May 2026, No 19

ISNR Newsletter

Attendees of the 12th World Conference on Neutron Radiography standing on the west bank of the Snake River in Idaho Falls.

Contents

Editorial

by Tobias Neuwirth

We are pleased to share this latest edition of our newsletter. This is also the first newsletter under my responsibility as the secretary of ISNR and I would like to express my gratitude to Thomas Bücherl (TUM) who held this position for many years. While some time has passed since the previous issue, this interval has allowed for a wealth of exciting developments to take shape. In fact, the past years have been a period of remarkable progress for the neutron imaging community. I am delighted to highlight the many advancements recently achieved in the field of neutron imaging. Notably, several updated and entirely new imaging instruments have been successfully brought into operation, marking a significant step forward for our capabilities. In this issue, we highlight TRIXIE (LVR-15) as a new instrument and NEUTRA (PSI) as a significantly updated one. During the same period, VENUS (ORNL), MoTo (ILL), and PorTo (ILL) have also come online, while the Thermal and Cold FISH instruments (TU Delft) have returned to user operation. Unfortunately, ESS, FRM II/MLZ, and NIST/NCNR are still progressing on their respective paths toward neutron delivery. Since the last Newsletter, the community has gathered at numerous conferences, including one WCNR (USA), three Neuwaves meetings (Japan, Sweden, and the USA), and one ICNS (Denmark). All of these events were very well received and fostered many fruitful discussions and new collaborations. Looking ahead, the next major neutron imaging conference, ITMNR-10, will take place this October in Annecy, France.

New Neutron Imaging Instrument in the Czech Republic

by Jana Matouskova

The new neutron imaging instrument TRIXIE is currently in the commissioning process at the LVR-15 reactor in the Czech Republic. The LVR-15 is a research reactor with a power of 10 MW located in Rez, near Prague, in the Czech Republic. The project of development of a new imaging instrument started in the spring of 2022 as a collaboration between the Czech Technical University in Prague, the Helmholtz-Zentrum Berlin and the Heinz Maier-Leibnitz Zentrum (FRM II). Before that, the Czech Technical University in Prague successfully built and commissioned a facility for neutron imaging at its very low-power research reactor VR-1. Based on the experience gained from the development and testing of the neutron imaging facility at the VR-1, CTU decided to use an opportunity of an unused beamline at the research reactor LVR-15.

The TRIXIE instrument consists of several main parts: beam filters and a collimator, a detection system, shielding and other components (e.g. positioning tables, beam limiters, etc.).

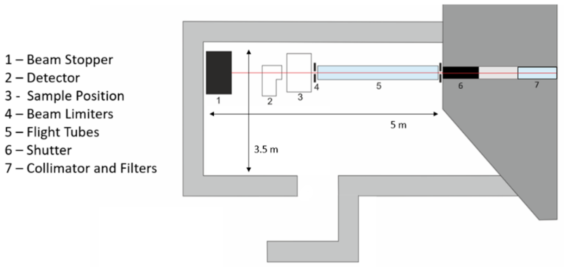

Figure 1:*The overview layout of the TRIXIE instrument*

The filters are designed to eliminate high ratios of fast neutrons and gamma in the neutron spectrum, resulting in a thermal neutron beam. The collimator is a fixed pinhole made of a combination of lead and borated polyethylene and will provide a collimation ratio of L/D = 150 – 250. The detection systems will comprise a standard neutron imaging detection system and also a high-resolution detection system. The shielding is based on heavy concrete shielding blocks in combination with borated PE desks.

Figure 2: *Photos of the shielding of the TRIXIE instrument*

The construction process started with installation of the shielding in the autumn of 2024, followed by the installation of filters and a collimator in the winter of 2024. The detector and positioning tables were installed during the Christmas shutdown of the reactor. Currently, the instrument enters the commissioning process, which is expected to take a couple of months. During the commissioning process, there will be only limited access to the user community, to provide feedback from experts. After that, it will provide access to national and international user communities in a general user program.

NEUTRA Upgrade

by Pavel Trtik

During the last International Topical Meeting on Neutron Radiography in Buenos Aires (ITMNR-9), the neutron imaging community was informed about the upcoming upgrade of the NEUTRA beamline [1]. In mid-November 2024, the last user experiment was carried out on the still functional NEUTRA instrument, after which the upgrade work officially began with its disassembly. Before describing the status of the NEUTRA upgrade project, it is worth acknowledging the remarkable achievements of the beamline. NEUTRA has been a day-one instrument of the Swiss Spallation Neutron Source (SINQ). Over nearly 28 years of operation, it has enabled many hundreds of peer-reviewed scientific publications across a wide range of disciplines. Numerous commercial beamtimes have supported industries – both from Switzerland and from abroad. For all that, much credit goes to Eberhard Lehmann, who established NEUTRA as the 'European reference facility for neutron imaging' [2]. As for the recent developments: apart from a single shielding block at the rear side of the beamline all that could have recalled the 'good old days' of the last millennium has been removed by January 2025 and the space where the beamline once stood was almost completely empty (see Figure 1).

