International NR Newsletter

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International Society for Neutron Radiology

(www.isnr.de)

Content

Editorial

Dear colleagues,

most of us are focused with limited or decreasing budgets. Moaning is a (easy) possibility but ineffective. Another way is to look for other solutions. When reading the contribution of Wolfgang Treimer on the history of polarized neutron tomography at HZB, Berlin, mostly the development and operation of "his" facilities PONTO I and II (page 4), the idea of a basic approach came to my mind. With the decision to shut down HZB in 2019 and PONTO already shut down at the end of 2016 an interesting question on the further use of "old" equipment was initiated. In this special case a move to PSI was agreed on, i.e. PONTO will most probably survive and be available again for the neutron imaging community in the near future, but I'm sure, that there are much more "facilities" and components worldwide, which no longer are in use by the initial owners, going to seed in storages or even worse being scrapped. Therefore a new category on our webpage is planned for the beginning of next year acting as a platform for the offering of such components. More information will be mailed to all members of ISNR as soon as it is activated.

The focal point of this issue is on archaeology and cultural heritage in combination with neutron imaging. Three articles on the investigation of tsubas (Francesco Grazzi et al., page 8), on special aspects of restauration and conservation of wooden samples (Amèlie Nusser et al.,page 11) and on first results on fission neutron tomography of a skull of a large therapsid (Malgorzata Makowska et al., page 13) demonstrate a section of the broad field of possible applications. A special forum for presentations and information exchange on these topics was conducted at the NINMACH conferences (page 24).

In the previous issue of the NR Newsletter (No. 12) you were asked to comment on the drafts of the revised constitution of ISNR and on terminology for neutron imaging, both compiled by Task Groups of the ISNR. Neither of the two conveners (Les Bennett and Markus Strobl) have received a single comment after 8 months (!) bringing up the interesting questions if either no one is reading the NR Newsletter, no one is interested in these two topics or the conveners and the members of their Task Groups did a perfect job! As I'm a positive thinking person - at least most of my time - I imply the third option. Anyway, as there will be a final voting on the constitution at WCNR-11 in Sydney, Australia, in September 2018 (page 3) by the participants you still have the (final) chance to influence its content. The work on the terminology will be continued, too, and major changes by delayed comments might not be considered anymore in the future. It's up to you to accept it as it is or to contribute actively.

Enjoy reading this NR Newsletter and many thanks to all the colleagues contributing to this issue.

Wishing you all the best

Thomas Bücherl

11th World Conference on Neutron Radiography
WCNR-11
September **2018** | Sydney, **Australia**

Australian Government | ansto

Call for abstracts

11th World Conference on Neutron Radiography

WCNR-11

September **2018** | Sydney, **Australia**

We invite you to submit abstracts on the following topics:

- Instrumentation
- Methods
- Software
- Geoscience
- Material science
- Engineering
- Food / Agricultural science
- Cultural heritage & Archaeology
- Palaeontology
- Medical Science
- Industry

IMPORTANT DATES

Call for Abstract: January 2018

Abstract Close: Mid April 2018

Accepted Advised: Early May 2018

Registration Open: April 2018

Registration Closes: End of July 2018

Email: wcnr11@ansto.gov.au
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ANSTO's OPAL reactor building.

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If you have any further enquiries about the conference please contact the organising committee wcnr11@ansto.gov.au

Some Words from Down Under

More than 3 years since the last world conference have passed and I would like to announce that the date and venue for the World Conference on Neutron Radiography 11 is set to 02 – 07/09/2018 in Sydney at the Maritime Museum. We will run the conference with an organisational, international and scientific committee. Please see the conference flyer for further details. The WCNR-11 conference website is online and the email sever is working. The most immediate step will be the call for abstracts in January combined with more information on accommodation and surroundings.

In addition to the world conference we plan to host a workshop on industrial engagement and a neutron imaging school. I would like to ask for some feedback on this matter; if you like the idea and what are your expectations. Any suggestions and volunteers for giving a lecture at the neutron imaging school please contact as through the WCNR-11 email address.

I am looking forward to see you all next year in Sydney.

Ulf Garbe

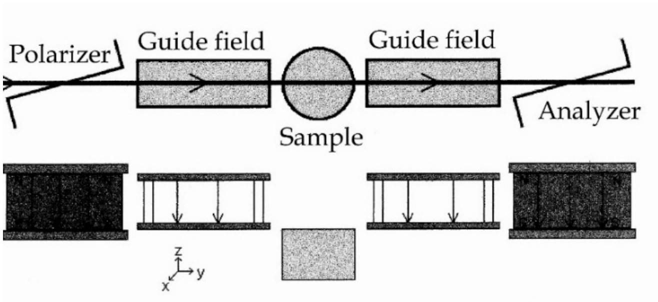
New and/or ongoing projects

Polarized neutron tomography – PONTO

Some historical remarks

Radiography with neutrons has long tradition because soon after the discovery of the neutron by J. Chadwick in 1932 [1], Hartmut Kallmann and Ernst Kuhn started in 1935 in Berlin, Germany, first experiments on neutron radiographies [2]. However, it lasts more than a half century when first high resolution neutron radiographies and tomographies were presented [3] and again nearly ten years to use polarized neutrons for high resolution neutron imaging.

However, first attempts on this topic have already been done in 1996/1997 when some of my very ambitious students (Jens Kraft [4], Christoph Ernst [5] and Christoph Herzig[6])



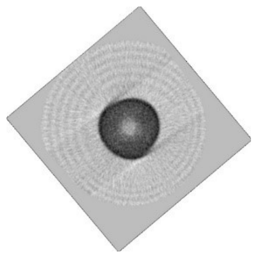


Fig. 1 „Historical" set up for imaging with polarized neutrons, polarizer and analyzer were super mirrors, small magnet with a hole (diameter ~ 20mm with hole ~ 5mm) and its stray field were 2D reconstructed. The E8 instrument at the BER II was in 1996/1997 the first set up of an imaging instrument for polarized neutrons, reconstruction was published with other experiments on neutron tomography in 2005 [8].

built up a double crystal set up (E8 instrument at the BER II reactor) and realized the first 2D reconstruction of the stray field of a small magnet (see Fig. 1). The set up was very simple: A perfect Ge- single crystal served as monochromator and neutrons were polarized by a super mirror. Behind a guide field, the small magnet was translated approximately 60mm perpendicular to the 0.5mm slit–collimated neutron beam, which width determined the spatial resolution. The spin was analyzed by a second super mirror. In order to get rid of the high back ground in the beam, neutrons were Bragg reflected by a graphite crystal towards a He_3 detector (not shown in Fig. 1 as well as the Ge monochromator in the neutron guide). The oscillating structure of the 2D reconstruction of the stray fields from raw data proved the spatially different path integrals and therefore different spin rotations of the polarized neutrons through the stray field.

Development of polarized neutron tomography (PONTO) at HZB (Berlin)

In 1999 Markus Strobl, coming from Vienna Atomic institute joined my group as PhD student and in the frame of his doctorate thesis he worked out several important developments on neutron tomography. On the basis of Jochen Schaper's diploma thesis in 1995/1996, who investigated in very detail refraction contrast effects and corresponding reconstructions using the double crystal diffractometer V12b (later these effects will be called "phase contrast"), he studied spin dependent refraction on wedge-shaped magnetic fields and worked out several experiments using Zeeman splitting and high resolution double crystal diffractometry [9]. All these work and effort were financed by three BMBF projects (03TRE9B6 (2001-2005), 03TR6TFH (2004-2008) and 05KN7KF1 (2007- 2010) guaranteeing man power and money for instrumental development.

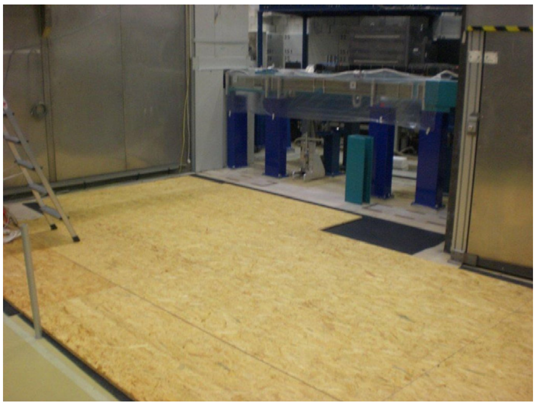


Fig. 2 Neutron guide and the wood-covered "Tanzboden"

In 2004 Nikolay Kardjilov started to build up CONRAD and already in 2005 first experiments could be done. In 2006 experiments with polarized neutrons were performed and we succeeded to image magnetic fields of an YBaCuO sample in superconducting state [10]. So soon it was clear to build an instrument mainly dedicated to polarized neutron imaging.

After some tedious and long-winded discussions (since 2007), in 2008 polarized neutron tomography, "PONTO", finally got a small slot between triple axis spectrometer FLEXX (operating often with high magnetic fields!) and CONRAD. PONTO was constructed and built up mainly by my very ambitious coworkers Omid Ebrahimi and Nursel Karakas, who both finished in 2008 their diploma theses. After several breaks in 2009, until October 2010 they could install polarizer and analyzer, collimator and the new 2D detector (Andor camera) and perform first test experiments on imaging magnetic fields in coils as function of different currents. Encouraged by results of these tests, experiments with polarized neutrons were accomplished concerning Meissner effect and magnetic flux pinning in superconducting lead (Pb) and Niobium (Nb), succeeding to visualize and quantify trapped magnetic flux [11] - [14].

Fig. 3 Monochromator shielding

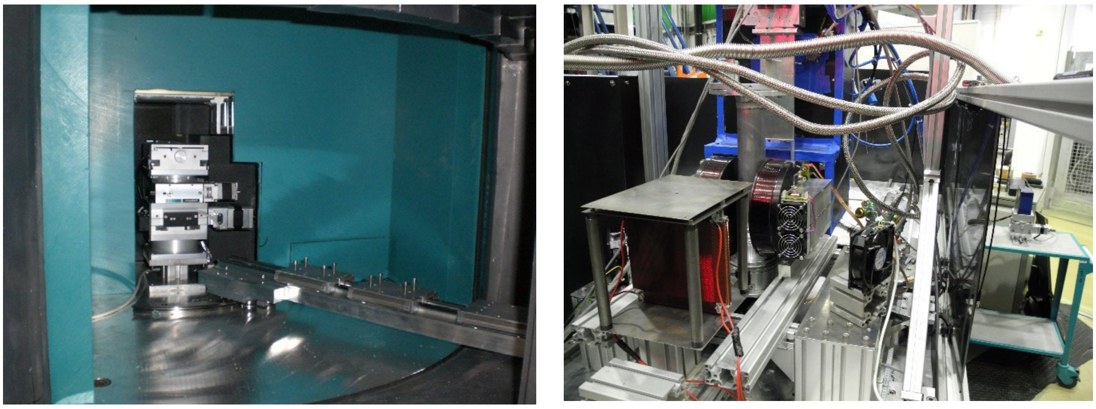


Fig. 4 Monochromator shielding with moveable arm of the optical bench (left) and polarizing equipment on the optical bench (right).

After another experimental break (exchange of neutron guides from October 2010 until March 2012) PONTO II was re-designed, renewed and installed on the site of the triple axis diffractometer which moved to the end of the neutron guide hall.

Figs. 2 – 5 show the installation and final layout of the new instrument PONTO II. It had several unique features, which were different from classical "pin-hole" instruments: The wavelength could be continuously varied with high precision from 0.31nm < λ< 0.47nm, covering relevant Bragg edges of elements such as Cu, Fe, Ni. $\Delta\lambda/\lambda$ (depending on $\lambda$was $1.7{\cdot}10^{-3}$ - $3.4{\cdot}10^{-3}$ and sharp enough to scan Bragg edges with high accuracy. The 2D collimation of 0.1° corresponded to a 2D - L/D ratio of 570 which could be increased up to >1000 and – also a unique feature – the L/D ratio was independent from the distance of the sample position and the virtual source (monochromator). The neutron beam was polarized and spin-analyzed with benders, yielding a total beam polarization P > 96%, spin flippers could rotate the neutron spin in any direction in front of the sample. The intensity at the sample position for un-polarized but monochromatic neutron beam for wavelength of 0.32nm was about $5{\cdot}10^6$ neutrons [$cm^{-2}{\cdot}s^{-1}$], which decreased to about $2{\cdot}10^6$ [$cm^{-2}{\cdot}s^{-1}$] for λ~ 0.46nm. We used an ANDOR camera, (2k×2k pixels, each pixel was 13.6µm×13.6µm, field of view (FOV) was ~70mm×70 mm) and got a spatial resolution of 55µm for un-polarized neutrons. The field of view for polarized neutrons was 40mm×40mm, the spatial resolution was 130µm.

