COST STSM Report

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STSM Topic: Combined neutron and X-ray imaging for non-destructive investigations of historical musical instruments

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1) Purpose of the STSM

For the examination of three dimensional objects of cultural heritage, imaging methods like X-ray and computed tomography are powerful tools to gain information about the structure, material properties and building techniques especially for musical instruments. The MUSICES – project – hosted at the Germanisches Nationalmuseum, Nuremberg - develops a standard for the 3-D computed tomography of musical instruments and the STSM has to be understood as an extension and addition to that project. X-ray technology can be used for penetration of materials with low densities, because the attenuation depends on the atomic number of the elements. That means that wood and other organic material with low densities can be imaged quite well. Materials with high densities like metals are very hard to penetrate by the X-ray very high energies have to be applied. Musical instruments often consist of a combination of materials with highly differing densities, which is a big challenge for X-ray-technology. Using neutron imaging, it is the other way around. The attenuation of very dense materials is low, while elements with a low atomic number like hydrogen cause a very high attenuation. With the combination of the two different techniques, three instruments should be examined in order to compare the examination methods for different scientific interrogations.

First, an instrument containing of wood should be scanned twice, once with neutron imaging, the second time on the same position with X-ray computed tomography. A small viola da gamba (pardessus de viole) by Michele Colichon was chosen. The specific question was, if one can decide while using these imaging techniques, whether the top plate is carved or bent. Second, a clarinet containing of wood with metal keys should be scanned twice as well in order to compare the

techniques for the imaging of instruments consisting of highly differing materials. Here, we wanted to find a specific “bore trick”, which is mentioned by a handwritten note in a book descending from the library of the maker. Third, a recorder should be scanned several times with neutron imaging using the property of the strong attenuation by water to make the breath moisture visible. The recorder should have been scanned in dry condition and then be played, then scanned again to evaluate for one thing the changes in dimension and for another thing to determine the penetration of water in the bore wall.

2) Description of the work carried out during the STSM

For the proposal three days of beam time at the NEUTRA facility at the Paul Scherrer institute in Villigen, Switzerland were assigned. Besides of the beam time, it was enabled to use all the facilities, hardware and the powerful software during the stay, also on weekend and bank holiday (Pentecost). NEUTRA is just one of several facilities, which use the same huge neutron source. Each has its particular specification.

On the first day of beam time (Wednesday, May 11) there was unfortunately a breakdown of the neutron source which lasts till the afternoon. Instead of starting with neutron imaging, the X-ray imaging of the viol was started. After a while, the X-ray source broke down and the scanning process stopped. In the late afternoon the first scanning process with neutrons could be started and took over night. Because the X-ray-source was seriously damaged, the repair on the next day took till the afternoon. Following this, the X-ray CT of the first instrument could be started at the second day (Thursday, May 12) with some restriction in energy and voltage, because the X-ray tube was still not fully functional. This scan took also overnight and there was just Friday (May 13) left for the rest of the measurements. Because it was impossible to finish the undertaking as proposed, it was decided not to scan the clarinet and scan some test specimens instead of the entire recorder. So two little tubes of maple made by Ilona Stein during her diploma thesis were used for examination[1]. In order to imitate the experiments of Stein, one of the tubes was oiled with linseed oil, the other one was untreated. A first scan by neutron imaging was executed. Then both tubes were wetted for ten minutes and then scanned again.

[1] Stein, Ilona: Die Blasfeuchte in Holzblasinstrumenten. In: Kölner Beiträge zur Restaurierung von Kunst und Kulturgut, hrsg. von Friedemann Hellwig, Teil 1: Holzblasinstrumente, Köln 2004.

On Sunday (May 15), Monday (May 16) and Tuesday (May 17) the reconstruction of the data sets was started and some examination of the images was done by using the powerful hardware and the brand new licensed software VG Studio Max 3.0. Because of the fact, that the X-ray images and the neutron images were made exactly at the same position, it is now possible to compare both data sets simultaneously in the software application. This has the advantage to be able to distinguish the qualities of the different techniques.

3) Description of the main results obtained

Since not all of the proposed scans could be accomplished, the results concern mainly the examination of the viol made by Michel Colichon.

It has to be distinguished between the gained knowledge about the technical structure of the instrument in the context of its building process and the evaluation of the two different examination methods and their possible application for musical instruments made of wood.

Since the neutron beam is attenuated by light material, it is sometimes not possible to see the inner structure of thicker wooden parts as for example the lower block or neck joint. The neutron image shows a brighter region at the edge of the material especially at thicker parts, the greyscale at the internal parts is much lower and no structure is visible due to the so called beam hardening effects.