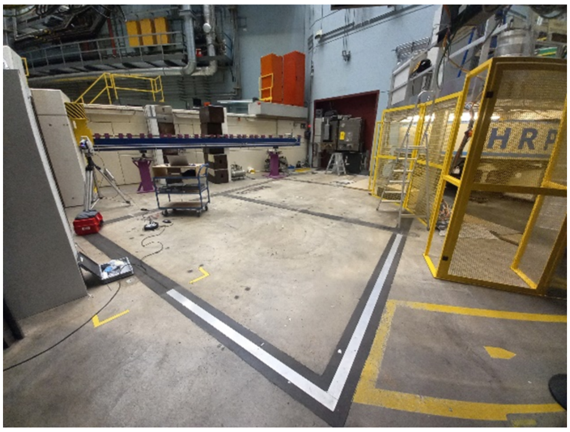

Figure 1: *NEUTRA beamline area in mid-January 2025. Please note the dark-blue neutron guide of the POLDI beamline at the centre-left and the blue letters of the HRPT diffractometer on the right side of the image.*

To illustrate the status of the project, the reader is referred to Figure 2. In comparison with the old NEUTRA, the space within the beamline bunker has been significantly enlarged, providing access to the previously inaccessible front measuring position (MP1). Numerous improvements have been implemented as part of the NEUTRA upgrade project; however, it is not the purpose of this article to describe every aspect of the upgrade in detail, especially as the work is still ongoing. The reader may rest assured, though, that the full journey of the NEUTRA upgrade (as partly illustrated between Figure 1 and Figures 2 & 3) will be presented to the neutron imaging community at the next International Topical Meeting on Neutron Radiography (ITMNR-10) in October 2026. However, it is a great pleasure to share the news that after 348 days of 'dark times' without a neutron beam, the beamline received provisional permission (with full approval pending from the Swiss Federal Office of Public Health) to open the shutters. This allowed the milestone of acquiring the first image to be reached (see Figure 3) with the beamline commissioning planned for December 2025.

Figure 2: *Interior of the NEUTRA beamline*

bunker (status as of mid-November 2025): (left) measuring positions MP1 and MP2, (right) measuring position MP3.

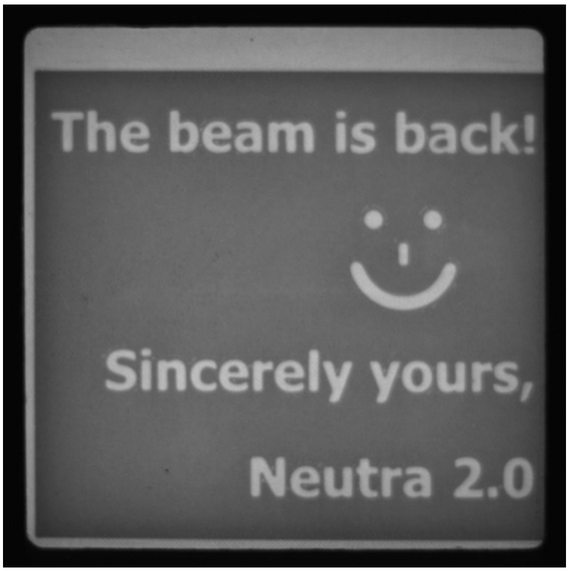

Figure 3: *The first image acquired at the upgraded NEUTRA beamline (scalebar and colorbar exceptionally not essential for the intended message to the reader).*

Consequently, the NEUTRA team is already looking forward to the restart of neutron production at SINQ in 2026 and to welcoming both new and returning NEUTRA users for upcoming beamtime experiments. The next deadline for proposal submissions is set for January 15th, 2026 for beamtimes from June to September.
On behalf of the NEUTRA upgrade team
Pavel Trtik (PSI)

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Neutron Imaging at weak neutron sources - NI@WNS

by BURKHARD SCHILLINGER & EBERHARD LEHMANN

Neutron Imaging is a non-invasive investigation method, used in various material studies for scientific and technical purposes. It has meanwhile been established at nearly all strong neutron sources and complements the neutron scattering methods on a high-performance level. It complements to X-ray methods, while both are still under further improvements. However, the number of strong neutron sources is limited and even declining due to their age, and only very few new installations are foreseen. Therefore, the access to the high performing installations for neutron imaging is difficult and organized via a proposal process within a long-term schedule. There are smaller and weaker neutron sources, either low-power reactors or medium-sized accelerator driven ones with a certain potential for neutron imaging applications. In a few cases [1, 2, 3 – see figure] it was already possible to demonstrate or effectively considered the options for neutron imaging applications.