The sample could be placed in any environment (cryostat, oven, magnet, etc.), also between two Helmholtz coils (diameter 200mm) whose magnetic field could be increased up to 20 mT (200 G), translated parallel (up to 3m) and perpendicular (up to ±300mm) to the incident beam, and it could be rotated by 360(0.01)°. The exposure time indeed was quite long in comparison with pin hole instrument which uses the whole neutron spectrum, so it varied in the case of a polarized beam from 15' up to 120' per image (frame).

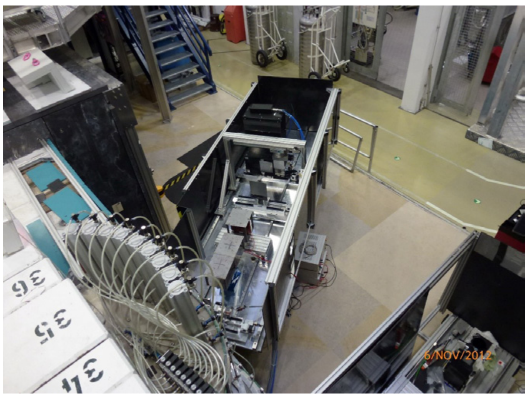


Fig. 5 PONTO II in the guide hall of BER II (finished in November 2012)

Between 2012 and 2014 Indu Dhiman (from BARC, India) and Ralf Ziesche, Luisa Riik, Johannes Nicol and Henning Höppner (all students from the Beuth Hochschule für Technik Berlin) joined the group after Omid Ebrahimi and Nursel Karakas moved to industry, and – having in March 2012 neutrons again – started detailed investigations on Meissner phase, flux trapping and thermodynamics in superconductors below Tc [15], Fig. 6. Within the next years we succeeded to realize a large number of experiments with astonishing results, which all still wait for detailed data analysis and publications. In summary, beginning with the development of contrast effects for neutron imaging and finally the use of polarized neutrons with PONTO I and II, and considering the quite short life time of PONTO I and II (< six years beam time), more than 25 peer reviewed publications have been published, more than 70 talks given and four book contributions have been written (another is planned).

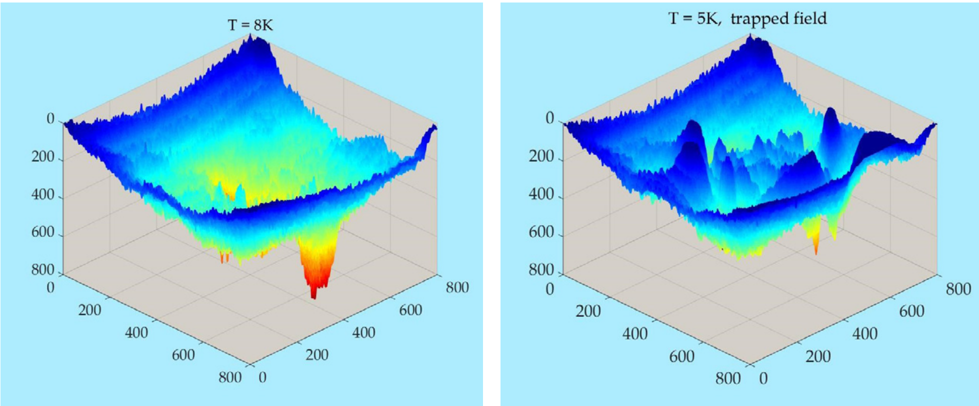


Fig. 6 Left: Pb sample, cylindrical shape, T=8K, right: after field cooling (8K →5K) @ B_{ext} = 6mT, then B_{ext} = 0 @ T = 5K.

PONTO II moves to the PSI

The closure of PONTO II at the end of 2016 was a strange decision, for myself quite incomprehensible. As a guest scientist since 1977! I got a lot of support and benefits from the HZB (former Hahn Meitner Institute) and I was quite certain running PONTO II until 2019, what would have made sense, because PONTO II - a BMBF financed instrument - was supposed to serve as user instrument. The shutdown of the BER II at the end of 2019 affected guest groups first, however, that PONTO moved to the PSI seems to me a very good solution, for the instrument and for physics, because my "old" PhD student Markus Strobl became head of the neutron imaging group of the PSI, and so the circle closes and PONTO (III?) will hopefully be used for further challenging experiments notably in the field of imaging with polarized neutrons.

Wolfgang Treimer
treimer@beuth-hochschule.de

Selected references

[[1] Chadwick J., Possible Existence of a Neutron. Nature 1932; 129:312
[2] A nice review about NR is given by J. S. Brenizer, Phys. Procedia 43, 10 – 20 (2013)
[3] B. Schillinger: „3D Computer tomography with thermal neutrons at FRM Garching", Journal of Neutron Research Vol. 4, pp. 57-63, 1996
[4] Jens Kraft, Diploma thesis „Konstruktion, Aufbau und Test einer Neutronenpolarisations- und analyseeinrichtung", FB II, Technische Fachhochschule Berlin (1996)
[5] Christoph Ernst, Diploma thesis „Untersuchung von π- Flippern mit kalten Neutronen", FB II, Technische Fachhochschule Berlin (1997)
[6] Christoph Herzig, Diploma thesis „Experimentelle Realisierung von 3D-tomographien aus Neutronenradiographien, FB II, Technische Fachhochschule Berlin (1997)
[7] Jochen Schaper, Diploma thesis "Untersuchungen zum Refraktionskontrast bei Tomographien mit themischen Neutronen", FB II, Technische Fachhochschule Berlin (1996)
[8] W. Treimer , N. Kardjilov, U. Feye-Treimer, A. Hilger, I. Manke, M. Strobl; „Advances in Solid State Physics", Vol 45, Ed. Bernhard Kramer, Springer Verlag, 407 – 420 (2005)
[9] M. Strobl, W. Treimer, P. Walter, S. Keil und I. Manke, Appl. Phys. Lett. 91, 254104 (2007)
[10] N. Kardjilov, I. Manke, M. Strobl, A. Hilger, W. Treimer, M. Meissner, T. Krist, J. Banhart, Nature Physics 4, 399 - 403 (1st May 2008)
[11] W. Treimer, O. Ebrahimi, N. Karakas, R. Prozorov, Phys. Rev. B 85, 184522-1 – 9 (2012)
[12] W. Treimer, O. Ebrahimi, N. Karakas, Appl. Phys. Lett. 101, 162603–1 – 162603–4. (2012)
[13] S .Aull, O. Ebrahimi, N. Karakas, J. Knobloch, O .Kugeler, W. Treimer, J. Phys. 340, 012001, p 1–7 (2012)
[14] W. Treimer, Journal of Magnetism and Magnetic Materials 350, 188–198 (2014)
[15] I. Dhiman, R. Ziesche, V. K. Anand, L. Riik, G. Song, A.T.M.N. Islam, I. Tanaka, W. Treimer, Phys. Rev. B, 96, p 104517-1-10 (2017)

Neutron imaging applied to archeology and cultural heritage

Characterization of an ancient multilayered steel Japanese hand guard (tsuba) from the Stibbert Museum.

The metal artifacts are probably among the most esthetically pleasing and technologically complex objects produced in Japan during the Edo period (1600–1868 A.D.). In particular, as part of the sword fittings, the protective plate of the sword handle (tsuba) is a very peculiar artistic object, typically made of steel or copper alloys. The tsuba were carved, gilded, and generally patinated using a wide number of different techniques that are unknown still today. Since katana evolved from being just weapons into status symbols, also the sword mounting gained great importance. Being its most evident part, visible at first glance, even with the sword reposed in its sheath, the tsuba must fulfill a double function. They need to be stiff enough for fighting, and nice enough for showing. Some tsuba were produced aiming to its primary importance as defensive component of the sword mounting. In this case, they were made of steel, with few or no surface decoration. Nevertheless, the external aspect was considered so important that a plain simply patinated surface was viewed as insufficient. A solution, combining aesthetic quality with high-level mechanic performances, was the use of multi-layered steel with alternated, high and low carbon content layers.

The stiffness of a plate, made using the aforementioned structure, is outstandingly better than any massive iron or steel plate of that time (full of weak slag inclusions) since the interface between two different layers of steel is able to absorb a high amount of impact energy. Moreover, the surface aspect of the layered material is amazingly beautiful and

Fig. 1 Pictures of the two sides of the Myochin School tsuba analyzed using neutron laminography. Spiral lines running on the whole surface are visual evidence of the complex multilayered structure.

comparable with the appearance of Indian wootz steel or with the pattern-welded blades (i.e. the Indonesian keris).

Our experiment aimed to characterize the inner structure of a tsuba exhibiting a composite surface as typical of artefacts manufactured according to the aforementioned technique. The identification of the volume distribution of the different layers of steel is quite important for the comprehension of the working procedure and the metallurgical skills of Japanese blacksmiths during the Edo period.

We performed a tomographic reconstruction using the technique of neutron laminography on a tsuba attributed to the Myochin family, which was famed in Japanese Edo period for producing the most appreciated steel artifacts with complex multilayered structure [1]. The tsuba is shown in Fig. 1 and was made available by the Japanese section of the Stibbert Museum in Firenze (Italy). The tsuba is approximately a round disk, 80mm in diameter and 5mm in thickness. Due to the shape of the sample, a non-standard 3D imaging technique as laminography was necessary in order to avoid the acquisition of blind

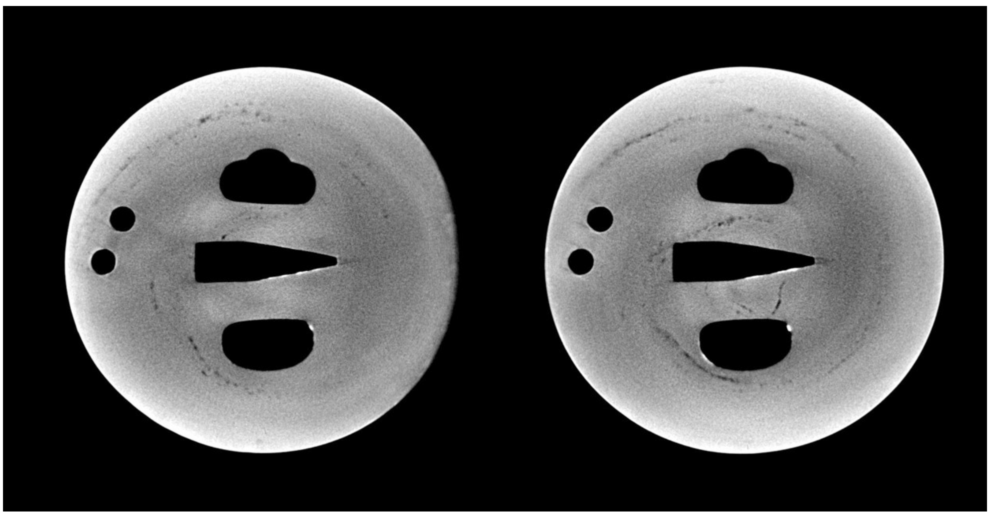


Fig. 2 Laminography slices inside the tsuba, spaced 1mm each other. It is evident the presence of welding lines (strong and weak) having spiral shape.

angle projections. Neutrons are clearly the only probe of choice to investigate the bulk of steel and to spatially map the morphological characteristics of the internal welding lines.

The experiment was performed at the ICON beam line [2] at the Paul Scherrer Institut, acquiring 625 projections at a tilt angle of 15° with a pixel size of 98µm.

Despite the reconstruction suffers of some blurring in the slices close to the sample surface due to the laminography reconstruction algorithm, slices in the core are quite clear and two of them (separated by 1mm in height) are shown in Fig. 2.

The most interesting feature revealed by the slices is the presence of several spiral shaped welding lines: the most pronounced one, outlined by black spots dotting its curve starts on the right side and moves clockwise towards the centre of the tsuba. Several weak ones follow a parallel path. This distribution can give very interesting details on the manufacturing method of the tsuba.

In fact, we can infer that it was made in two steps: at first a multilayered squared piece of steel was prepared, obtained thought the standard technique of hammering and folding (orikaeshi) [3] used to refine the steel for the making of Japanese swords. The weak (high quality) welding lines present in the tsuba are originated by this process.

Then, a slice of this multilayered steel was cut out from the block and wrapped (and welded) over itself by keeping the multilayered structure parallel to the top and bottom surfaces. The welding was performed during the wrapping, starting from the center and moving outward, and the exceeding volumes were removed to obtain the rounded shape. The quality of this final welding is highly variable because of the complexity of the process as demonstrated in fig. 2 where the large dark grains present on the most part of the welding volume follow portion of, very homogeneous solid metal along the same line.

