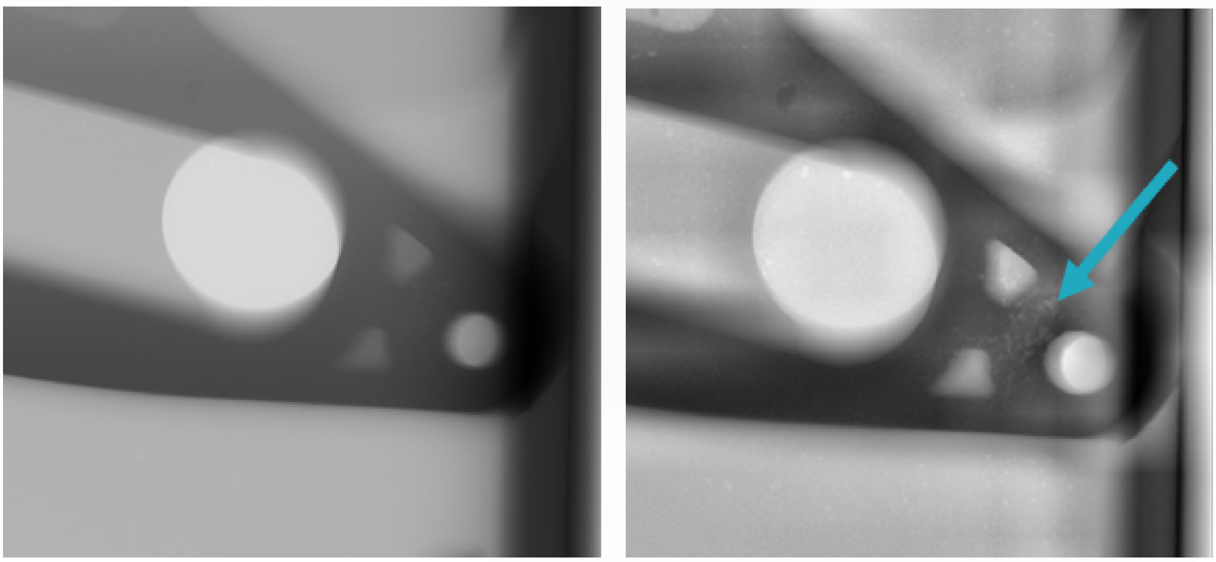


Figure 4: Left – X-ray image; right – the same X-ray image after contrast adjustment. The blue arrow is showing internal defects which might be overlooked in the convential X-ray image.

CT ANALYSIS OF A CUSTOM SKELETON HELMET

The close cooperation between Vagus and One3D created a team that developed and manufactured a lattice-based helmet tailored to a Czech skeleton competitor. To ensure maximum comfort for the athlete, they scanned her head. Based on the resulting 3D data the final structure was then produced using industrial 3D printing (highlighted in Figure 5). The result is that the helmet fits perfectly on the head and there are no disturbing movements or shifts. The helmet is also strong enough to protect the rider's skull upon impact, and light enough to not add pressure at 5G speeds.

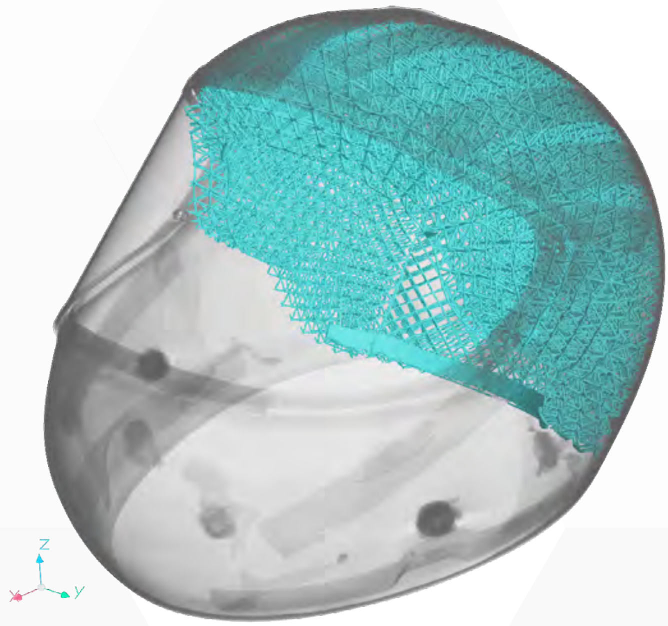


Figure 5: Entire helmet with lattice structure.