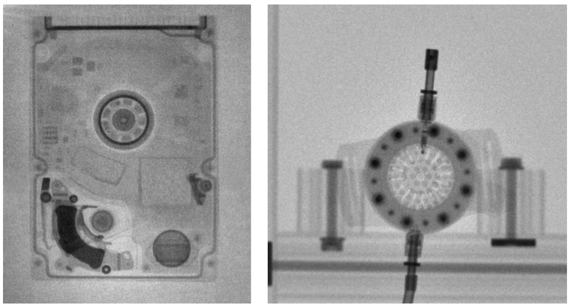

Figure 1:*Examples from studies NI@WNS: left: Hard disk (8 cm * 12cm) after a 20 minutes exposure at VR-1 (Prague), 100 W power; right: droplet inside a mobile PEM fuel cell, diameter about 6 cm, 10*5 minutes exposure at AKR-2 (Dresden), 6W power*

However, simple table-top D-D or D-T accelerator sources have proven too weak for reasonable imaging; mainly because the needed moderation process destroys any beam collimation and the limited number of thermalized neutrons is not high enough for valid imaging data acquisition. As the number of useful neutrons at such weak sources is quite low, detection systems with high efficiency and sensitivity must be applied. Due to the longer acquisition time, such systems need to have low noise and stabilities over longer time ranges. However, modern detection systems are more sensitive than those used in the past (e.g. films) … and a low level counting becomes more feasible today. Because of the low flux of the (mostly thermal) neutrons, optimization between higher spatial resolution (given by the beam collimation) or better time resolution becomes even more important, though at a much lower level than at the high-performance sources, and an optimization must be done on practical experimental basis. From the practical point of view, some lessons can already be derived: for higher detection efficiency, e.g. ZnS+Li-6F screens of 200 μm thickness deliver better detection efficiency at only slightly reduced resolution. Gadox screens generally deliver a very high detection efficiency, but way too much light for low intensity sources. Modern astronomy CMOS cameras need less cooling than high-end CCD cameras and can well operate up to ten minutes exposure time with air cooling on the warm end of their Peltier cooler only, cooling the camera down to -10 to -15°C. 3D print files for simple but efficient detector boxes housing cooled astronomy cameras are available for free at FRM II. It is an important point, that such low power sources are mostly operated in institutions with a scientific environment for education and applied research. Therefore, different other scientific branches might take profit from the availability of preliminary neutron imaging setups for dedicated studies. The results of (positive) pre-tests can be taken as kick-off for proposals at stronger high performing installations, though many questions can already be answered at low-flux sources. To establish neutron imaging methods at further neutron sources with low neutron flux it is important to optimize the layout of the beam extraction system, to define and to install the most suitable detection system and to establish test methods for the characterization of the whole system. In some cases, existing beam tubes may end very close to the core, optimized for epithermal neutron extraction, and adding a few cm of polyethylene as a plug at the end of the beam tube nozzle may improve the extracted flux significantly. The neutron sources can be used (mainly) for thermal neutrons due to the highest detection efficiency, but also for imaging with fast neutrons and the accompanying gamma radiation. It is recommended to establish contacts to groups with experience in neutron imaging. The worldwide neutron imaging community is generally helpful and can often provide detection systems in a test phase before proprietary systems are defined and installed for the routine work. In this way, neutron imaging methods can be spread and used in wider range of applications as tools in science and technology. The two authors invite additional facilities and their users, who see a potential for trials of neutron imaging attempts. They are willing to share the experiences and able to give recommendations for the particular cases under consideration.

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Development of the LumaCam Detector

by Alexander Wolfertz

Introduction

The LumaCam is a new type of position-sensitive detectors that is gaining attention in the neutron community. They are scintillator based detectors that detect the scintillation light on an individual photon basis via an image intensifier and a fast image sensor. LumaCams have a similar structure as established camera-based imaging detectors, but their readout operates in event mode i.e. it produces information about individual neutron interactions. The reconstruction of individual neutron interactions from the sensor data enables to achieve superior spatial and temporal resolutions. Past usage of LumaCam detectors has mainly focused on neutron applications, but developments specifically targeting high-energy photons and ionizing particles are currently ongoing.