The picture of the two surfaces of the tsuba (in Fig. 1) shows a homogeneous wavy pattern , without any evidence that welding lines were made in different steps and feature different quality as it was instead clearly revealed by neutron laminography. By using this technique, we were able to understand the manufacturing process of a complex and, at first sight, very puzzling structure of the multilayered tsuba made by the Myochin School.

We gratefully acknowledge the collaborative attitude of the Stibbert Museum of Firenze and, in particular, of Dr. Francesco Civita.

Francesco Grazzi, Floriana Salvemini, Anders Kaestner
contact: f.grazzi@ifac.cnr.it

References

[1] R. Burawoy, The Picture Book of Old Tsuba, Arts Graphiques d'Aquitaine (1983)
[2] A. Kaestner et al., Nucl. Instr. and Meth. in Phys. Res. A 659, 387 (2011)
[3] L. Kapp et al., The Art of the Japanese Sword: The Craft of Swordmaking and Its Appreciation, Tuttle (2012)

Neutron Tomography to Support the Preservation of Charred Wooden Archaeological Objects

Various archaeological objects have been interrogated with neutron imaging techniques, mainly to identify organic materials behind metal layers or to detect original surface structures underneath coatings of corroded materials. In case of fragile wooden artefacts, it is common practice to obtain stability by impregnating with a fixative agent by immersing the object or applying the agent with a brush. In any case, this results in a distribution of an organic substance within an organic wooden matrix so it should be identifiable by the hydrogen content. As a consequence, neutron imaging was used here to trace the whereabouts of the applied consolidant.

This study [1] was carried out on a charred wooden torso from the Seleucid era found in Uruk (Vorderasiatischen Museum, SPK, Berlin, Inv. VA 11689, Fig. 1) stating a problem in so far that it remained highly fragile in spite of several restoration attempts. Due to its state it was impossible to take this artefact to any far distant laboratory for further studies. In order to study the distribution of usually applied consolidating agents wooden mock-ups were produced by controlled charring of wooden pieces in a kiln. While one part of these mock-ups was left untreated as controls, the others were treated like an archaeological artefact to be preserved (Fig. 2). All specimens have been subjected to computer tomography (CT) with fission neutrons at the NECTAR facility at FRM II which has been proven to be suitable for interrogating large wooden sample up to some 30 cm in diameter in previous studies.

Fig. 1 Damaged Torso of a sacral figure from Uruk, dated back to the Seleucid era (SPK, Berlin, Inv. VA 11689). The back side illustrates the deteriorated state of the artefact.

Fig. 2 Mock-up prepared from wood charred in a kiln for testing preservative measures.

The scope of the study did not allow investigating one and the same specimen before and after treatment. So histograms have been calculated from the reconstructed image data to demonstrate the density shift between treated and untreated samples (Fig. 3). Principally, two groups of agents could have been identified, one with a high uptake paralleled with a gain of some 30% in weight and another one with a poor total uptake of 5% or less. In the first case, the distribution of the consolidant was clearly visible in the CT result, while in the other it was not (Fig. 4). Nevertheless, there was a clear density shift in the histograms. This could have reasons as in raised densities within a certain range only in contrast to an expanded histogram range. Essential to know is where such changes might have taken place. Therefore, a range with changes should be identified that are

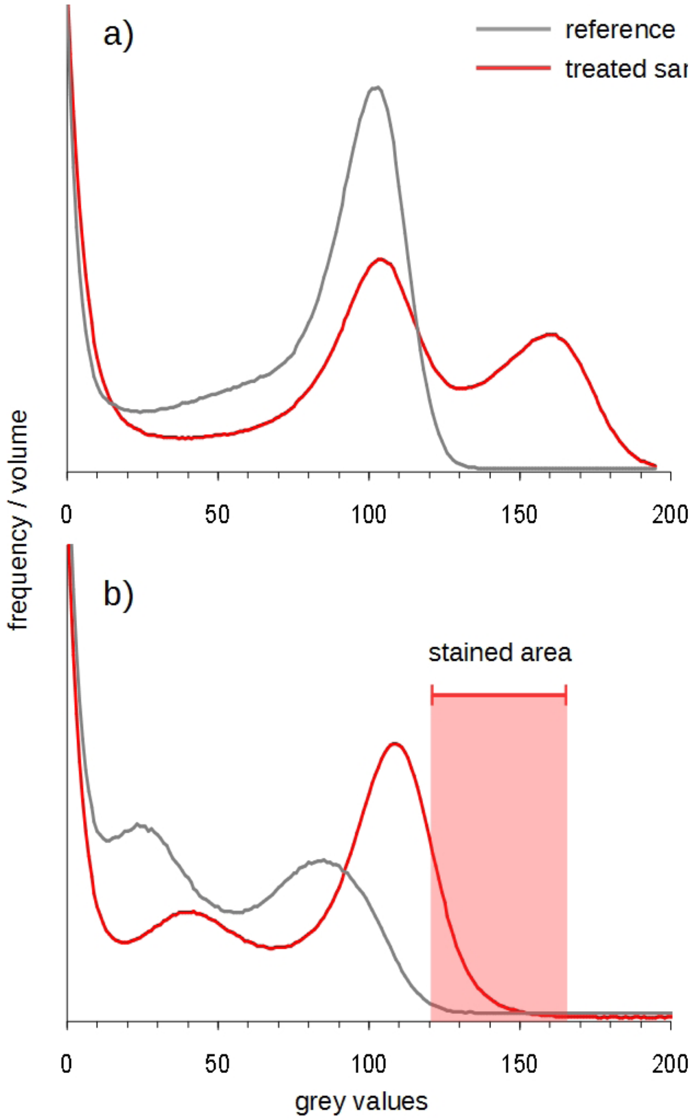


Fig. 3 Histograms of the CT results, abscissa: grey value bins, ordinate: relative frequency of voxels, a) hight uptake of impregnant (linseed-oil furnish in ethanol), b) low uptake (Polyvinylbutyral B30H).

most likely attributable to added material after the treatment, i.e. in the area where differences between treated samples and untreated controls differ and density values are less represented in the control specimens. Such an area is marked with the red colour in Fig. 3 and Fig. 4. Interestingly, the labelled areas are located peripherally in the zones between the char and the wood not destroyed by the heat.

It is expected that stabilisation can be achieved by filling gaps raised in the damaging process with an adhesive filling rather than soaking the whole object but with questionable adhesive properties. Certainly more detailed studies may be needed to obtain a clear-cut idea of treatment results and of a gain of stability but also certainly not without imaging techniques as the one presented here.

Amélie Nusser, Kurt Osterloh, Stefan Röhrs, Sonja Radujkovic,
Andreas Schwabe,Stefan Söllradl, Ina Reiche
contact: A.Nusser@smb.spk-berlin.de

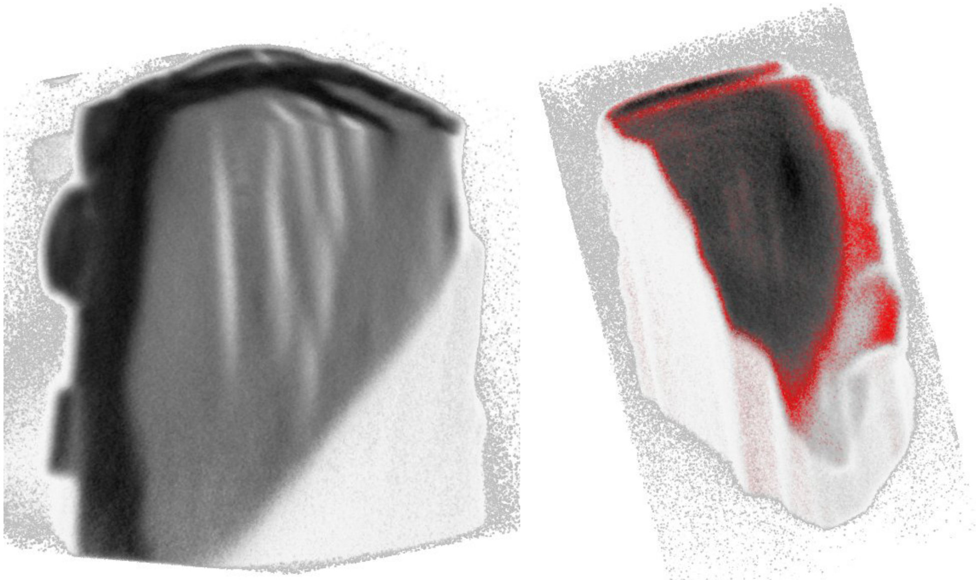


Fig. 4 CT results of high and low uptake (as in Fig. 3): a) high uptake as visible in the dark areas, distribution evidence does not need stain marking, b) areas with increased densities marked in red as indicated in Fig 3b.

Reference

[1] K. Osterloh et al., N.i.Ke.-Schriftenreihe 1, 2017, 94-99, ISSN 2567-1251

Tomography of large fossils at NECTAR facility

NECTAR (NEutron Computerized Tomography and Radiography) is a unique neutron imaging facility utilizing fission neutron spectrum [1]. The highly energetic spectrum is achieved by placing a so-called converter plate containing 540g of highly enriched uranium in front of the beam tube. Neutrons from the reactor core reach the converter plate after traveling through the moderator, resulting in fission reactions. Consequently, fission neutrons enter the beam tube without any further moderation and the beam with a spectrum with a mean energy at about 1.9 MeV is available for imaging experiments.

High penetration power of fission neutrons enables non-destructive investigation of inner structures in large samples, which is not possible with thermal beam and thus, fission neutron imaging is a technique well suited for studies of large archeological and paleontological objects.

Recently, a large jaw and a skull of the 230 my year old therapsid Stahleckeria potens was studied by computed tomography at NECTAR. The goal of the study on this largest therapsid from the Mid-Triassic was to gain more insight and information about the hearing mechanism of this animal. This first attempt to apply fission neutron imaging at NECTAR to paleontological material is presented in Fig. 1 and Fig. 2.

Recent investigations supported the hypothesis that a bony plate at the lower jaw of small therapsids, the reflected lamina, could have allowed them to detect sounds [2]. A reflected lamina was also present at the lower jaw of S. potens, but it was extremely large and

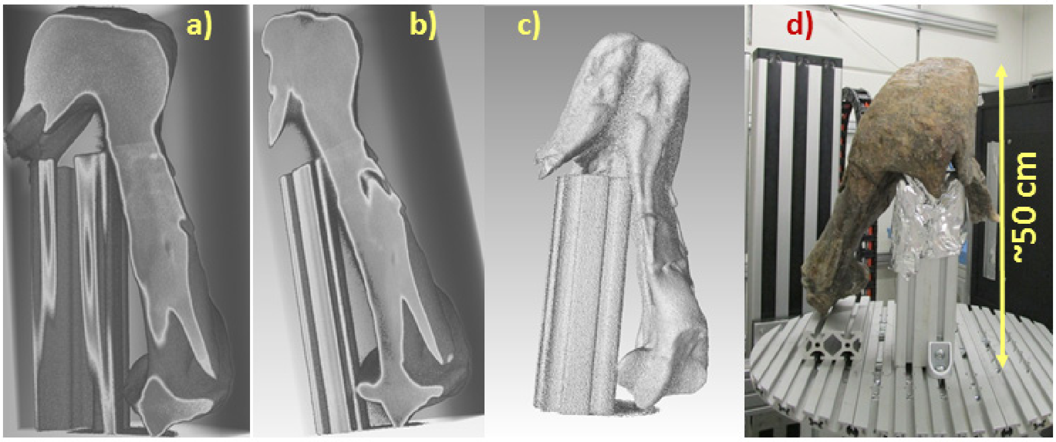


Fig. 1 Fission neutron tomography studies of the lower jaw of Stahleckeria potens (Paläontologische Sammlung der Universität Tübingen, GPIT/RE/7106-2), a-c) 3D visualization of the reconstructed object, b) photograph of the sample positioned at the sample stage.

