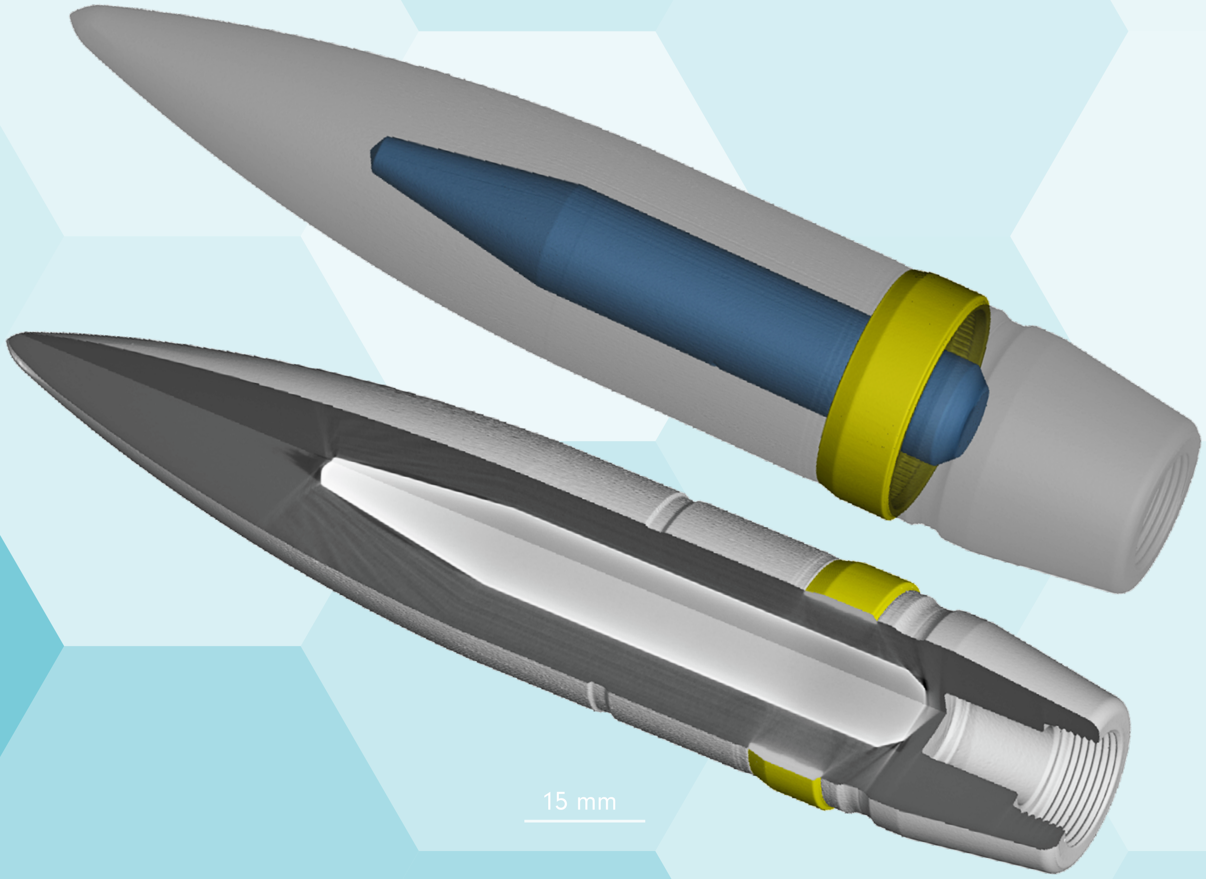

Piercing projectile on page 4.

NEWSLETTER AUTUMN 2020

Dear Readers,

It is a pleasure for me to introduce to you a new issue of the newsletter of our Laboratory of X-ray micro and nano computed tomography CEITEC BUT. You can read here about some of our recent analyses, including a lithium-ion battery inspection, carbon formula disc inspection and piercing projectile center of gravity inspection. We will describe a fielf-of-view extension and share some of the latest news, such as cooperation with Japanese company Rigaku and a new product *xy* translation stage.