Demonstration measurements

LumaCam detectors have been used successfully for different types of neutron imaging measurements. Their fine timing resolution makes them especially interesting for time-of-flight application such as the silver resonance radiography shown below (from [1] with permission) with epithermal neutron ToF, bragg-edge imaging, and even fast neutron ToF imaging where a resolution on the order of a few nanoseconds is required to resolve the features [2].

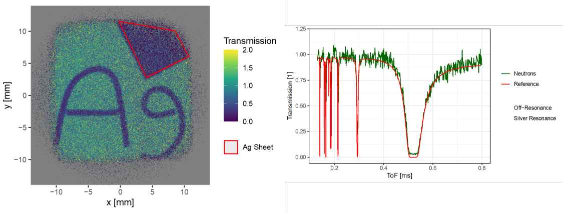

Figure 1:*The LumaCam detection principle suppresses noise and scintillator afterglow, and improvements during white-beam radiography for fast-changing samples and at low flux sources have been demonstrated. In addition to the imaging community, the LumaCam has also been successfully used as a high-resolution diffraction detector [3].*

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Efficient Compact Cameras using fast f/0.95 lenses and large APS-C Detectors

by ALAN HEWAT

The development of fast, short focus lenses for APS-C (24x16 mm) size detectors means that more efficient cameras are now possible, especially for fast neutrons or backscattered x-rays, where intensities are low. Previously we claimed [1,2] that a large detector implied a large Field-of-View (FOV), because the fastest full-frame lenses could only focus down to 50cm. We advocated the use of fast f/1.4 short focus lenses with 1” (12.5x10 mm) Sony CCD’s. But by adapting even faster f/0.95 commercial APS-C lenses we can now gain an efficiency factor of x6; x2 from the lens and x3 from the area of the detector [3].

Our 125x100mm camera with dimensions 90x146x222 mm was originally developed for backscattering Laue diffraction, where intensities are low due to the x-ray form factor, but can equally well be applied to fast neutron imaging with a different scintillator. The camera uses a mirror as usual to take the detector out of the direct beam, but for backscattering a 2mm collimator pierces the mirror to allow the beam to pass through the camera and then reflected back to collect the Laue pattern. That is unnecessary with neutrons. The x6 gain in intensity was confirmed by x-ray laboratories at the T.U. Darmstadt and Julich. A backscattered Laue pattern typically required 180s with our cooled 1” CCD camera, but less than 30s with our new cooled APS-C camera.

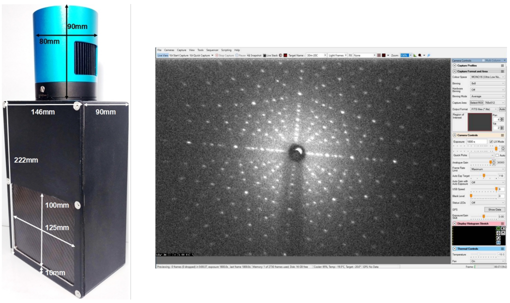

Figure 1: *Left: The compact 125x100 mm APSC-C cooled CMOS camera (left) with a 0.5 mm carbon fibre window for x-rays (an aluminium window is used for neutrons) Right: A backscattered x-ray Laue pattern obtained in 30s with 8x8 binning on a 2kW generator with a W cathode operated at 35keV (a modest x-ray generator).*

The ToupTek CMOS camera unit and the 7Artisans lens are inexpensive and available commercially, but both must be modified to achieve focussing at such a short distance, which is essential for maximum efficiency. The optical resolution, with 6248x4176 pixels of 3.76 μm is better (20 μm) than needed for most scintillators or neutron beam lines, but the pixels can be binned up to 8x8 to increase intensity at the expense of resolution. The usual SharpCap capture software is used, allowing sequential exposures synchronised with angular movements, required also for tomography.

These compact APS-C cameras have already been supplied to users in France, Germany and China, and a larger 250x200 mm version has been supplied for use on an accelerator driven neutron source at the Institute for Plasma Research in India (using a wider angle 35 mm f/0.95 lens). A larger 180x120 mm Laue camera has also been supplied using an 18 mm /0.95 APS-C lens.

Already in 2013 with Sylvain DESERT we constructed a compact neutron imaging camera for the SANS machine at Saclay using a 25 mm f/0.95 Voigtlander lens and a smaller 17x13 mm Photonic Science sCMOS detector imaging a FOV of 100x78 mm at a distance of 200 mm - something of a “tour de force”. The old Voigtlander lens had strong vignetting (intensity fall off with angle) and would certainly not cover the larger APS-C sensor.