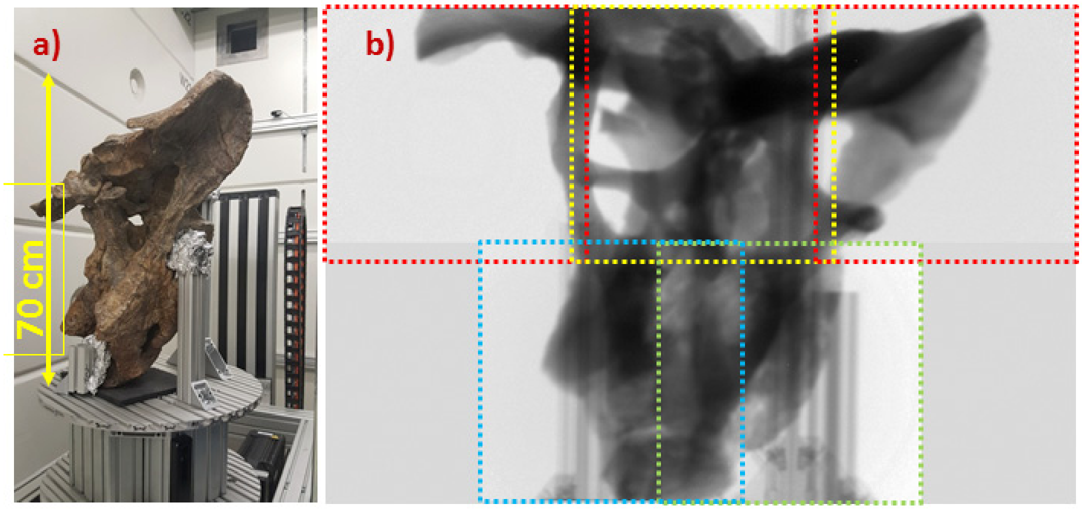


Fig: 2 Fission neutron tomography studies of the skull of Stahleckeria potens (Paläontologische Sammlung der Universität Tübingen, GPIT/RE/7107) with a) the skull placed at the sample position and b) a projection obtained via stitching of five normalized radiographs.

thick in comparison to small species, and therefore, it is not clear whether S. potens could actually hear sound with such large bones or whether it represents an old structure with lost or changed function. 3D imaging with fission neutrons was applied to examine the ear region of the skull and potentially to reconstruct the hearing mechanism to gain more information, which could allow to answer this query.

The dimensions of these samples (up to 75cm) were significantly larger than the field of view (FOV) available at NECTAR (which is limited to 30cm x 30cm) and thus, for each angular projection, two images of the jaw and five images of the skull were acquired. Firstly, the single images were stitched in order to create one projection image for each angle (Fig. 2 b), and afterwards it was possible to perform a reconstruction using Octopus software.

Malgorzata Makowska
Michael Laaß
Ingmar Werneburg

References

[1] T. Bücherl, S. Söllradl, NECTAR: Radiography and tomography station using fission neutrons, 277 J. large-scale Res. Facil. JLSRF, vol. 1, p. A19, Aug. 2015.
[2] M. Laaß, The origins of the cochlea and impedance matching hearing in synapsids. Acta Palaeontol. Pol. 2016, 61(2), 267–280, DOI: http://dx.doi.org/10.4202/app.00140.2014.

News from the Lab and Out of Practice

The Munich Neutron Imaging Group (MUNIG) at MLZ

The Munich Neutron Imaging Group (MUNIG) has been established to combine the imaging expertise at MLZ. The objective of the group's installation is to foster exchange between the individual instrument teams and to enable mutual benefit by standardization of instrument control, data processing procedures and evaluation software. The group also offers professional support for neutron imaging users and other groups that use neutron imaging as a complimentary technique. The neutron imaging group at MLZ, which is managed by Michael Schulz, operates the two neutron imaging instruments ANTARES and NECTAR at MLZ and contributes to the development of the new neutron imaging beam line ODIN, which will be built at the European Spallation Source (ESS) in Lund, Sweden in collaboration with the Paul Scherrer Institut (PSI), Switzerland and the ESS, Sweden.

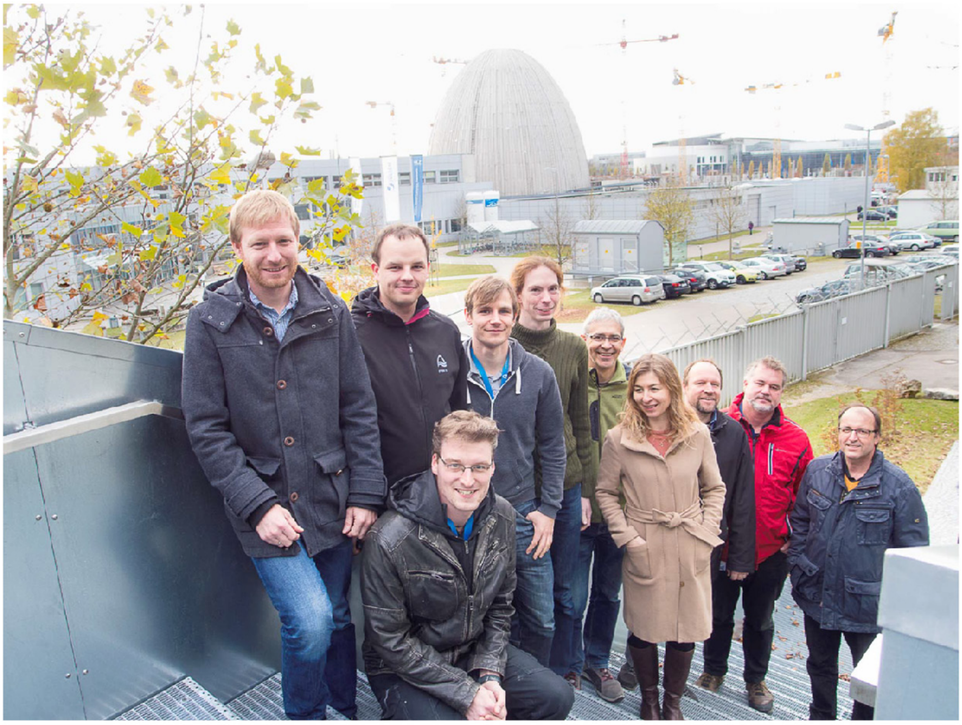


Fig. 1 Most of the neutron imaging group members (from left to right): Michael Schulz, Tobias Neuwirth, Dominik Bausenwein, Tommy Reimann, Alexander Backs, Elbio Calzada, Malgorzata Makowska, Michael Lerche, Burkhard Schillinger, Thomas Bücherl.

While ANTARES is an imaging station located at the cold neutron source of FRM II, NECTAR is a worldwide unique facility that employs fission neutrons for neutron imaging; it is currently being upgraded to additionally provide a thermal neutron beam. Furthermore, the group has access to a microfocus X-ray CT machine and, with certain limitations, to an intense gamma-CT facility using Co^{60} as transmission source. Using this combination of different and complementary neutron spectra together with the X-ray and gamma-ray imaging facilities allows us to select the technique that is best suited for each application and provide the best possible service for our users. In the following a brief overview of our instruments and their capabilities will be given.

ANTARES

The cold neutron spectrum, which is available at ANTARES provides high sensitivity to small changes in the composition of a sample. Generally cold neutrons give a strong contrast for materials containing hydrogen, while many metals are very transparent. This, combined with a very flexible choice of collimation ratios, makes the instrument ideally suited for high resolution imaging on small and medium sized samples. Larger samples can be investigated at a second detector position where the beam has a maximum size of ~35cm x 35cm. Standard applications of ANTARES include, but are not limited to, archaeology and cultural heritage where particularly organic materials can be observed with high contrast, the investigation of pores in geological samples or technical applications such as in-situ investigations of material transport in batteries, fuel cells and hydrogen storage systems.

Recently, a neutron grating interferometer (nGI) has been installed at ANTARES and is now available as a standard technique for our users. With this new imaging technique, based on an interference pattern generated by three gratings installed on the beam line, the small angle scattering signature of structures in the sample on a length scale of ~100nm to ~10µm can be observed. This directly connects to the real space resolution of the instrument and extends the sensitivity range of the instrument by bridging the gap between imaging and scattering techniques. Among other applications, nGI has been used to investigate the domain distribution in electric transformer steel blades.

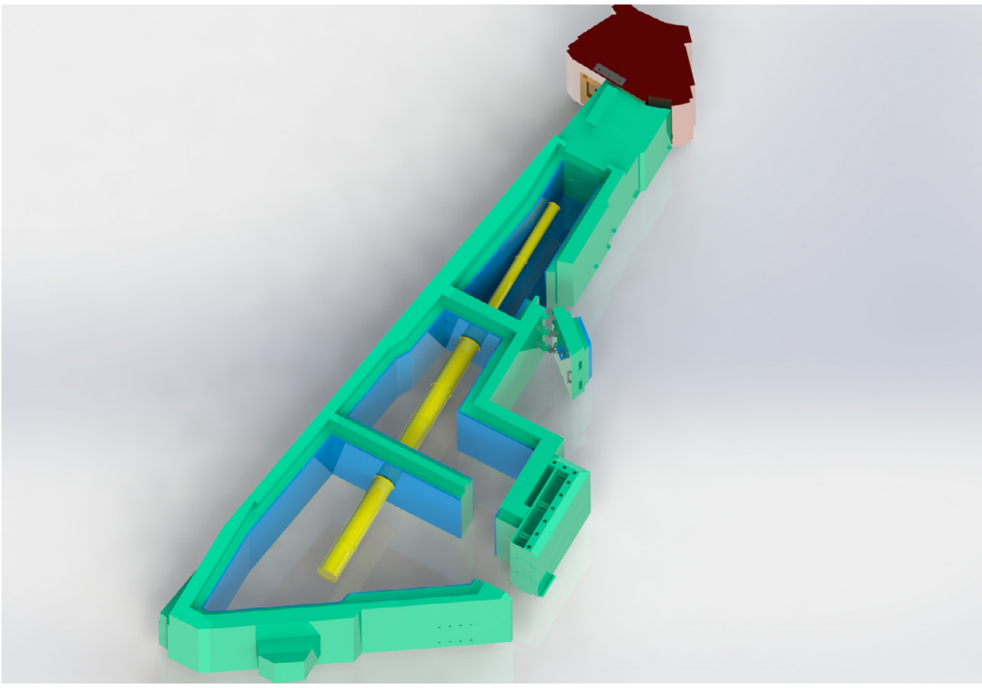


Fig. 2 ANTARES technical drawing

Furthermore, ANTARES provides a neutron velocity selector and a double crystal monochromator, which enable energy selective imaging such as Bragg edge imaging for metallurgical phase identification. Additionally, polarized neutrons are available to visualize magnetic fields or magnetic properties of materials.

The ANTARES team: Michael Schulz, Burkhard Schillinger, Dominik Bausenwein

NECTAR

The instrument NECTAR is a unique facility, which uses two Uranium plates placed in the moderator vessel of the reactor to convert thermal neutrons into a fission neutron beam. These fission neutrons show very high penetration even for large samples, while giving a contrast that is perfectly complementary to X-rays. This means that light elements such as H show strong contrast while heavy elements such as Pb or other metals are very transparent. On NECTAR samples with a maximum size of ~1m^3 and a weight of up to 800kg can be investigated with a spatial resolution of the order of ~0.5mm. Applications of NECTAR include moisture distribution and transport in wood or concrete, in-situ investigations of full-size hydrogen storage tanks and non-destructive testing of large machine parts.

By removing the Uranium converter plates and the permanently installed B_4C filter from the neutron beam, NECTAR can also provide a thermal neutron beam which is comparable in intensity and collimation to other state of the art neutron imaging facilities. The advantage of a thermal beam over the cold spectrum available at ANTARES is a higher transmission for strongly absorbing materials such as H or Li. Furthermore, higher spatial resolution can be achieved with thermal neutrons than with fast neutrons. The instrument is currently being upgraded to provide a thermal neutron beam as a standard option which enables multi-modal imaging using fast and thermal neutrons under the BMBF project 05K16VK3.

The NECTAR Team: Thomas Bücherl, Malgorzata Makowska, Rudolf Schütz, Samantha Zimnik (BMBF), Martin Mühlbauer (BMBF)

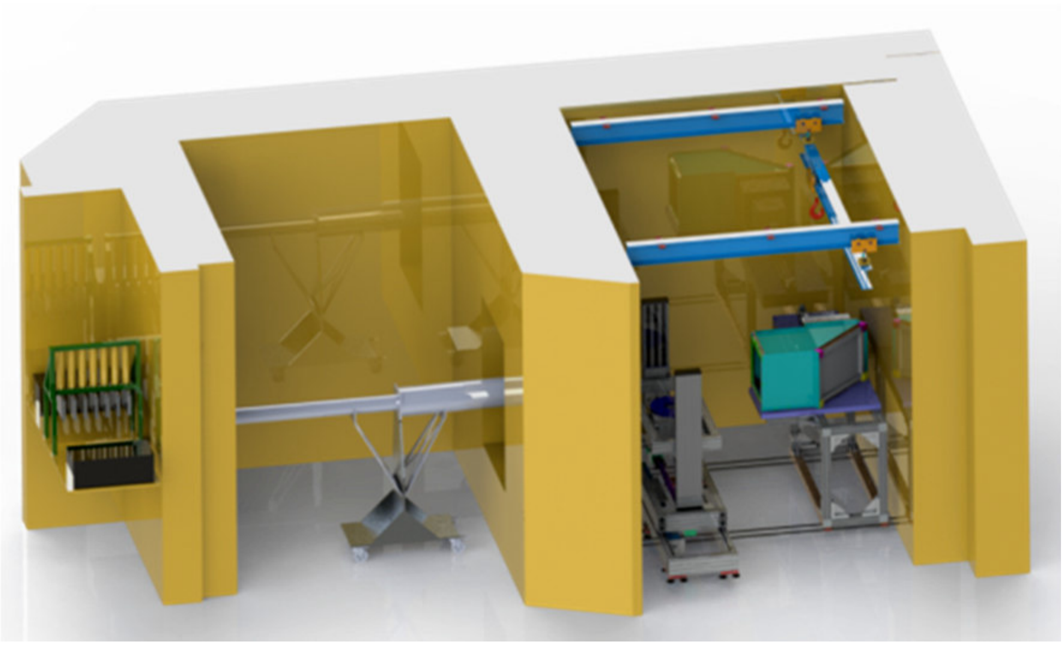


Fig. 3 NECTAR technical drawing (by Martin Mühlbauer) showing the set-up for thermal neutron radiography and tomography. Neutrons are coming from the left, passing the filter bench, the room for medical applications (with a mobile beam tube for thermal neutrons) and then entering the NECTAR room with the sample manipulator and the detector system.