Enjoy reading!

Tomáš Zikmund
Head of the laboratory

CTLAB
X-ray Computed Tomography

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Central European Institute of Technology
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CT ANALYSES

LITHIUM-ION BATTERY INSPECTION

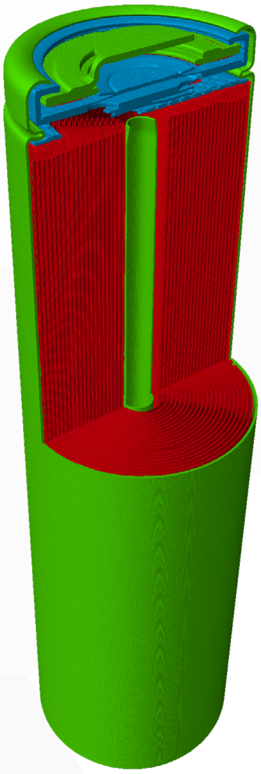

Figure 1: 3D render of the battery helical scan.

Lithium-ion accumulators (Li-Ion) are among the most common types of rechargeable batteries, widely used in mobile phones, consumer electronics, or in one of the growing industrial areas – electro mobiles. State-of-the-art accumulators can perform hundreds of charge and discharge cycles until failure. We can advantageously use X-ray computed tomography to analyze morphological changes during the cycle and defect detection as it can image the inside structure of the battery without its destruction (Figure 1).

The field of view of the detector is a very limiting factor if using a standard circular scan. We can either measure the whole battery cell (Ø18 x 65 mm) with low resolution, which prevents distinguishing particular battery components, or perform a high-resolution scan of a small part of the cell.

The CT laboratory at CEITEC VUT is equipped with unique microCT Heliscan, which allows the utilization of helical trajectory scanning of a whole battery with high resolution (down to 8 μm linear voxel size), see Figure 3. We can then distinguish particular layers of electrodes, take high accuracy measurements, and obtain complex information about accumulator morphology and inside structure, which suffer harmfull changes due to the cycle of charging and discharging

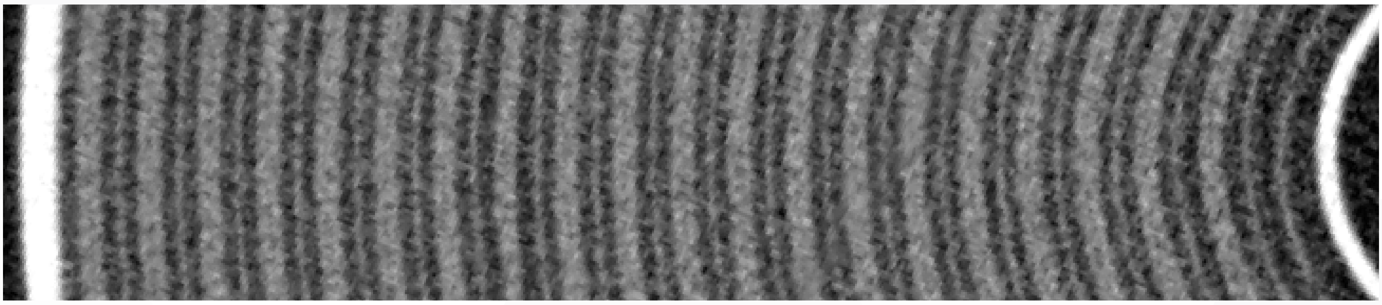

Figure 2: Transverse tomographic cross-section of the cell, result of the circular scan. Low resolution (linear voxel size 22 μm) lowers the accuracy of the analysis.