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The establishment of a «Buddhist Data Base” for Asian bronzes – under development and open for contributors

by Eberhard Lehmann, David Mannes & Pavel Trtik

For more than ten years, a small team within the neutron imaging group (now AMG) at SINQ has been engaged in studying the hidden internal structures of Asian bronzes created for Buddhist religious purposes. It was recognized early on that thermal and cold neutrons are particularly well suited for such investigations due to their excellent penetration capability through heavy metallic casings and their strong contrast for the various inner filling materials. Neutron radiography and tomography made it possible to visualize and describe how these objects were originally filled centuries ago. Because opening these valuable artifacts is strictly prohibited for religious reasons, non-invasive neutron imaging techniques provide the only viable approach. Attempts to use X-ray imaging as an alternative have largely failed, as X-rays cannot deliver the necessary penetration through bronze casing while simultaneously providing sufficient contrast for the filling material. Most investigations begin with simple neutron radiography scans to determine whether fillings are present, to estimate the packing of the filling materials, and to assess whether a more time-consuming neutron tomography run required. To date, we can report on studies involving 125 samples from several governmental and private collections. However, this number represents only a fraction of the diversity of forms, manufacturing methods, and ritual features found across Buddhist bronze artifacts. For this reason, we have decided to establish a ‘Buddhist Data Base (BDB)’ that compiles our principal findings for interested individuals and institutions. Although we have already published selected results [1–4], the full volume of data cannot be presented through conventional publications alone. The BDB therefore presents an excellent opportunity to share knowledge, integrate additional datasets, and collectively expand the understanding of ancient Buddhist bronzes.

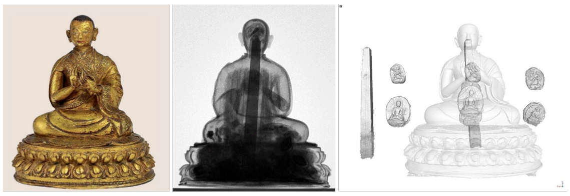

Figure 1: *Photo, neutron radiography and segmented parts from inside a bronze sculpture (Tsa-tsas and the “life tree”)*

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Visualising water transport in thermochemical materials

by Natalia Mazur1, Ruben D’Rose, Hartmut Fischer & Anders Kaestner

Energy storage is critical in implementing renewable energy on a large scale and advancing the energy transition. Currently, there is a large amount of solar and waste heat available but not on the right place and/or time. This spatial and temporal mismatch in energy supply and demand could be resolved with an energy storage system. Traditionally, heat storage is done in form of sensible heat. This technology utilizes heat capacity of the material, for example water, and stores the heat by heating it up and recovers it when it cools down. This technology is mature, however is suffers from two issues: 1) low energy density and 2) high self-discharge rate. A novel alternative is thermochemical heat storage (TCHS) which uses a chemical reaction to store and release heat. TCHS is based on a fully reversible reaction between a thermochemical material (TCM) and a working gas. An example of such eco-friendly working pair is a salt hydrate and water vapour. The heat is stored by desorption of a gas from the solid. Later, the heat is discharged by adsorption of the same gas. As long as the solid and gas are stored separately, thermal energy is stored in a compact and loss free manner. The working principle based on the hydration-dehydration reaction of the potassium carbonate can be written as:

$K_2CO_3\,(s) + 1.5\,H_2O\,(g) \longleftrightarrow K_2CO_3\,.\,1.5\ \mathrm{H2O}(s) +$ Heat

During charging and discharging, water molecules move out and into the crystal structure of the salt. On macro scale, this movement leads to a recursive shrinkage and swelling of particles. For practical application, salt hydrates are often compacted to millimetre sized particles and loaded into a reactor-type vessel forming a packed bed. The volumetric changes of individual particles can be quite damaging to the performance of the bed, but they are difficult to visualise in-situ and operando. Commonly, they are monitored with various optical techniques, which often give only the top view of the particle or particle bed. Nevertheless, to see what is happening on the inside, a destructive method must be employed [1]. Neutron imaging opens new possibilities for visualising water transport, state of charge and morphological changes in individual particles and particle beds, both in-situ and operando under conditions that reflect the typical operational environment of a TCHS. Recently, a series of such studies have been conducted at PSI at ICON imaging station [2]. By controlling temperature and water content inside a custom build reactor (see Figure 1) with the aid of custom humidifier [3], parameters critical to performance of TCMs can be extracted.