It requires a robust shell and shock-absorbing inner material. Often, designs incorporate thick padding that may perform poorly when compared to more complex, flexible materials. Lattice structures are interlocked materials that can be precisely configured and 3D printed. This leads to high impact performance and flexibility, which makes them perfect for customized fits and wearing comfort. CTLAB were given the task of looking into the final lattice structure to verify their real geometry. We checked whether all segments of the structure are correctly connected and whether they have a defined diameter (see Figure 6). We also examined the attachment of the structure to the helmet body.

You can check the CT analysis video here.

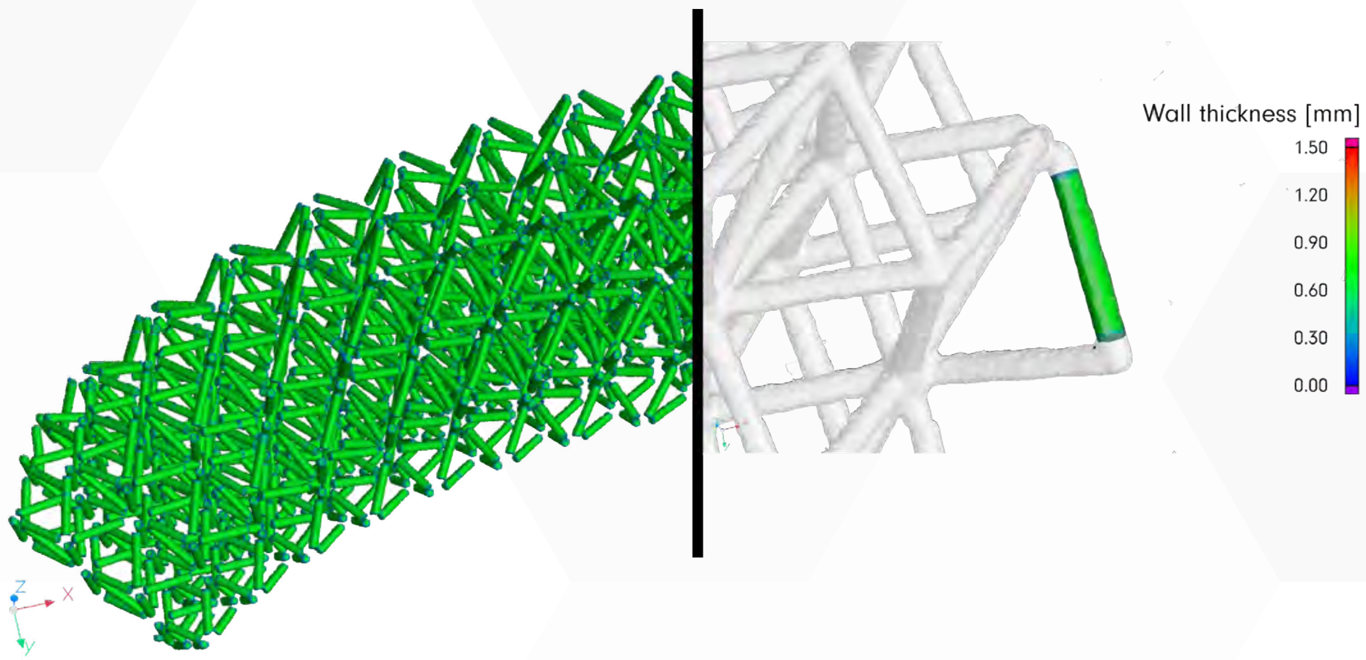


Figure 6: Wall thickness analysis of the lattice structure of a segment.