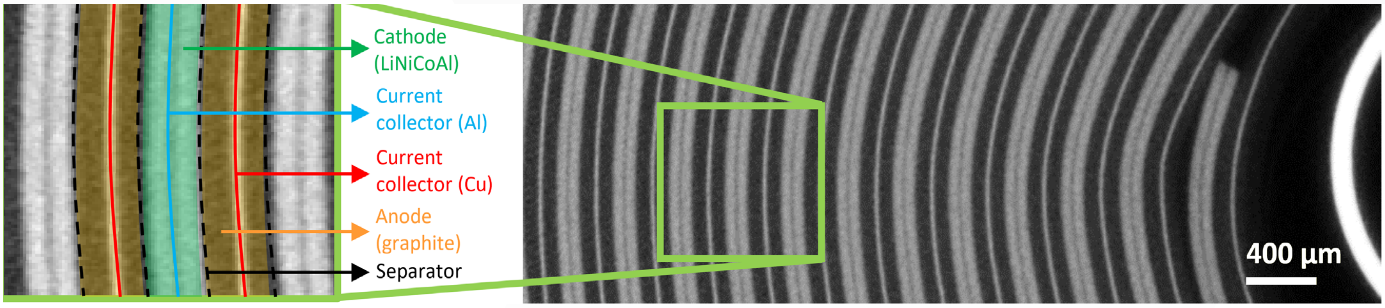

Figure 3: Transverse tomographic cross-section of the battery, result of the helical scan. High resolution (linear voxel size 8 μm) allows us to distinguish particular components of electrodes in whole battery volume

CARBON FORMULA DISC INSPECTION

Formula Student is an international engineering design competition. The goal is to develop and provide a platform for student engineers to experience, build, and learn. Considering the character of racing circuits, the highest priorities are reduction of weight, unsprung mass and moment of inertia. This is the reason why the racing team at Brno University of Technology has decided to develop its own discs made of carbon.

Figure 4: 3D render of the measured carbon disc.

Single pieces of carbon fabric are placed into a multipart mould which allows the fabrication of a disc in one peace without any glued joints. However, such a disc needs to be inspected for redundant amount of air cavities in the inner structure that might lead to decreased stiffness of the whole part.

That is why one of these carbon discs was analysed using micro CT. The whole 360 mm big part was imaged during one acquisition process using GE v|tome|x phoenix L240 that allows enlargement of the field of vision thanks to detector deflection (more in Education section). Inspection of the acquired CT data has revealed many air cavities between the carbon layers. But it was only subsequent unrolling of the conical surface that has shown certain regularity of their distribution in the foam filling. Most defects occur in the regions where two pieces of fabric are connected. Based on this finding, the production process will be modified.