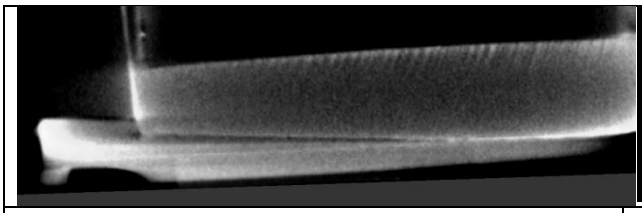

Image 1: Neutron, Cross section of the lower block

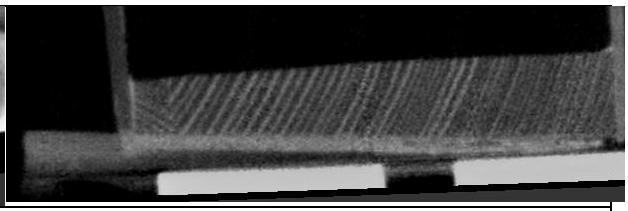

Image 2: X-ray, Cross section of the lower block

In the X-ray cross sections of the lower block and the neck joint, one can see that the block is made out of two pieces with different orientation of the annual rings and the top plate is fixed by a nail in the upper part. A cross section of the neutron image through the ribs does not show the bevelled joint of the ribs in the corners. This technical detail is visible in the X-ray image.

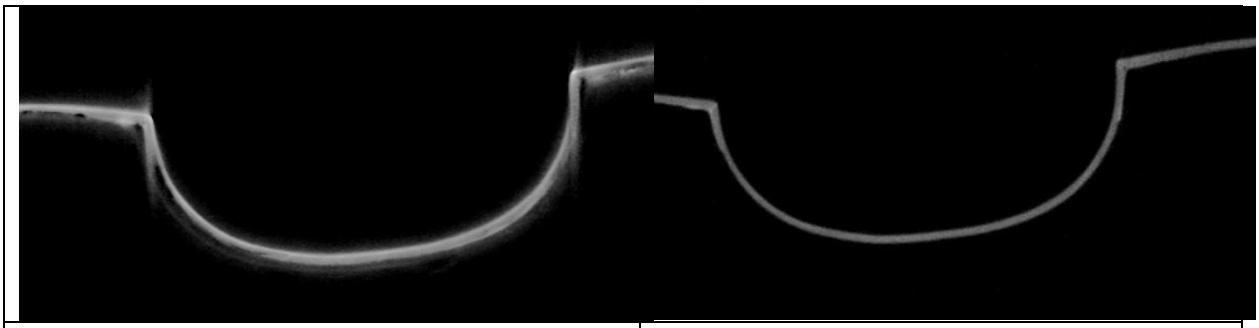

Image 3: Neutron, cross section of the ribs, corner joints	Image 4: X-ray, cross section of the ribs, corner joints

Also the painted decoration on the top plate is not shown in the neutron image, because of the metal pigments which were used. These pigments cause barely attenuation to the neutron beam and are therefore only visible in the X-ray image.