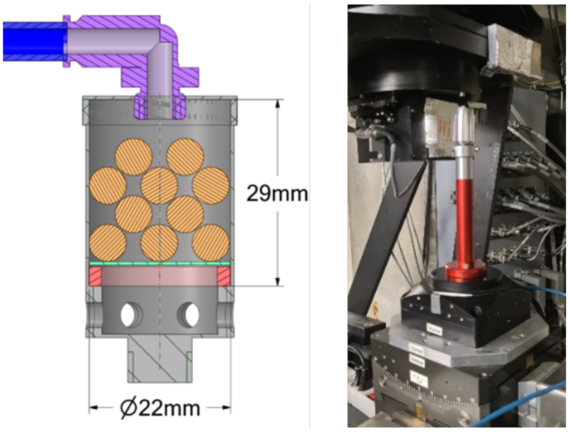

Figure 1: *Left: A schematic of a mini reactor used in neutron imaging experiments with air flow coming via the top (blue part), interacting with the TCM particles (orange circles) before exiting at the bottom. Right: A photo of a mini reactor without the lid placed in front of the detector at ICON.*

The simplest of studies focused on 1D water transport through a single, model particle, as shown in Figure 2. In such experiment a single particle of K2CO3 was exposed to two water vapour sources from the top and the bottom, while the sides of the particle were blocked off with a tape. Both water vapour sources had different partial vapour pressure (relative humidity). This difference in relative humidity affected the speed at which the water penetrated the particle and the kinetics of the hydration reaction. The bottom of the particle (Tablet height 0 mm in Figure 2) was exposed to higher relative humidity than the top of the particle, resulting in deeper penetration of the water into the structure. Based on the particle properties, such as size and density and the relative humidity of the air, diffusion constants and reaction kinetics have been extracted from the measurements. Those values are in good agreement with models previously presented in the literature [4] and for the first time a fundamental process occurring in a TCM particle was visualised in situ and operando.

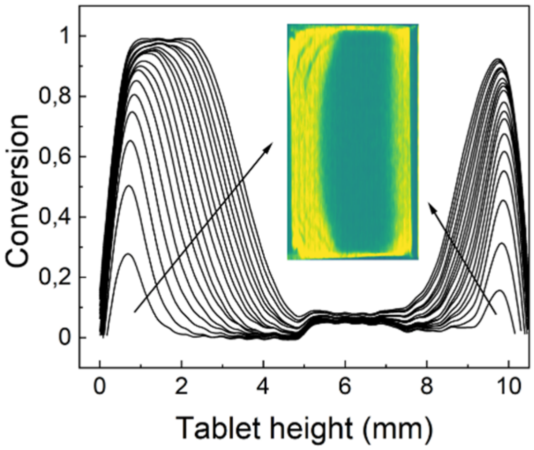

Figure 2: *Left: A selected slice through the model K2CO3 particle after hydration reaction (Yellow: hydrated, Blue: anhydrous) Middle: Conversion fronts recorded every 30 minutes as a function of the particle height. Right: Front image of the model particle after the hydration reaction.*

A more complex study looked at water vapor transport and sorption through a particle bed. In this case the entire reactor volume was packed with selected TCM particles. In such study the effect of particle shape, packing density and packing direction on the conversion was studied. It has been noticed that if particles were packed densely and perfectly parallel to the air flow, the interaction between the water vapour and the TCM was minimised, and conversion rate was poor. Conversely, when the packing was more random, the particles created obstructions for the air flow, promoting an interaction between air and TCM and enhancing reaction kinetics at the expense of energy density as less material was fitted in the reactor. Selected slices of the neutron tomograms from such experiment are presented in Figure 3. One can see that the reaction proceeds from outside in, according to classical shrinking core model. Although this mechanism has been proposed numerous times before and modelled using various mathematical models, this is the first time it was fully visualized and confirmed. Furthermore, the area where particles are in direct contact with each other stay dark for longer meaning that they take up water slower. The high resolution of the images shows crack formation in the particles during the reaction. Once again, until now, this phenomenon was observed only after full disassembly of the reactor thus making it impossible to pinpoint which particles, in which parts of the reactor and at what time during the reaction crumble. Finally, movement of the particles in the reactor during the reaction due to morphological changes can be tracked and quantified. With the results of these studies, it is possible to elucidate the effect of packing and particle shape on long term mechanical stability of the material. Such particle fragmentation can be highly damaging for a large scale TCHS as the pulverization of the material can lead blockage of the air flow paths. Understanding the process and its causes is thus crucial for successful upscaling of the technology.