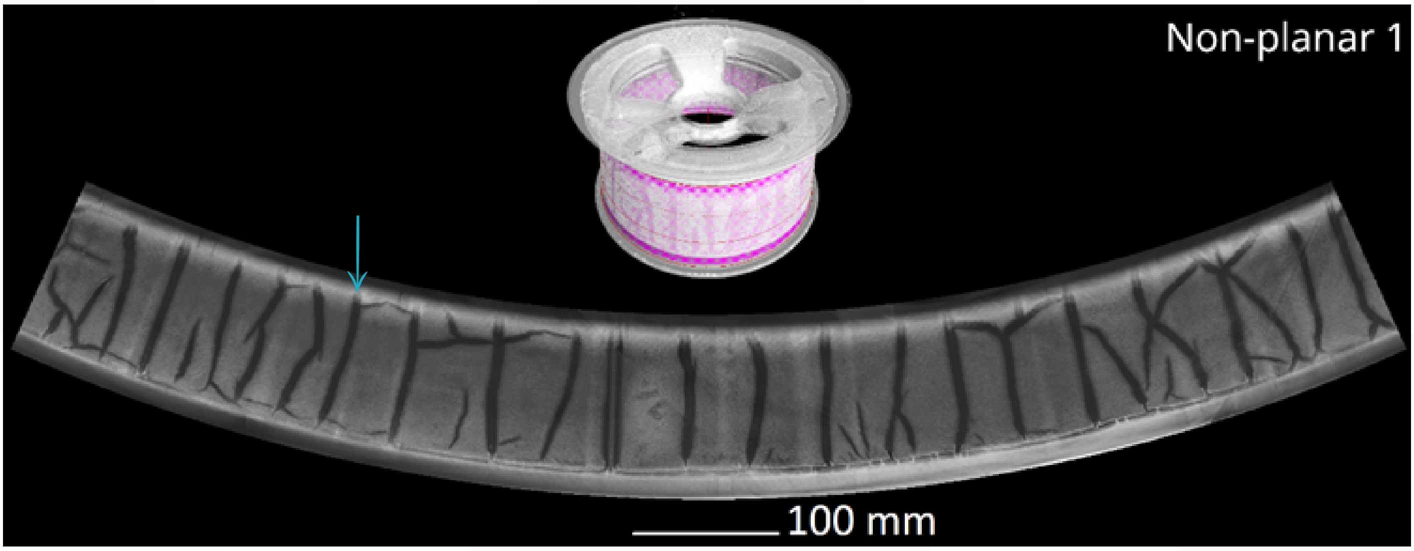

Figure 5: Non-planar tomographic cross-section showing the distribution of air cavities. Position of the original unrolled cone is shown by pink colour in the 3D render.

PIERCING PROJECTILE CENTER OF GRAVITY INSPECTION

Not every direction leads to the goal, not every innovation is a benefit. The idea of the manufacturer of the armor-piercing bullet was simple: Reduce the laboriousness and duration of the piercing ammunition calibre 30 mm production. Projectiles consist of heavy piercing pseudoalloy tungsten core and the dural body. Use of rotary forging in the production of a semi-finished product was an innovative element in this case. This resulted in significant time savings for subsequent machining.

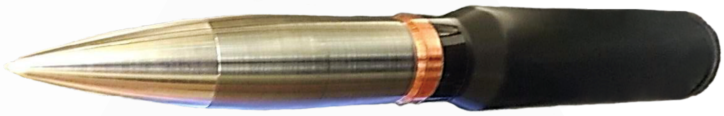

Figure 6: Piercing projectile picture.

However, with this technology it is difficult to meet the requirements of the drawing documentation. The projectile must be accurate and effective. Determination of the center of gravity of the whole assembly and the coaxiality value of the dural shell with the tungsten core were the main parameters for assessing the accuracy of the production process. The analysis of selected projectiles showed excessive variance in these both monitored parameters. This was subsequently confirmed by the result at the shooting range.

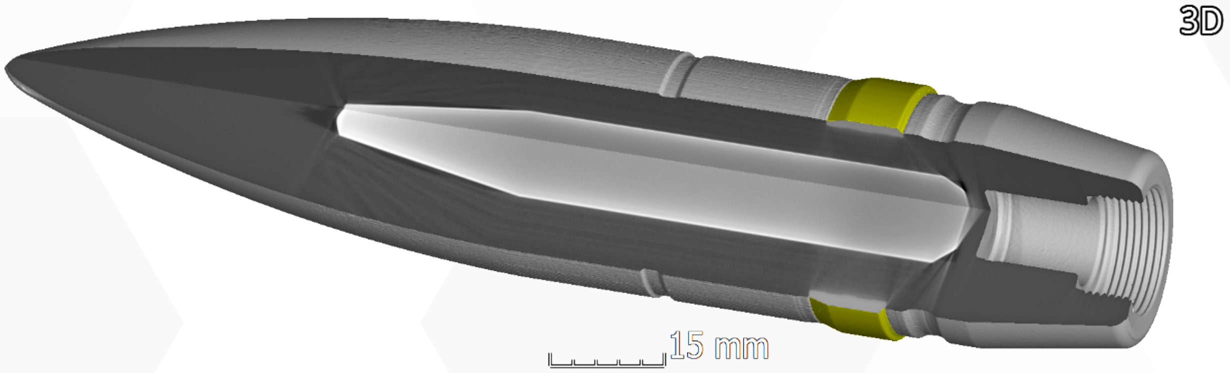

Figure 7: 3D render of a projectile, the cross section shows the differences in the density of used materials.