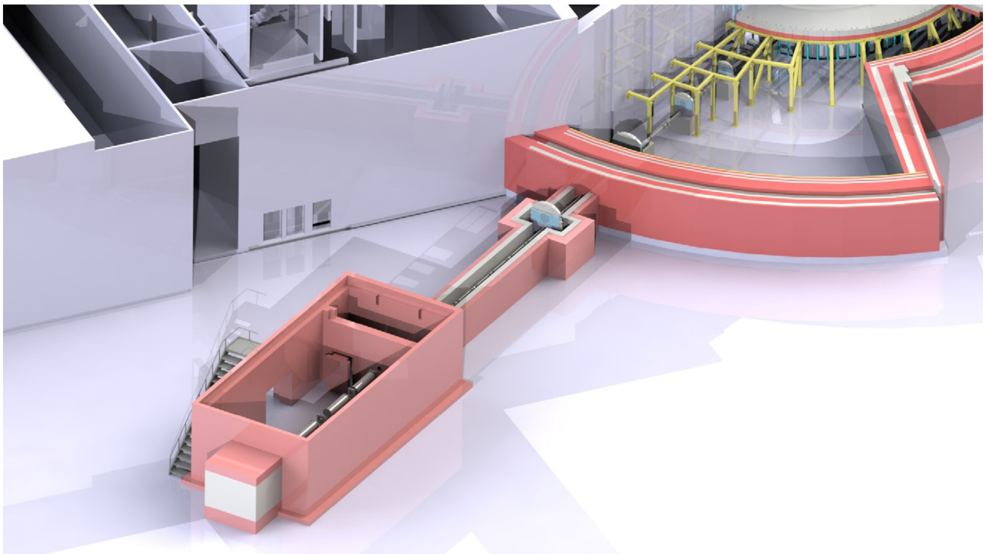


Fig. 4 Design drawing of the 60m long Time-of-Flight neutron imaging instrument ODIN at ESS. To obtain high performance for advanced imaging techniques a complex chopper system and a 50m long neutron guide will be installed.

ODIN

The experience of our group in designing and building neutron imaging instruments is additionally being used to contribute to the construction of the neutron imaging beamline ODIN at the European Spallation Source (ESS) which is being built in Lund, Sweden. ODIN will be a 60m long Time-of-Flight (ToF) neutron imaging instrument. While the white beam intensity will be comparable to ANTARES, ODIN makes use of the intrinsic wavelength resolution of the pulsed neutron beam at ESS to obtain much higher performance for all advanced, ToF based techniques, which require a wavelength dispersive measurement. To achieve this, a combination of a complex chopper system and neutron guides will be employed. ODIN will be among the first instruments at the ESS to become operational when the source comes online.

The ODIN team: Michael Lerche, Elbio Calzada

Michael Schulz

NEWS from NIAG at PSI

2017 has seen the retirement of one of the pioneers of our field in Europe, Eberhard Lehmann, as the head of the Neutron Imaging and Activation Group (NIAG) at Paul Scherrer Institut (PSI). A Symposium marking this occasion has been organized at PSI on 28th July, 3 days in advance of the official retirement. Despite the high summer season the event attracted a large number of national and international experts and users which have been involved with 22 years of neutron imaging at PSI, that were shaped by Eberhard. Starting with the opportunity to record neutron images on film on the former research reactor SAPHIR at PSI 22 years ago, Eberhard has built up a world leading group operating two dedicated neutron imaging beamlines and having secured 50% utilization of two further beamlines defining the state of the art in neutron imaging. The vast range of developments and applications over the year was reflected in a number of scientific presentations of close companions and collaborators from over the years. Topics were conveying scinitillator development, method development, cultural heritage and electrochemistry and the

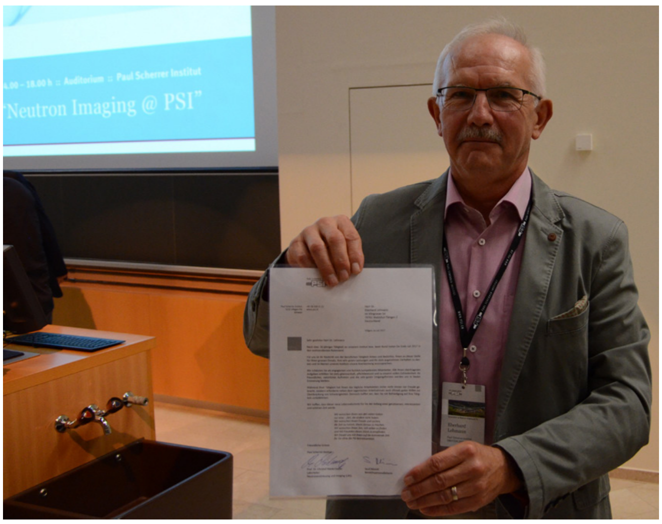


Fig. 1 From top to bottom: Eberhard in 1994 in his favorite role; audience following Eberhards wrap up of 22 years of neutron imaging at PSI; Eberhard's commendments presented to him as a goodbye present from the group through the new group leader Markus; Eberhard in his least favorit role with his document of retirement;

program was rounded of by Eberhard presenting his personal view on his history and an outlook to the future of neutron imaging in particular at PSI by the new head of the group, Markus Strobl, and a social program of course.

On 1st July 2017 Markus has taken over the affairs of NIAG in the role of the group leader and the neutron strain diffractometer POLDI has been officially implemented as an additional and complementary neutron instrument in the group. Currently one instrument position is open to be filled early 2018 at POLDI and at NEUTRA, the thermal imaging beamline. A further postdoc position shall be advertised early 2018. In addition, the imaging instrument project ODIN at ESS is realized by NIAG together with TUM and has passed the tollgate 2 review end of May 2017 to enter phase 2 of construction. NIAG is also responsible to deliver the image analyses software for ESS and ODIN through an In-kind contribution which has started in Nov 2017. While SINQ will face a shutdown in the framework of an instrument and guide upgrade project in 2019, resources will particularly focus on the ESS project and strengthen NIAGs international engagement in the promotion of neutron imaging. Eberhard is still an active part in these efforts as an engaged advisor and ambassador in international affairs, in particular with IAEA.

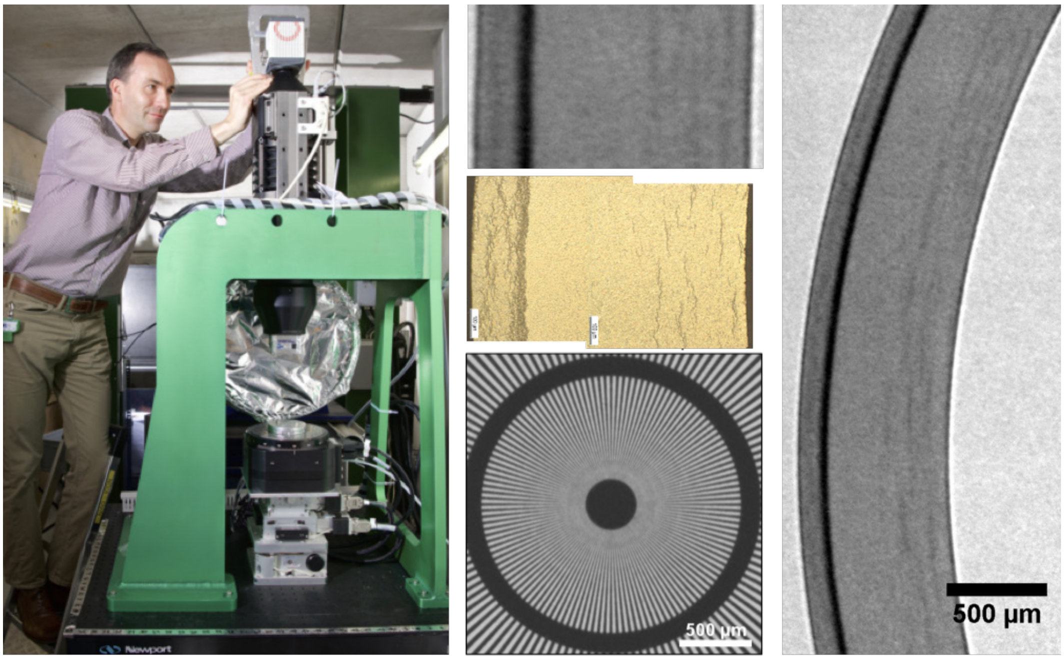


Fig. 2 Pavel Trtik setting up his Neutron Microscope producing high resolution as demonstrated on a Siemens star pattern as well as applied to hydrogen distribution in a Zirconium gladding of nuclear fuel compared to a microscopy [1] which does in contrast not allow hydrogen quantification.

NIAG has in this year successfully implemented its dedicated high resolution detector system, referred to as Neutron Microscope, in the user program and has seen overwhelming request for the detection system mainly operated at the POLDI beamline, where in this phase half of the beamtime of the year was dedicated to it. The Neutron Microscope, realized by Pavel Trtik, enables to achieve spatial resolutions of down to 5 micrometer on a field of view of some ten square millimeters, on which POLDI provides an intense focused thermal beam. An example of a very successful study is provided in Fig. 2 [1], a study of hydrogen distribution in nuclear fuel claddings. A comparison with optical microscopy is provided, which features slightly better spatial resolution still, but is, in contrast to the neutron microscope, not able to provide quantification of the hydrogen content. The instrument is easily transferrable to other beamlines within SINQ (ICON, BOA) and high

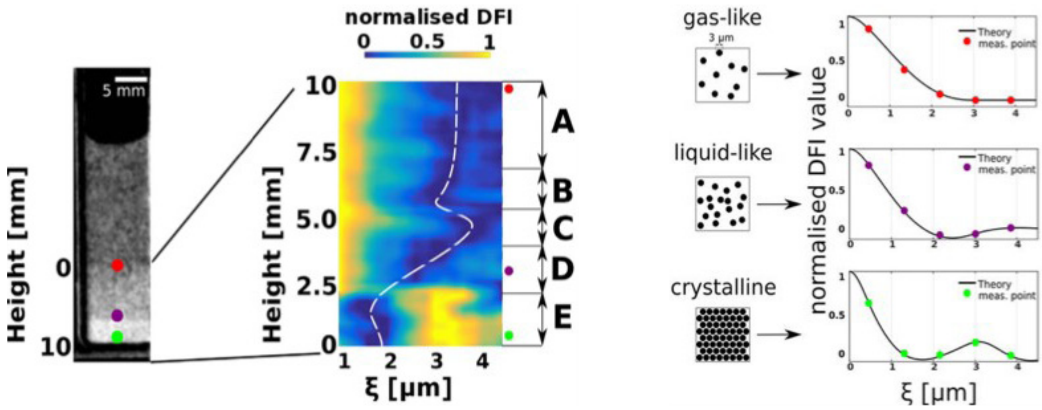


Fig. 3 Quantitative darkfield imaging of the sedimentation and quasi crystallization state of microspheres in dilution;

resolution tomographic investigations have been recently performed at BOA providing resolution of pores down to 10 micrometer in high atomic number material [2].

Another scientific highlight was the application of dark-field imaging and its quantitative potential in characterizing microstructures, developed by NIAG members, to the quasi-crystallisation of dispersed microspheres published in Scientific Reports [3].

The study revealed different phases of the system from gas like, a low concentration dilute phase, a liquid like phase, where a structure factor contribution appears in the real space correlation due to decreased next neighbor distances in a highly concentrated state and finally a crystalline phase where particles sediment and order in a crystal-like structure. Within the liquid like phase a gas-like depletion zone could be identified which appears characteristic for this kind of sedimentation driven quasi-crystallisation.