3D RECONSTRUCTION OF VASCULAR SYSTEMS OF A RODENT ORGAN

Many essential parts of the body contain tubular-like structures such as vascular or respiratory tract. Visualising complex tubular structures made of soft tissues in 3D is challenging. Traditional microscopic imaging of anatomy is in two dimensions, physically slicing the tissue. This approach shows the cross-sections of tubes, but not how they connect and interact. An alternative to this approach is to use micro-computed tomography scans, which use X-rays to examine structures in three dimensions.

The challenge with micro CT imaging is that soft tissues, which tubes in the body are made of, do not show up well on absorption contrast. One way to solve this issue is to fill the tubular structure with a resin, making a cast of the entire structure. The radiopaque resin is injected into the selected tubular system, and after the resin sets in the sample is ready to scan. In the cases where there is a need to simultaneously visualize 2 tubular systems, the method can be modified to fill each system with resin which differs in radiodensity. This approach enables differentiation of both systems in the tomographic data based on the attenuation of used resins.

The following micro CT scan allows precise reconstruction of the structure in 3D (Figure 7), revealing the length, volume, branching, and other interactions. This new imaging technique can improve the understanding of defects occurring in tubular systems of animal disease models. The proposed 3D analysis was already utilised in the research of Allagile syndrome, which affects the formation of blood and biliary vessels in the liver.