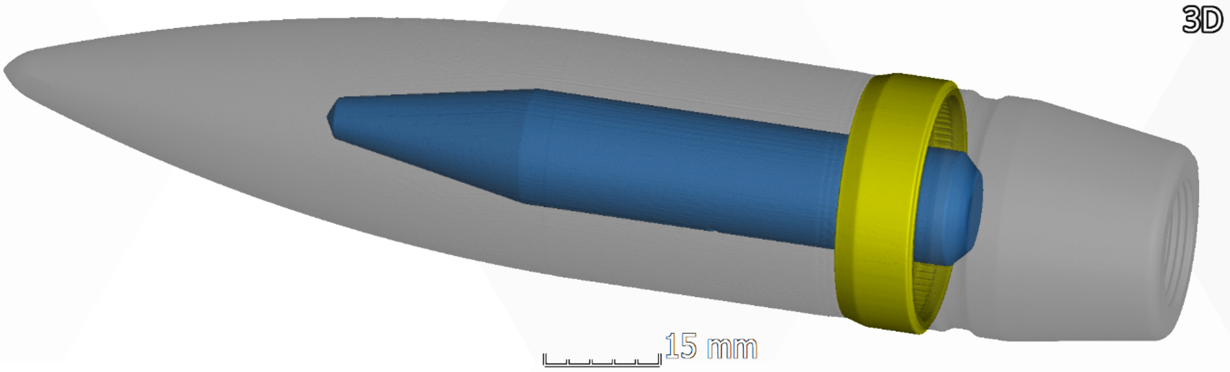

Figure 8: 3D render of a projectile with individual components: Blue - penetrating core of pseudoalloy tungsten, yellow - copper sealing ring, ray - duralumin body.

FIELD-OF-VIEW EXTENSION FOR WIDE SAMPLES

Computed micro and nanotomography (µCT and nCT) scanners enable nondestructive measurements with high spatial resolution, but sample sizes often need to be very small. The size of the field of view (FoV) of these devices is usually determined by the size of the detector used, and other characteristics, such as magnification. The limiting size of the detector can be overcome by a modified scan geometry and additional data processing

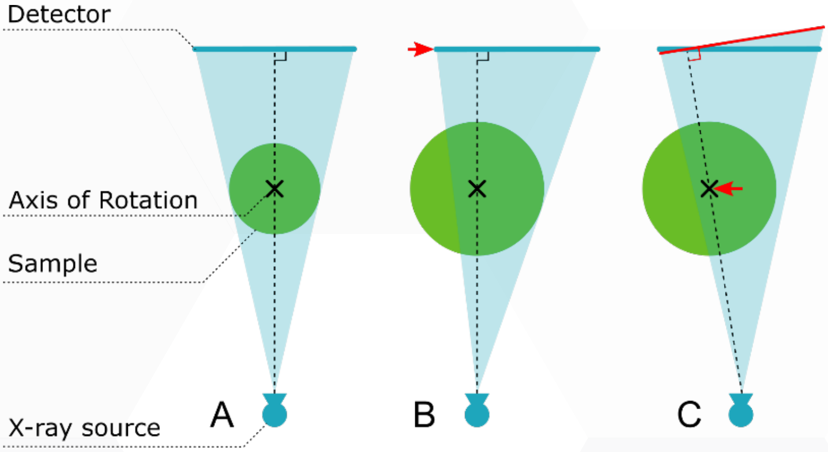

Figure 9: Regular CT measurement (A) and measurements with an extended FoV through a shifted detector (B) and AoR (C).