Markus Strobl

References

[1] Gong, W., et al., in preparation

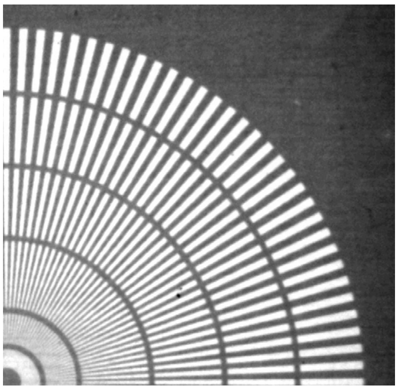
[2] Trtik, P., Neutron microtomography of void in gold, accepted for publication in MethodsX

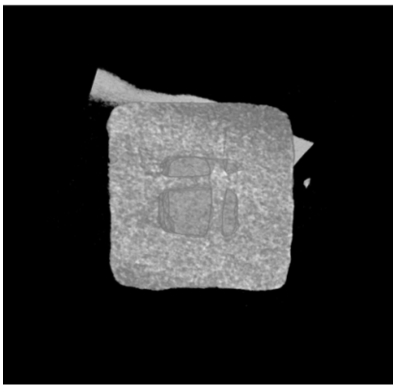
[3] R. P. Harti, M. Strobl, B. Betz, K. Jefimovs, M. Kagias, C. Gruenzweig, Sub-pixel correlation length neutron imaging: Spatially resolved scattering information of microstructures on a macroscopic scale, Scientific Reports 7:44588 (2017) | DOI: 10.1038/srep44588

Resolution improvement in tomography at DINGO

DINGO is expanding its capabilities and we are now able to offer a full tomography with 14 micron pixel size. Please see the PSI Siemens Star imaging taken under these conditions and a first result published in Peng et al. "Ferrite-based soft and hard magnetic structures by extrusion free-forming," RSC Adv.

We are planning for further upgrades on DINGO with focus on high resolution imaging. The next step is an additional beam limiter. The design is already finished and it will be installed next year. New scintillation screens and a custom made lens will complete the upgrade.





The overall performance and demand on DINGO shows that there is a large potential for further growth in the southern hemisphere and the Asian Oceanian region. With a over-booking factor of 1.5 on average since operation, 20 publications and 8 completed commercial jobs, we have good arguments for further growth at ANSTO and in the region.

Ulf Garbe

In the next issue of the NR Newsletter there might be an article on news from your lab, too. If you are interested in, please contact Thomas Bücherl (thomas.buecherl@tum.de) for further information.

What is needed to build a neutron imaging competence?

Based on the experience in the own institutes – and the others in the "club 15" of user facilities (class one facilities) - we want to consider how to extend the know-how and the competence in the field of neutron imaging and develop it towards a routine method for material research and technical applications.

Basic requirements:

1. Beam port: permanent access to a beam port with neutron intensities of more than 1E+5 $cm^{-2} \cdot s^{-1}$ (what is available at a 250 kW reactor) in a regime of the source for regular operation (6-8 hours per day, or on demand).
2. Facility: digital system, camera based – the lower the beam intensity, the more sensitive has the camera to be … (in practice it is quite opposite!); for the best approach → see below!
3. Manpower: Only if qualified and highly motivated personal is available it will be possible to succeed.
4. Management: acceptance & support is needed to build a facility and a user program; local interests and clients have to be considered from the beginning.
5. Competition: X-ray expertise and a neutron scattering community should be used for a complement – and not seen as competition.

Situations of neutron sources, mainly reactor based:

1. In industrialized countries the trend to close essential reactors (HZB, Saclay, …) is obvious; no new reactors for beam extraction are planned as compensation. The only European activity is ESS with ODIN as facility for neutron imaging.

2. Remaining sources have the potential to implement modern imaging facilities or for upgrades respectively: Norway, Czech Republic, Netherlands, some stations in USA, Hungary, …

3. New reactor projects are on the way of realization, mainly in emerging economies: Jordan, Argentina, China, … They plan neutron imaging facilities from the beginning. The competence of the involved persons is still diverse.

4. There are established reactor sources with only limited utilization but high potential: Thailand, Indonesia, Morocco, Algeria, Malaysia, Vietnam, Egypt, Chile, Brazil, …. The reason not to implement useful neutron imaging facilities has to be investigated carefully case by case – and the right attempts have to be decided: see below!

5. A lot of reactors are located in Eastern Europe and the states of the former Soviet Union. There is no clear picture about their situation and future potential. The communication with the ISNR community is limited; the IAEA support/exchange of information is highly required to be successful.

There are two ways/options to proceed for the implementation of neutron imaging at the potential sites mentioned above.

1. Top down: the neutron source makes the decision to go for the implementation of the neutron imaging techniques with full consequence under the particular conditions in the country. Since neutrons are the most expensive and important component is the systems, funding and infrastructure have to be tuned according the state-of-the art conditions with respect to layout, components and manpower. There is well-established know-how around to build the most useful system at the particular beam port, including cost-efficiency.

2. Bottom up: the source declares to be unable to build state-of-the-art infrastructure, but is willing and interested to establish "some" imaging capability based on the limited resources. All components are defined and ordered according to lowest prices and just functional properties.

In the cases 1, real partnership can be created between the experts in neutron imaging either on commercial basis or on bilateral agreements. If the professional facility is operational, efforts of the experts can be compensated by beam time usage later.

In the case 2, only limited performance can be obtained, resulting in misleading imaging data and publications with low chance for acceptance in leading journals. A user program will hardly be established due to the missing reliability and the high effort for the support to the users.

A case 2 should never be made valid for institutions with high budget because it may demolish the reputation of neutron imaging in the end, even if some preliminary good results might be obtained on short notice.

Until now, IAEA supports activities according to scheme 1 by sending experts, ordering proven technology and supporting training in a professional amount, e.g. AUNIRA 1-3.

There is no guarantee to succeed in this process, but cases of Egypt, Indonesia and Jordan can be taken as a reasonable good output. It is still in the hand of the local operators to which extent they can perform on the highest professional level.

Conclusions:

Case 2 will fail on long-term if it is not possible to move to case 1. It is necessary to convince the sources management about the importance to have a neutron imaging competence in the country and at the site. Better to neglect the technique than to have bad simple solutions without potential for further improvements. But initial simple solutions will prove feasibility and may initiate a professional program with appropriate funding. In addition, simple initial experiments will help to build up competence and understanding about the involved components from the very basics, which will help to competently design more advanced systems.

But as mentioned above, it should be avoided by all means to stop development at a simple test system and to present the initial test results as new standard competence of the facility.

E. H. Lehmann, B. Schillinger

Review on conferences and workshops

NINMACH 2017

NINMACH
BUDAPEST 2017

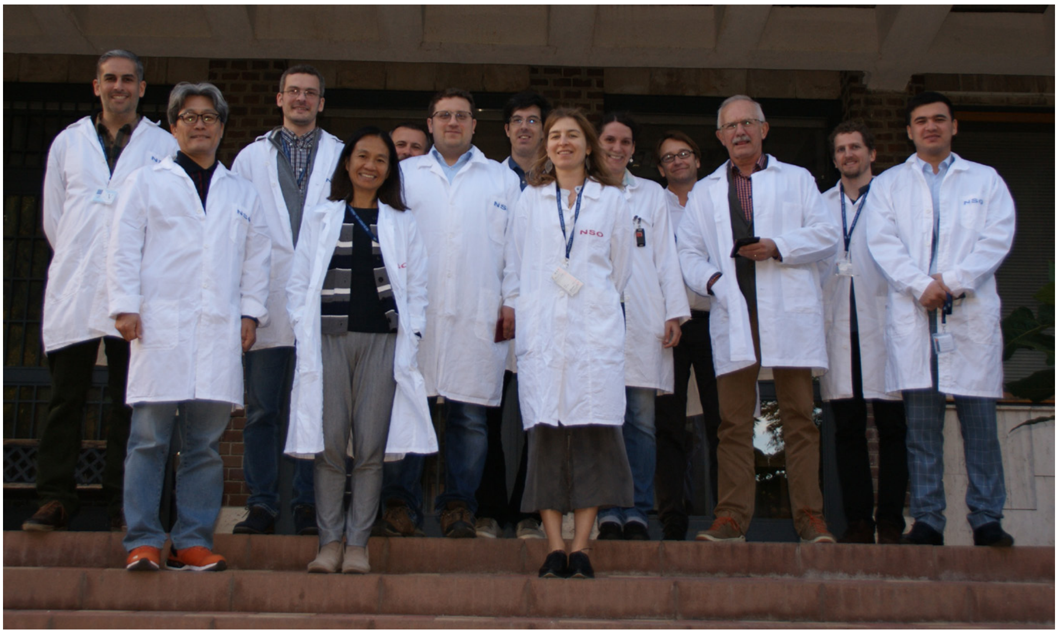
The second International Conference on Neutron Imaging and Neutron Methods in Archaeology and Cultural Heritage

The mission of the NINMACH conference series is to address neutron scientists, as well as archaeologists and conservators, by creating a stimulating environment to exchange ideas and to make a bridge between them. Since the first NINMACH took place in Garching, Germany in 2013, this field became even more mature, substantial experimental experience was accumulated, and an advanced community of specialists was formed. In 2017, the Hungarian neutron- and cultural heritage communities received the honour to organize the second NINMACH.

The three-days-long meeting took place in the landmark building of the Hungarian Academy of Sciences, right next to the famous UNESCO world heritage river banks in Budapest, Hungary. The event was organized by the Budapest Neutron Centre (BNC), the consortium of Centre for Energy Research and Wigner Research Centre for Physics, Hungarian Academy of Sciences, in cooperation with the International Atomic Energy Agency (IAEA).

In the spirit of interdisciplinarity, both neutron scientists and heritage experts have presented their most recent results about developments or applications of various neutron-based methods. New technical developments, case studies on different materials (metals, ceramics, stones, organic matter) and historical objects (utensils of ordinary life, monetary units, weapons, funerary attachments, religious relics, building materials) of Cultural Heritage significance were discussed.

Sessions were devoted to present studies from neutron imaging, neutron activation analysis and prompt gamma activation analysis as well as neutron scattering. The technical



Participants during the visit at BNC.

background was highlighted in sessions called Facilities, techniques and data processing and multi-technique approach and complementary techniques. The four keynote speakers represented the state-of-the-art of neutron imaging (Eberhard Lehmann, Burkhard Schillinger) and the interdisciplinary (Thilo Rehren) and multi-technique approach (Thomas Calligaro) of heritage science. Two of the five invited talks were focussing on archaeological interpretation (Katalin T. Biró, Friedrich Wagner), one on conservation application of historical buildings (Francesca Sciaretta) while the two others on instrumental approaches (László Szentmiklósi, Nikolay Kardjilov). The dense program of the conference included 27 oral presentations and 20 posters. In addition, a workshop by the Volume Graphics, supplier of high-end data visualization software, was also part of the program. The most represented topic was neutron imaging with three sessions, in total 9 lectures.

This meeting was a successful one with 66 registered and 62 actually attended participants representing a wide range of disciplines (physics, chemistry, geology, archaeology, conservation science, engineering) and nationalities (Argentina, Australia, Cyprus, Czech Republic, France, Germany, Greece, Hungary, Italy, Japan, Korea, Netherlands, Portugal, Romania, Russia, Switzerland, UK, USA). Peer-reviewed proceedings will be published in a special issue of Journal of Archaeological Science: Reports.

László Szentmiklósi

References:

Budapest Neutron Centre - http://www.bnc.hu
NINMACH 2017 conference website - https://indico.kfki.hu/event/518/
Book of Abstracts - https://indico.kfki.hu/event/518/material/4/

NIST hosts NEUWAVE-9

NEUWAVE-9 kicked off with the traditional walking discussion. Some choose a lovely walk along the Potomac river tow path, others ascended to Maryland Heights to get a better view of Harper's Ferry and the confulence of the Shenadoah with the Potomac river.

NIST, in Gaithersburg, MD USA hosted the 9th Workshop on NEUtron WAVElength Dependent Imaging (NEUWAVE-9) June 12-14, 2017. There were 57 participants from 8 countries and contributions from 5 continents. NEUWAVE-9 had 10 oral sessions and one poster ses-

Impressions of the traditional walking discussion.

sion. Participants shared their latest advancements in and applications of neutron Bragg-edge imaging, phase and dark field imaging, imaging detector technology, magnetic field imaging, tomography and neutron imaging facility developments. User instruments that were represented included the NIST thermal and cold neutron imaging instruments at the NCNR, the RADEN instrument at J-PARC, the thermal and cold instruments at PSI, the ANTARES facility at the FRM2, the IMAT facility at ISIS, the CG1d beamline at ORNL, the CONRAD-2 and PONTO instruments at HZB, the SANRAD facility of NECSA, and the epithermal beamlines at LANL.