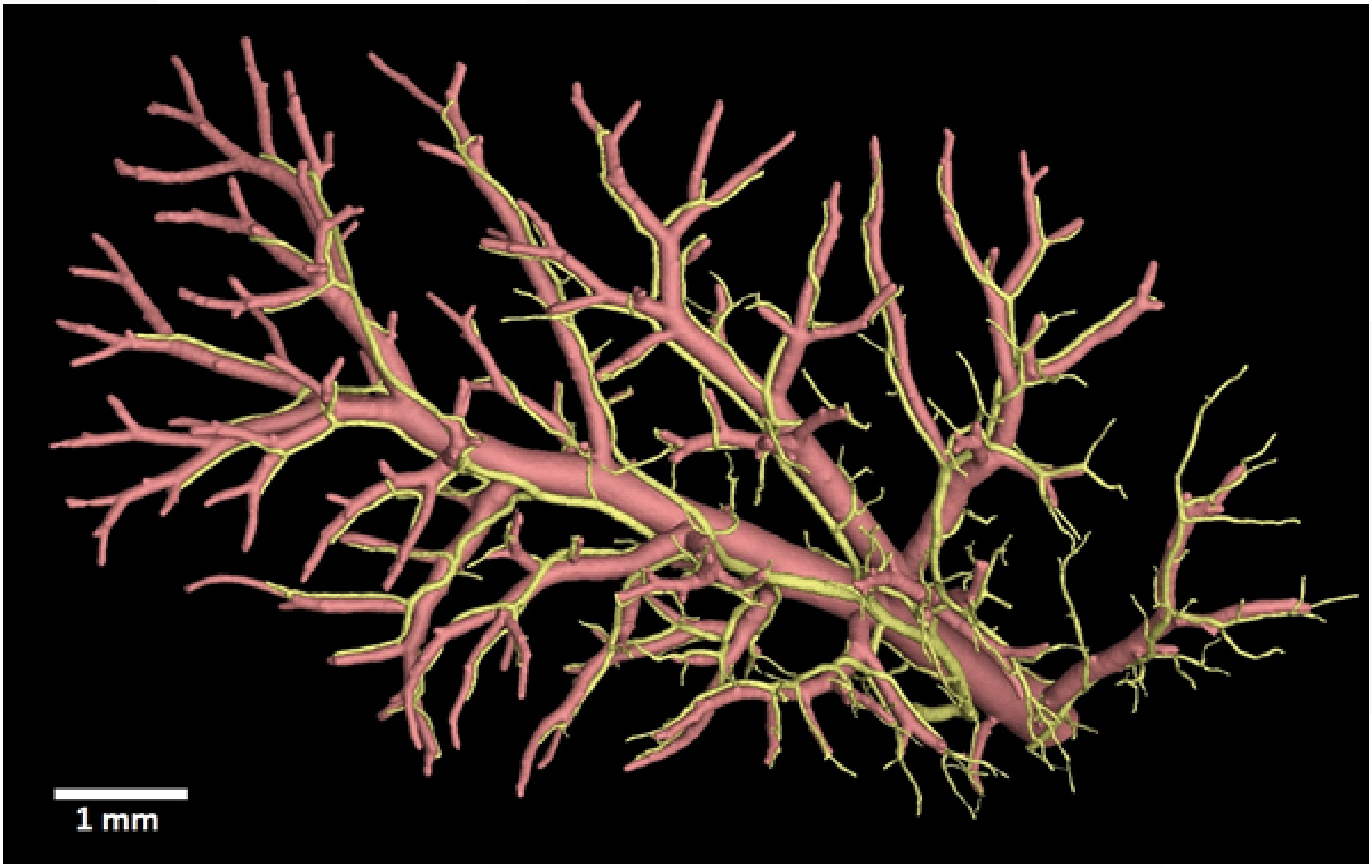


Figure 7: Example of 3D visualization of tubular structure: the vascular system (red) and biliarysystem (yellow) in the kidney lobe of mouse.

NEW CT LABORATORIES

Our largest CT device, the GE phoenix v|tome|xL240, which was located at the Faculty of Mechanical Engineering was moved to a new place at CEITEC BUT because original laboratory was established before the existence of CEITEC. The move was quite complicated, the several-ton lead cabinet had to be picked up with a crane. In the new refuge, it was necessary to dismantle a piece of the outer shell of the building and reinforce the concrete foundations of the floor in the room. All the CT equipment is now operated in the new spaces within the CEITEC BUT complex.

Figure 8: Moving the GE phoenix v | tome | x L240 to a new space.

MOTORIZED TRANSLATION STAGES FOR CT SAMPLE MANIPULATION

We can announce that the product portfolio of xy Translation Stages is extended. They are used for quick mounting and fine centering of the sample during your CT analysis. They are designed for the needs of specific samples manipulation, so their load capacity is enhanced. They are wireless and compact, controlled from outside of the cabinet. There are 3 different configurations to fit into most of the CT systems and enable usage of the different samples dimension and weight wise.

The reason for the creation of SaguaroX was a sample centering and placement problem that we needed to solve in our lab. Since there was no available commercial solution on the market that was suitable for our needs, we decided to develop it on our own in 2019 and commercialize it through the creation of CactuX company, where this solution was also finalized into a marketable product.

	SaguaroX M Heavy	SaguaroX M	SauaroX S
X, Y - axis travel:	100 mm x 100 mm	100 mm x 100 mm	50 mm x 50 mm
Sample area:	220 mm x 220 mm	220 mm x 220 mm	135 mm x 135 mm
Maximum load:	30 kg	15 kg	7 kg

Figure 9: Translation stages portfolio and their parametres.

SMART X-RAY DETECTION OPENS NEW HORIZONS IN CT

Our laboratory recently had the opportunity to test an ADVACAM photon-counting detector in our industrial CT system. Photon-counting detection is a very exciting recent technology in CT and radiography in general. It promises low noise, increased detection efficiency, and the ability to detect individual incident photons and their energy. This is a major advantage over conventional detectors, which record only the total amount of all incident light over their exposure period. The possibility to discriminate between energies of detected radiation opens incredible new possibilities for dual-energy and spectral CT, another area of major interest for the modern CT community.