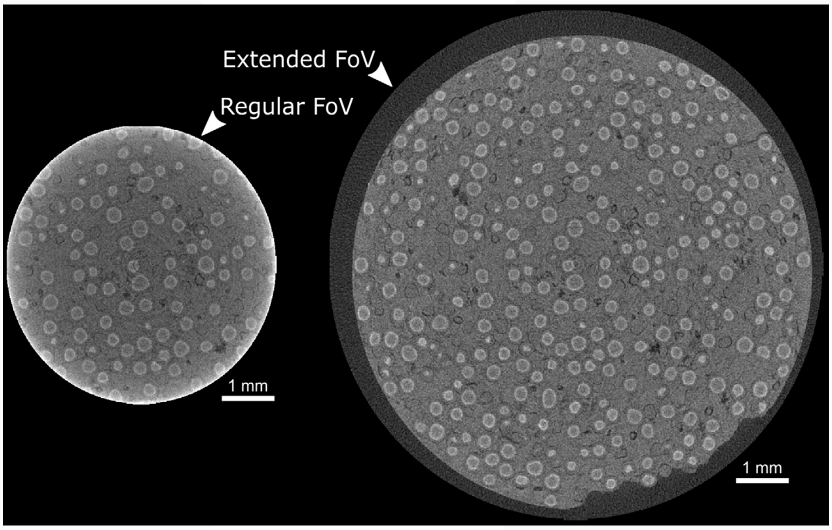

Figure 10: Comparison of a CT measurement of a pill with a regular (left) and extended (right) FoV.

The FoV of a scanner can easily be extended laterally, in a direction perpendicular to the sample's axis of rotation (AoR). Lateral extension is ideal for wide samples. A common method of lateral FoV extension is based on offsetting the detector (figure 9B) or the AoR (figure 9C) to one side and performing a full 360° scan. Such a scan contains sufficient information about the sample for reconstructing cross-sectional slices if the AoR is still contained within the FoV. This means that the FoV can be extended to almost twice its original width.

Some X-rays are recorded twice during a single CT scan, whereas others are seen only once. This is addressed by processing the data after acquisition, making sure all datapoints contribute equally to the result. Differences in data acquired with a displaced detector and AoR must also be taken into account – many common CT scanners use the first option due to easier work with the data after acquisition. However, if a dataset is acquired using an offset AoR, it can be slightly rotated (red line in figure 9C) and so converted to a dataset with an offset detector.

The result is a tomographic technique that greatly enhances the possibilities of CT scanners. This is illustrated by the example in figure 10, where the scanned sample does not fit in the scanner's regular FoV, but the extended FoV is wide enough.

COOPERATION WITH JAPANESE COMPANY RIGAKU

In the spring of this year, prof. Radimír Vrba, the director of CEITEC Brno University of Technology, and Dr. Kazuhiko Omote, director of the X-ray research laboratory of Rigaku corporation, signed a new donation agreement with validity till 2022. This agreement is the result of long-term and successful cooperation between the Laboratory of X-ray Computed Tomography and Japanese company Rigaku. This donation agreement will enable financing costs related to study internships of our students in research facility of Rigaku located in Tokyo. Selected students will have the opportunity to be a part of development of Rigaku CT devices, advanced tomographic techniques and also dedicated software for tomographic reconstruction.

Figure 11: Our student with the Japanese colleagues.

Together with signing of the previously mentioned donation agreement, the extensive update of our nanoCT device Rigaku nano3DX took place. This update included the replacement of the old X-ray source for an absolutely unique source using unrivalled technology of a rotational anode with two separate material layers (Dual-Target anode). Our laboratory specifically selected a combination of copper and molybdenum, which will enable CT measurements of a vast spectrum of samples in terms of their material and structural properties from biological, pharmaceutical or textile samples. This update also allows practical implementation of dual-energy tomography used for reduction of metal artifacts or evaluation of specific sample properties.