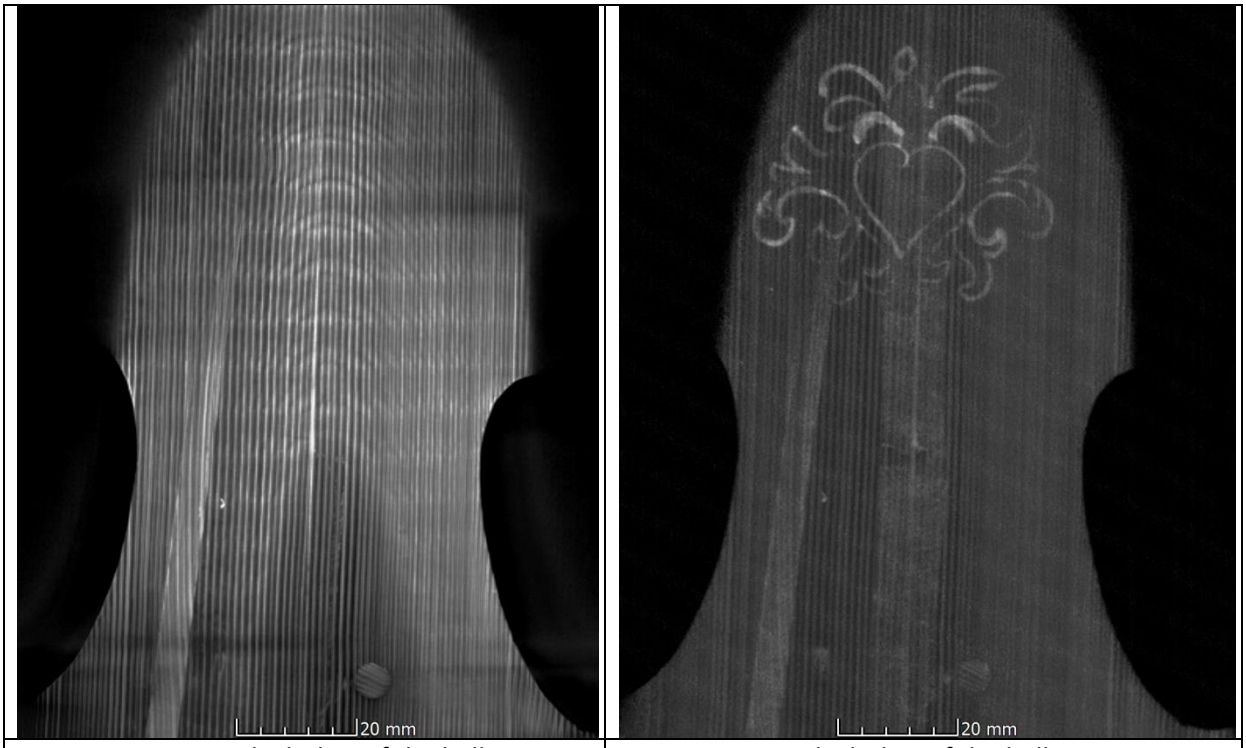

Image 5: Neutron, thick slice of the belly	Image 2: X-ray, thick slice of the belly

The undoubted advantage of the neutron imaging is the high contrast. For example on the inner part of the back plate, the traces of the tooth plane are visible, where the X-ray image just shows a more or less uniform surface. Also the contrast of the annual rings is much higher, which allows better analysis for example for dendrochronological dating.

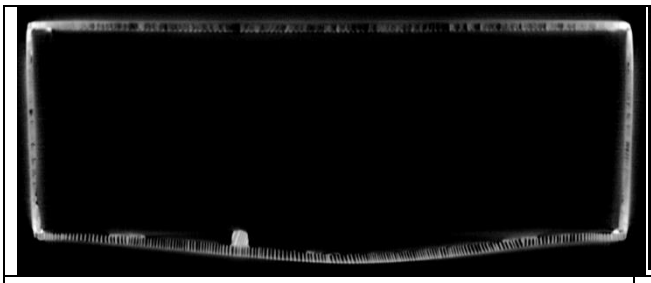	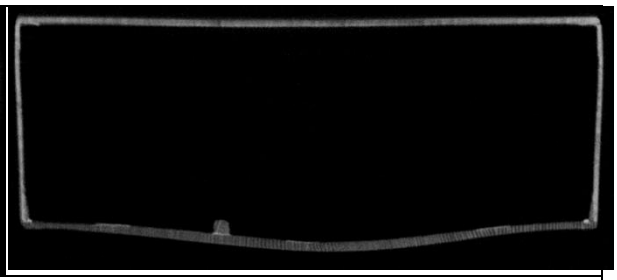
Image: Neutron, Cross section of corpus	Image: X-ray, Cross section of corpus

The insights concerning the technical details of this particular instrument are also remarkable. Based the images it can now be proven, that this instrument equates to the other known instruments of this maker. It can be seen that there is no upper block, but the neck and the upper block are made of one piece. There are no blocks in the corners and the belly is made of five different pieces. Thanks to the high contrast of the neutron images, the orientation of the annual rings can be tracked in the cross sections. The fact, that in the arched section of the belly, the annual rings turn slightly outwards, while in the more flat regions they have a similar radial orientation, can be seen as a good hint for the presumption that the belly is bent.

The results of the examination of the tube models were not finished at the moment of submitting the report, but first reconstructions seem to be promising.

4) Future collaboration with host institution

To extend the research on 3-D imaging methods for musical instruments, a future collaboration of the Germanisches Nationalmuseum and the Paul Scherrer institute is planned. During the STSM two meetings in this concern were held and some specific project also in cooperation with other Swiss institutes where discussed.

5) Foreseen publications/articles resulting or to result from the STSM

In context of the comparison of the two methods, a common publication is intended.