The scope of the workshop can be realized from the following highlights. Y. Kiyanagi of Nagoya University gave an overview of the widespread use in Japan of compact neutron sources for carrying out Bragg edge and resonant absorption imaging experiments. M. Lerche and M. Morgano, of Technical University Munich and PSI respectively, presented the current design of the instrument and guide system for ODIN, the highly anticipated imaging instrument to be built at the European Spallation Source (ESS). In addition, the new reactor-based imaging instruments at Norway's Institute for Energy and Argentina's RA-10 facility were described showing continued growth of neutron imaging as a valuable non-destructive evaluation tool. Several presentations focused on dark-field and phase imaging techniques, in particular L. Butler of Luisana State University applied dark field imaging to investigate fracture in additively manufactured metals. Morten Sales of the Technical University of Denmark (TUD) described his approach to the vector tomography problem of the magnetic field emanating from a solenoidal electromagnet. S. Schmidt of TUD presented continued improvement of grain mapping, and M. Raventos of PSI discussed a new effort for grain mapping using a polychromatic beam. Many new applications of Bragg edge imaging were given: D. Ito of Kyoto University studied the solidifaction process of the lead-bismuth eutetic and M. Connolly of NIST described efforts to provide a better measure of hydrogen stress intensity factors for pipeline steel.

Following the tradition of the NEUWAVE series, a networking event was held on 11 June 2017 at the Harper's Ferry National Historic Park, enabling in depth discussions while enjoying views of the Potomac River and learning about the role of Harper's Ferry during the US Civil War. By consensus of the attendees, NEUWAVE-10 will be hosted by the Paul Scherrer Institut in 2019.

Daniel S. Hussey

Neutron Imaging school AUNIRA-3 at FRM II

In collaboration with the International Atomic Energy Agency IAEA, the Heinz Maier-Leibnitz Zentrum (MLZ) and FRM II hosted the neutron imaging workshop AUNIRA-3 (Advanced Use of Neutron Imaging for Research and Applications) from August 28. to September 1. 2017, which was attended by young researchers from countries all over the world from wherever a new reactor with imaging facilities is being built, or existing reactors are refurbished with modern electronic imaging systems. After two previous workshops in Switzerland (Paul-Scherrer-Institut) and Berlin (Helmholtz-Zentrum Berlin) two and four years ago, the workshop presented the current level of research in building and applying neutron imaging facilities.

A private excursion to mount Wallberg at the Tegernsee on Sunday gave the participants opportunity to meet each other, and discuss their respective facilities. Only a select group chose the tough way of walking up the mountain, while the majority preferred the cable car as the less strenuous option.

Monday to Friday was covered by theoretical lectures and practical exercises.

Subjects included design of the beam geometry, appropriate high-efficiency shielding, new detectors and modern imaging techniques like neutron Grating Interferometry and Dark Field imaging.

Each subject was presented by a local or external specialist who explained fundamental but also practical design aspects, and reported about his own experiences and research. Although the basics of an imaging facility are widely known by now, even the specialists learned new details from their colleagues, where tiny changes can make a large improvement in image quality.

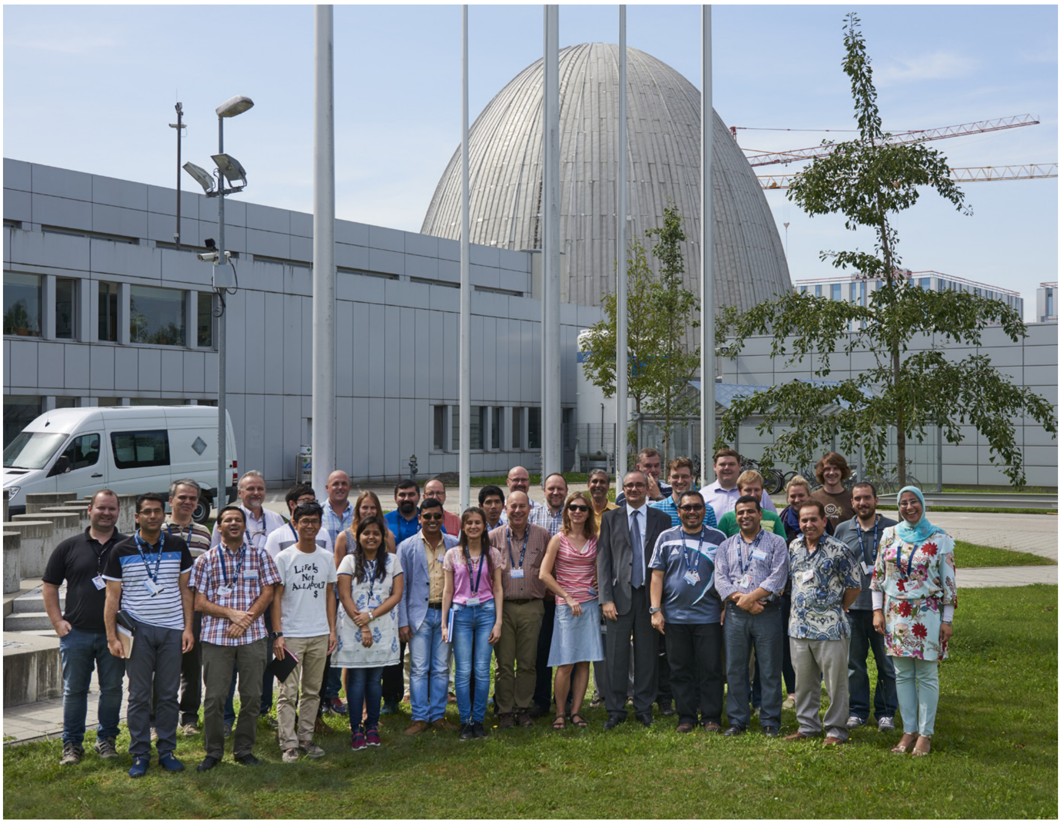
Aaron Craft from Idaho National Lab notably reported about first trials in collaboration with FRM II to install a digital imaging system for the examination of spent nuclear fuel in a high-radiation environment where all electronics and detectors must be extremely well-shielded in order not to crash from the intense gamma radiation.

After theoretical lectures in the mornings, the participants were able to try out their new theoretical knowledge in practical exercises at the thermal neutron imaging facility ANTARES and the fast fission neutron imaging facility NECTAR at FRM II, where the effects of different beam collimation and different neutron energies were tried out, as well as a mobile X-ray source at Radiochemie München RCM, as the planned exercises with the gamma-CT system based on a Cobalt-60 source at RCM couldn't take place due to non-availability. Image processing and 3D data treatment were tried out in specific computer exercises, some of them held by VolumeGraphics.

During a poster session and an evening at a beer garden, more contacts were made and collaborations formed between scientists with similar reactors and/or from neighboring countries.

The participants left with new friendships and collaborations made, and to apply new ideas at their home facilities.

Burkhard Schillinger



Group photo of the neutron imaging workshop AUNIRA-3 *(photo by Wenzel Schuermann /TUM)*

The ASTOR Conceptual Design Review Meeting took place in Buenos Aires, 13-14 March 2017

ASTOR (Advanced System for Tomography and Radiography), the neutron imaging instrument being developed at the Argentine Neutron Beams Laboratory LAHN, received its first external evaluation

During the second week of March, the ASTOR team met with the Scientific and Technical Advisory Panel (STAP) for the Conceptual Design review in the headquarters of the Atomic Energy Commission of the Argentine Republic (CNEA). The meeting was opened by the Scientific Director of the LAHN (Laboratorio Argentino de Haces de Neutrones), Javier Santisteban, who introduced the audience to the novel project for the development and construction of a Large Scale Neutron Beams Laboratory in Argentina associated to the RA-10 research reactor developed by CNEA. Next, the science requirements for ASTOR were presented by Santisteban. The ASTOR team leader, Aureliano Tartaglione, outlined the conceptual approach to the instrument, its goals and preliminary design requirements. Each team member explained in more detail the performance analysis, mechanical design ideas, shielding considerations and interface control.

The STAP was composed of three external evaluators: Eberhard Lehmann (PSI, Switzerland), Burkhard Schillinger (MLZ, Germany), and Muhammad Arif (NIST, USA) who could not assist to the meeting but whose review and suggestions were received from Daniel Hussey (NIST, USA). The panel spent two days with the ASTOR team and the LAHN project team reviewing the conceptual design.

The panel members met in closed session after the ASTOR presentations to prepare its conclusions. A preliminary oral summary was given to the project members on the last day.

Fig. 1 Aureliano Tartaglione, team leader for the ASTOR imaging instrument at LAHN

A few days after the meeting, a formal written document with recommendations was submitted to the Project by the STAP. The panel advices included shielding and layout aspects, beam collimation, filters and maximum available neutron flux. The ASTOR design team has been working in these recommendations, looking for the improvement of the instrument design, with the goal of producing a world class neutron imaging instrument for LAHN.

ASTOR will be located in the reactor hall, provided by neutrons from a liquid deuterium cold source at 23K. The bunker will have at least two separate rooms along the beam with an internal height between 3 and 3.5m, occupying the ~16m between the biological shielding and the reactor wall.

ASTOR will offer the possibility of selecting an L/D ratio (i.e. collimation of the beam) between 120 and 1500 by using a secondary collimation drum device with six options and at least three standard detection positions along the beam. The full illumination area is expected to vary between 5 x 5 cm^2 and 26 x 26 cm^2 with a maximum expected neutron flux of ~ $4 \cdot 10^8$ $1/cm^2s$ (for L/D=120).

The instrument will exploit the cold neutron beam advantages by incorporating to the design different wavelength selection options: a basic method with a beryllium filter, which will allow the transmission of neutrons with $\lambda \geq 4$Å, and additional devices such as a velocity selector or a three chopper system which are currently under study.

According to the schedule, the conceptual design should be finished during the second half of 2017.

Gabriela Aurelio

Fig. 2 The ASTOR team with the review panel experts.

Fig. 3 First row: Eberhard Lehmann, Burkhard Schillinger, Pavol Mikula, Michael Hofmann and Javier Campo, the review panel members for the ASTOR

News from the Board

Task Group "Constitution"

In the last issue of the NR Newsletter (No. 12, March 2017) a draft of the revised constitution of the International Society for Neutron Radiology (ISNR) was presented and asked for feedback. Up today no single comment was received by the convener of the Task Group Les Bennett.

At the next WCNR-11, Sydney, September 2018, during the Board meetings, there will be a brief discussion and finally a vote on the revised constitution by all participants present at WCNR-11. In preparation, please review the revised constitution and sent your comments to Les Bennett (bennett_l@rmc.ca).

Task Group "Terminology"

The Task Group "terminology" published a first compilation on terminology for neutron imaging in the last NR Newsletter (No. 12, March 2017) asking for comments. The convener Markus Strobl did not receive a single comment after 8 months. Comments are still welcome until end of February 2018 (markus.strobl@psi.ch). Then the compilation is prepared for voting at the ISNR Board meeting at WCNR-11 and the work will be continued defining more specific terms.

Task Group "Characterization and Standardization"

Recently new experimental procedures for estimation of the spatial resolution in radiographic (2D) and tomographic (3D) experiments were developed. The imaging group at PSI (Dr. A. Kaestner) designed and manufactured a test pattern with fine periodical structures of 5µm Gd layers sputtered on glass substrate, Fig. 1a. The pattern can be used for direct estimation of the resolution in radiographic images. In addition the colleagues are proposing a method using polished Gd edge for calculating the Edge-spread function at different distances from the detector, Fig. 1b. In this way information about the geometrical blurring at different sample positions as well as the beam collimation property - the L/D ratio can be obtained. The corresponding device was designed and produced at PSI. A phantom sample for estimation of spatial resolution in tomographic experiments was proposed as well, based on spheres with different diameters placed in a cylindrical container, Fig. 1c. The corresponding data processing procedures and details about the work performed at PSI can be found in the paper accepted in the Proceedings of ITMNR-8 [1]. These activities at PSI have been performed with the support from the IAEA. A round robin test series is planned for the new set of samples.