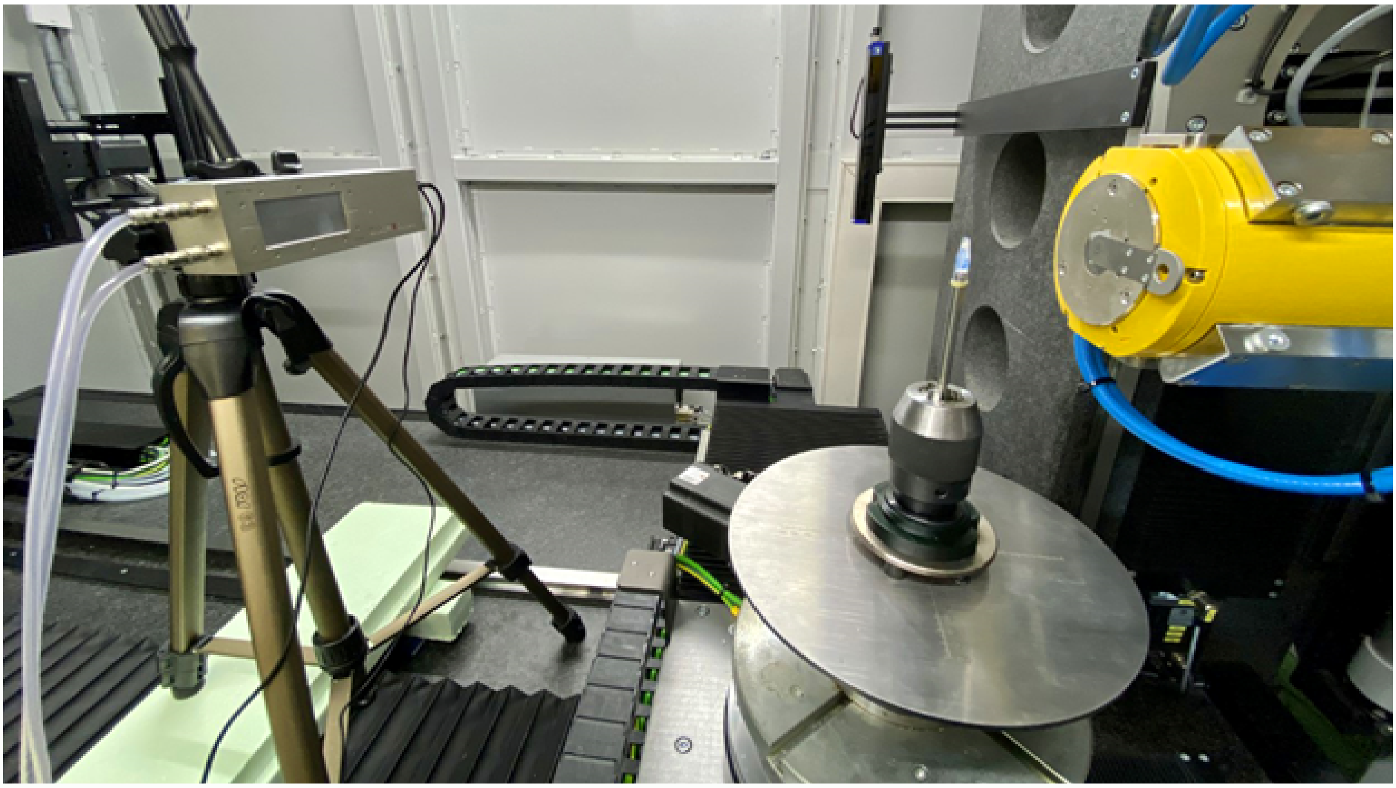


Figure 10: An Advacam photon-counting detector (left) mounted and ready for testing in the chamber of our CT system.

CONTACT US

Ing. Tomáš Zikmund, Ph.D.
tomas.zikmund@ceitec.vutbr.cz
+420 541 142 846

www.ctlab.ceitec.cz
ctlab@ceitec.vutbr.cz
+420 541 142 875

CEITEC BUT
Brno University of Technology, Central European Institute of Technology
Purkyňova 656/123, 612 00 Brno