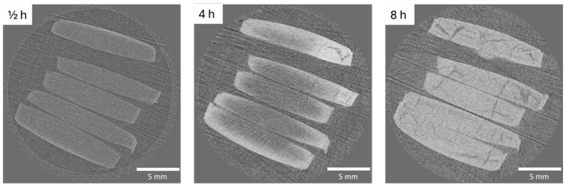

Figure 3: *Selected slices through reactor bed packed with TCM particles at selected times during the reaction. Lighter colours indicate water present in the material.*

Those two examples are just highlights of the data gathered at ICON at PSI. Thanks to the high resolution of the images, it was possible to gather data that are impossible to obtain by using any other technique. Operando monitoring of water uptake in thermochemical materials and the (morphological) changes are not only novel but are also critical from an application point of view. Only through understanding the interplay between all the processes taking place in a reactor (gas flow, conversion rate, swelling, fragmentation, etc) a robust and well performing system can be designed. Thanks to those studies new models can be developed, validated, and used to further our understanding of this complex system.

This work is based on experiments performed at the Swiss spallation neutron source SINQ, Paul Scherrer Institute, Villigen, Switzerland.

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Additive manufacturing devices for in situ and operando neutron characterization at PSI

by Florencia Malamud, Sergio Soria, Shieren Sumarli, Steve Gaudez, Steven Van Petegem, Natan Garrivier, Gergely Nemeth, Malgorzata Makowska & Markus Strobl

Additive manufacturing (AM), also known as 3D printing, includes a broad range of technologies to build parts layer-by-layer, enabling the creation of components with complex designs. The process can also combine different metals and alloys to create innovative multi-material components with tailored properties, such as strength and thermal conductivity, with superior capabilities than single-material designs. Among the various AM techniques, laser powder bed fusion (LPBF) stands out for its ability to produce high-precision metallic parts with intricate, customized geometries that would be hard to manufacture using conventional methods. LPBF employs a laser to selectively melt and fuse fine metallic powder layers, enabling the production of complex components with high precision. On the other hand, wire arc additive manufacturing (WAAM), which is a direct energy deposition (DED) AM technique, is the most suitable AM technique to produce large-scale parts due to its high deposition rate. In comparison with LBPF, WAAM employs wire feedstock, making it more cost-effective and reducing issues related to powder handling and contamination. Another DED technique uses a laser and powder feed integrated into a positioning head, combining the features of WAAM and LPBF. However, due to the rapid cooling rates, directional solidification and phase transformations occurring during the printing process, the components exhibit complex microstructures that differ from their wrought counterparts. Among other microstructural features, defects, residual stresses, crystallographic phases, grain structure, and crystallographic textures define the mechanical and functional properties of the AM-built parts. Therefore, the understanding of the formation of such features in the bulk of the components during the printing process, and its dependence on printing parameters, is critical to control and optimize the final material properties. Unlike traditional post-mortem analyses, in-situ and operando neutron imaging allows real-time observation of key phenomena such as melt pool dynamics, solidification behavior, and defect formation during the printing process. The possibility to perform these real-time studies provides critical information and understanding of the processes during manufacturing required for optimizing process parameters, improving and even local tailoring of material properties, and developing defect-mitigation strategies, ultimately enhancing the reliability and performance of metal AM technologies. In order to enable such studies, operando additive manufacturing devices compatible with neutron diffraction and imaging techniques were recently developed at the Paul Scherrer Institute (PSI). A downsized LPBF device, the n-SLM device [1] (Figure 1) allows in situ and operando neutron measurements, including neutron diffraction and imaging, and advanced methods such as Bragg-edge imaging (BEI), inelastic scattering contrast and polarization contrast neutron imaging (PNI). The n-SLM is designed for compatibility with different beamlines at the Swiss Spallation Neutron Source (SINQ) at PSI but can also be transferred to other neutron facilities. The device enables LPBF processing like in commercial machines, allowing the manufacture of a centimeter-sized structures with a wide range of printing parameters, which can be modified during print jobs. The capabilities of the n-SLM were recently employed to investigate the evolution of crystallographic phases during 3D printing of bimetal mixes of CuCrZr/316L employing concurrent inelastic contrast and PNI at the BOA beamline [2] and to perform operando defect characterization in nickel-based superalloy employing white beam neutron imaging at POLDI [1]. On the other hand, in situ and operando neutron diffraction experiments were conducted at POLDI to characterize the transient and real-time evolution of the sample microstructure during processing, including the development of residual stresses in textured 2205 duplex stainless steel [3], the development of elastic strain in nickel-based superalloy [1] and the dislocation density evolution resulting from in-situ laser heat treatment during LPBF of austenitic steels [4].