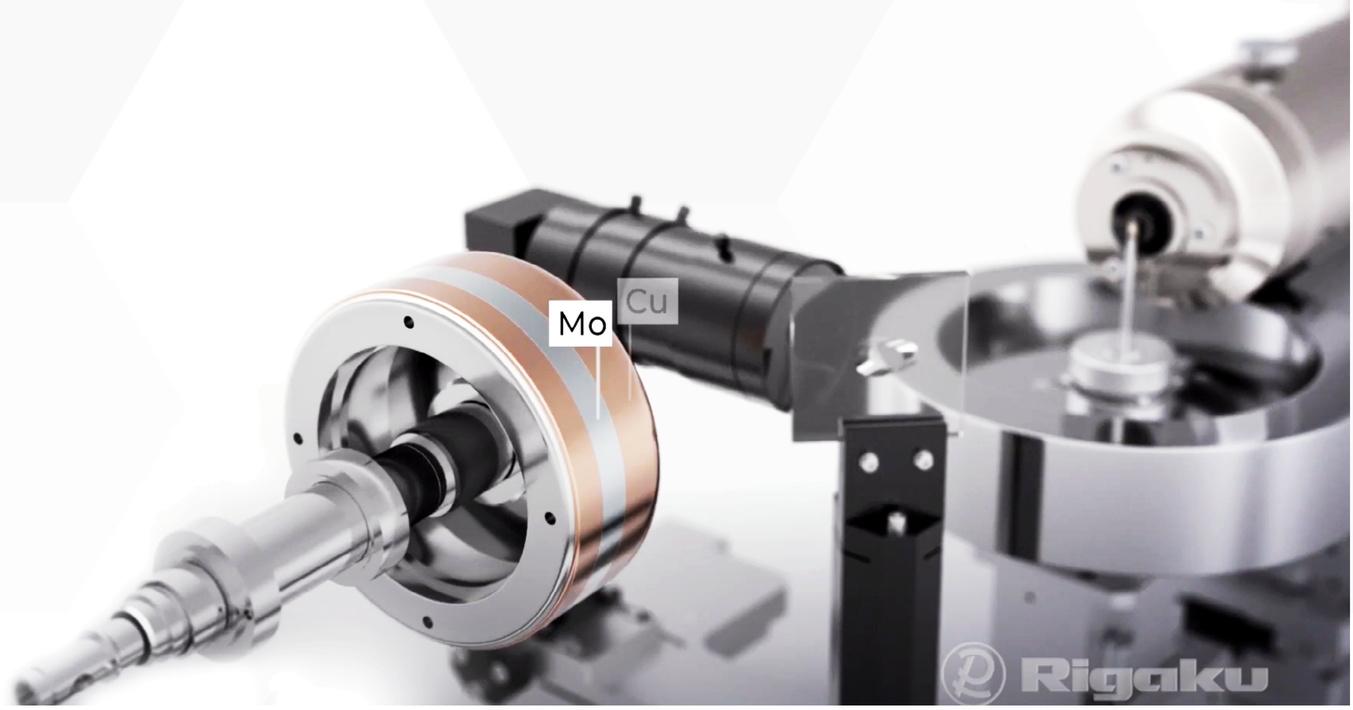

Figure 12: Dual-Target anode Rigaku.

XY TRANSLATION STAGE

Our laboratory has developed a motorized sample stage for µCT stations. It makes manipulation with the samples easier and less time consuming. It is controlled by a wireless joystick from outside the cabinet. The stage area is 220 x 220 mm². The movement is ensured in two perpendicular tracks in the range of 100 mm.