N. Kardjilov, A. Kaestner

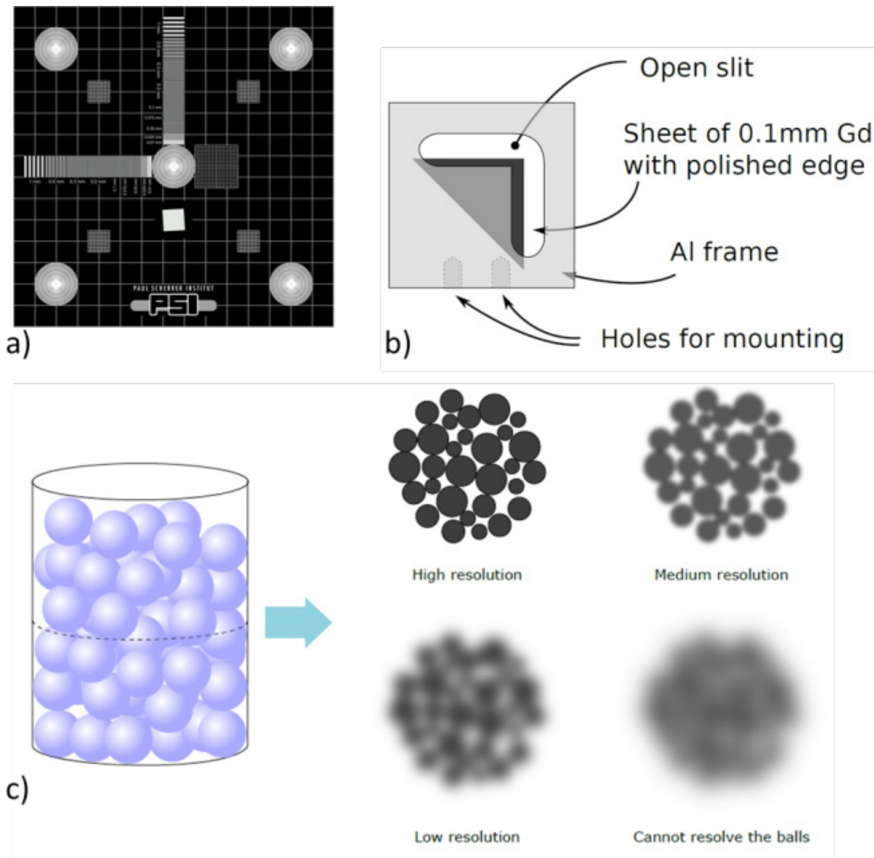


Fig. 1 (a) Test pattern for neutron radiography. The pattern includes features to measure resolution (Siemens star, line patterns, and a slanted edge box), pixel size, and geometric distortion; (b) Edge resolution device made of Gd to provide highest possible contrast. The edge is mounted in an Al frame. Placing the device at different distances from the detector allows to estimate the collimation ratio. (c) Discrete resolution devices for computed tomography [1].

Reference

[1] *A.P. Kaestner, Z. Kis, M.J. Radebe, D. Mannes, J. Hovind, C. Grünzweig, N. Kardjilov, E.H. Lehmann, Samples to determine the resolution of neutron radiography and tomography, Physics Procedia, Vol 88, 2017, Pages 258-265, DOI 10.1016/j.phpro.2017.06.036.*

Task Group "ISNR Webpage"

The content of the webpage strongly depends your, (i.e. the members of ISNR) input. I only can provide the platform for the presentation of (your) news and other information etc. and initiate new categories. For example begin of next year there will be two more categories. One with a list of suppliers providing tools and equipment for the setup and operation of a neutron imaging facility and for data processing in evaluation. The other new category will act as a platform for the offering of components no longer need by a facility but still worthwhile to be used at some other place. More information will be mailed to all members of ISNR as soon as both categories are activated.

Thomas Bücherl

Task Group "Computational Imaging"

Analysis tools for neutron imaging – the open source tool

Neutron imaging experiments produce large amounts of data that need to be processed and analyzed before results can be published. The typical data processing chain is illustrated in figure 1 below. There are many steps of which some are common to most experiments, but later stages processing steps become more specific and may, or may not, be experiment dependent. Many users get support to make the initial processing already on-site during their experiment. After this initial support, they are left on their own to continue the analysis. This can be a very time-consuming task, it can take up to 100 times more time to analyze than performing the experiment itself. In particular for new users with little experience with image processing which often also lack the specific required tools and underestimate resource requirements. This often causes unnecessary delays between experiment and publication. Many facilities took initiative to enable initial processing by providing corresponding software tools, workflows and support. However, distributed and isolated development is often inefficient due to the redundancy of the code produced. In the past year the Neutron Imaging and Activation Group at Paul Scherrer Institut started to work with open source development and some groups have joined to work on a common repository.

Collaboration and open source

As a result, many development projects have opened their sources and published them on public repositories. Contributions are welcome from the community. Apart from coding there are other ways to contribute to the development of tools for the analysis of neutron imaging data in the project. Non-coding tasks involve providing feature requests, testing with issue reporting and finally also to provide user documentation and tutorials. The development should be community driven which means that feedback is desired in order to identify and implement required features and workflows.

In November this year PSI organized a coordination meeting with participants from ESS, ISIS, SNS, PSI, TUM, JPARC and the Technical University of Denmark which was held in the

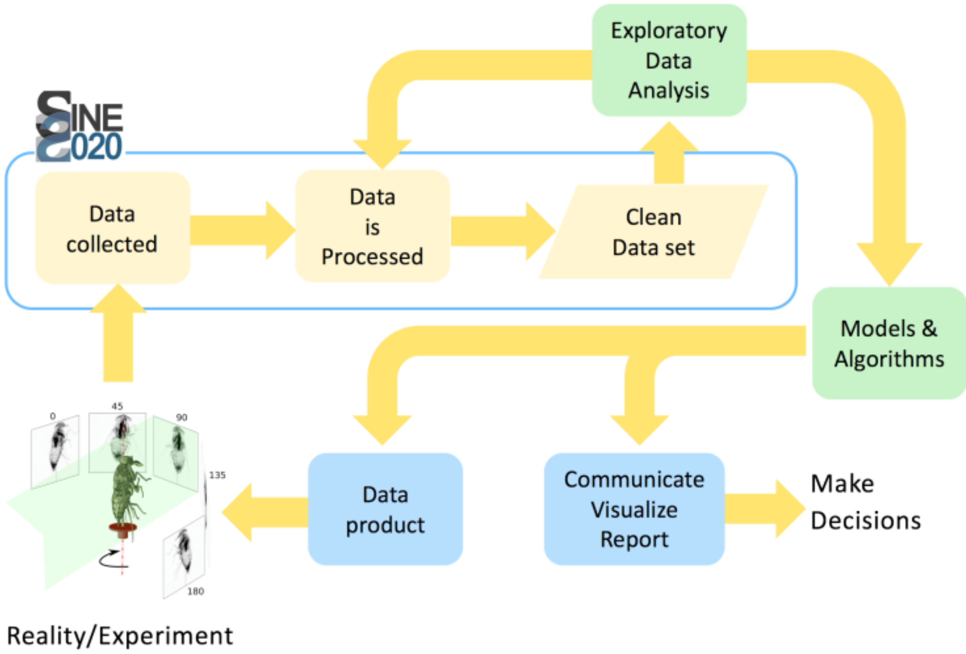


Fig. 1 Data processing chain for an imaging experiment.

Black Forest in Germany. The aim of this meeting was to increase the collaboration in particular in the field of time-of-flight (ToF) imaging and with view on ODIN at ESS, but also to coordinate the development of traditional analysis tasks. There was a general agreement to start working on a common repository and to increase the exchange of experiences and test data.

Languages and data formats

The general trend in the development community goes in the direction of free programming languages with the main focus on Python and C++. Python is used for flexible development of specific analysis tasks for everyday use. The language is also a good alternative to some commercial numeric programming languages and being free of charge it is easy to share pieces of code with users. For computationally intense tasks that are frequently used, it is, however, recommended to use the more complex language C++. In both cases, there are already base libraries available that make work easier and it is recommend to start from these libraries to avoid starting from scratch and reinventing the wheel if someone wants to contribute.

The amounts of data collected at the beamlines are steadily growing and with new open data requirements from funding agencies, there is a need to provide meta data describing the experiment conditions together with the image information. Today, most facilities work with single files per radiograph. This is inefficient for data transfer and data handling in general. The NeXuS experiment data format which is based on HDF5 addresses both the meta data and multiple file problem. This is a new format to the neutron imaging community but is mature for other neutron experiment techniques. This will be the future data format at the pulsed spallation neutron sources. There is already ongoing development to use NeXuS at ISIS, SNS and ESS will also use the format. During the meeting in the Black Forest it was agreed to provide test data stored in NeXuS files for development and evaluation. These data sets are important to guarantee that the same formatting and naming conventions in the files are used by the community. Concerns raised about e.g. easy access to single images and easy combination of several files for example in case of interrupted measurements, but also easy implementation of meta-data of custom sample environments have to be taken seriously and need to be addressed from the beginning.

Discussion

The neutron imaging community sometimes has similar requirements with respect to software tools needed to analyze experimental data as other imaging communities and can benefit from existing tools and developments, free or commercial. Still, there are some points where the tasks or the typical workflow differ. This appears to be where the efforts of the community should be focused on. By joint development efforts on open source tools, the neutron imaging community can improve the scientific output from the experiments at its neutron sources with less effort as compared to isolated developments of individual tools sets at each facility. A further advantage of common development is that users will easier familiarize with the available tool set when it is coherent between different neutron sources. The greatest benefits are gained when in addition the same data formats are used for the experimental data. Users only need to be trained on a single tool suite, which will save time for users and local support. This will also make the process of analyzing and relating results produced at different neutron sources and instruments much easier.

Publications on different tools and algorithms are important to give the developers credit for their work but also to allow clear specifications and references with respect to specific analysis performed on particular data published.

Finally, don't hesitate to contact the author if you are interested in contributing to the collaborations we already have started. The tools will grow faster and become more robust the more people contribute.

Anders Kaestner, Markus Strobl, and Winfried Kockelmann

Links

http://www.imagingscience.ch
http://www.github.com/neutronimaging
https://github.com/nGImagic
http://www.nexusformat.org/

Upcoming conferences and workshops

WCNR-11
11th World Conference on Neutron Radiography
02.-07. September 2018, Maritime Museum, Sydney, Australia
www.ansto.gov.au/Events/WCNR-11/index.htm

NEUWAVE-10
10th Workshop on Neutron Wavelength Dependent Imaging
2019, Paul Scherrer Institut, Switzerland.

ITMNR-9
9th International Topical Meeting on Neutron Radiography
12-16 October, 2020, Argentina

11th World Conference on Neutron Radiography
WCNR-11
September **2018** | Sydney, **Australia**

Australian Government | ansto

Call for abstracts

11th World Conference on Neutron Radiography
WCNR-11
September **2018** | Sydney, **Australia**

We invite you to submit abstracts on the following topics:

- Instrumentation
- Methods
- Software
- Geoscience
- Material science
- Engineering
- Food / Agricultural science
- Cultural heritage & Archaeology
- Palaeontology
- Medical Science
- Industry

IMPORTANT DATES

Call for Abstract: January 2018
Abstract Close: Mid April 2018
Accepted Advised: Early May 2018
Registration Open: April 2018
Registration Closes: End of July 2018

Email: wcnr11@ansto.gov.au
Web: wcnr-11.sydney

ANSTO's OPAL reactor building.

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If you have any further enquiries about the conference please contact the organising committee wcnr11@ansto.gov.au

ITMNR-9

12-16 October, 2020, Buenos Aires, Argentina (most probable venue: Auditorium of the UCA, Puerto Madero)

Head of Organizing Committee: Karina Pierpauli, Argentine Atomic Energy Commission

Head of Scientific Committee: Javier Santisteban, Argentine Atomic Energy Commission

Pictures of "Puerto Madero, Buenos Aires", the location of the proposed venue for the conference.

Other Conferences

Conference Neutrons for Culture and Arts
June 19-22, 1918, Lenggries, Germany
indico.frm2.tum.de/event/56/

WCNDT 2020
20th World Conference on Non-Destructive Testing
June 8-12, 2020, Seoul, Korea
www.wcndt2020.com

Call for bids

Candidates for hosting the **12th World Conference on Neutron Radiography (WCNR-12)** in 2022 are asked to send their interest to the secretary of ISNR (secretary@isnr.de) until **28. February 2018**, latest.

Candidates interested in hosting **WCNR-13** (in 2026) and **ITMNR-10** (in 2024) are also asked to send an informal letter of intent to the secretary of ISNR (secretary@isnr.de)

Deadline for contributions for the next **NR Newsletter**: Deadline **30. April 2018**

... and finally

Please review your data on the website (*www.isnr.de/index.php/about-us/list-of-members*) and inform me on errors and / or changes.

Editor

Thomas Bücherl
TU München
Walther-Meissner-Str. 3
85748 Garching
Germany
thomas.buecherl@tum.de
secretary@isnr.de