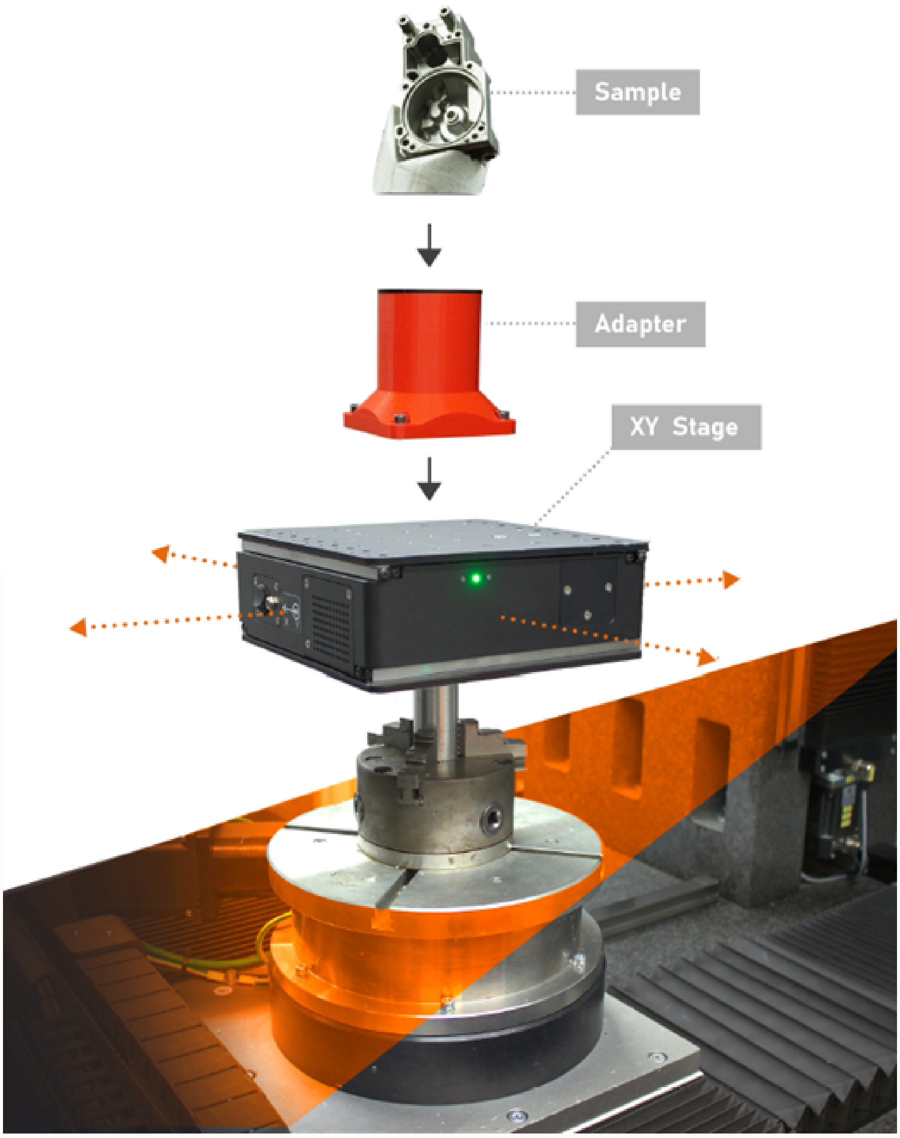

Figure 13: xy translation stage.

A sample up to 10 kg can be mounted on the manipulator. The sample holder is realized by using a special cylindrical adapter attached on the top of the stage. Different types of adaptors help us to increase samples mounting variability. This allows even the smallest samples to be mounted and adjusted close to the X-Ray source.

A new start-up company called CACTUX has been founded for the purpose of commercialization of this prototype. Prestigious magazine Metrology.news wrote about this in their article „*XY Translation Stage Provides µCT Direct Center of Rotation*".

Thanks to the innovative control concept and technical solution, the manipulator has wone CEITEC Innovation Entrepreneurship Award 2020 and got a grant from South Moravian Innovation Center called To Prototype and to Verify.

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