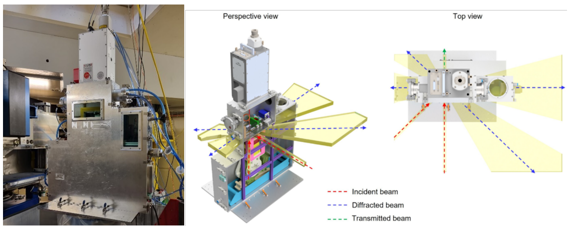

Figure 1: *a) n-SLM machine at POLDI b) Scheme of configurations illustrating the incident and diffracted beams for strain measurements along transverse directions [1]*

In-situ WAAM prototypes (Figure 2) were developed to enable operando measurements at SINQ beamlines. The CNC-WAAM prototype is based on a commercial computerized numerical control (CNC) router coupled to a SPEEDTEC® 400SP welding machine by Lincoln Electric. The system, designed for in-situ welding at POLDI, allows diffraction and imaging, including BEI, characterization of WAAM processing of different specimen structures. The prototype was recently commissioned at POLDI and employed to follow in-situ and operando the microstructure evolution of 316L walls and structs. In collaboration with the Laboratory for Nuclear Materials (LNM) at PSI, a more advanced WAAM system called MADISON was developed for x-ray and neutron studies and was recently tested at POLDI. This sophisticated system, designed for use on both neutron and synchrotron beamlines, includes a head positioning system suited for both, a WAAM welding torch and a Direct Energy Deposition (DED) system combining a laser and powder supply. The system is compatible with simultaneous diffraction and imaging measurements and was recently employed studying in-situ the crystallographic texture formation of 316L printed samples employing BEI at POLDI. The integration of advanced in-situ and operando neutron techniques with additive manufacturing technologies offers a unique potential to enhance the understanding of processes that lead to the finally established parts and material properties in AM and, thus, to control and tune such mechanisms to achieve tailored and well optimized results. By providing real-time insights into key phenomena such as melt pool dynamics, phase transformations, and residual stress evolution, these techniques and the insights they provide will allow for precise control of the printing process and the development of strategies to tailor microstructures and mitigate defects. As additive manufacturing continues to evolve, these capabilities will be key for enabling the production of high-performance and custom-engineered components for various industries.

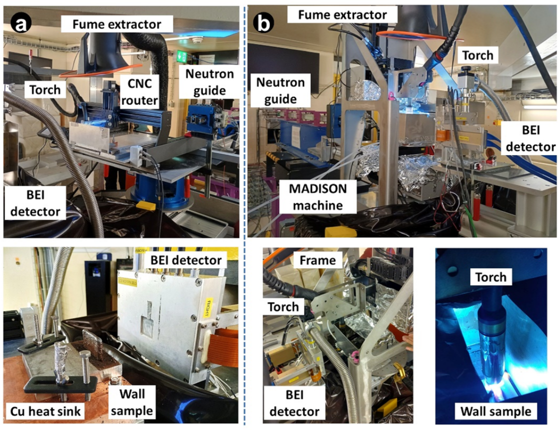

Figure 2: *a) CNC-WAAM device and b) MADISON system at POLDI beamline.*

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WCNR-12 - 12th World Conference for Neutron Radiography

by Aaron Craft

12TH WORLD CONFERENCE ON NEUTRON RADIOGRAPHY
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In June 2-7, 2024, around 130 providers and users of neutron imaging converged from 30 countries to meet in Idaho Falls, Idaho in the United States for WCNR-12. WCNR-12 included geographically diverse colleagues from Algeria, Australia, Aus-tria, Bangladesh, Brazil, Burundi, Canada, China, Czechia, Denmark, France, Ger-many, India, Indonesia, Iran, Israel, Italy, Japan, Netherlands, Pakistan, Philippines, Poland, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, the United Kingdom, and the United States. The conference was hosted by Idaho National Laboratory (INL), which was estab-lished in 1949 originally as the National Reactor Testing Station to serve as the Unit-ed States' proving ground for first-of-a-kind nuclear reactors for peaceful uses of nuclear energy. In INL's storied history, 52 nuclear reactors have been built at the INL site west of Idaho Falls. Four reactors continue operating at INL, including the Advanced Test Reactor (ATR), the Advanced Test Reactor Critical (ATRC) facility, the Transient Reactor Test (TREAT) facility, and the Neutron Radiography Reactor (NRAD). Neutron imaging has been used at INL for over 60 years, and neutron imag-ing efforts continue using NRAD and TREAT reactors, primarily for post-irradiated examination of nuclear fuels and materials. The conference opened with a keynote presentation from Dr. Joseph Bevitt titled Neutron Tomography and the Virtual World of Paleontology. Technical presenta-tions spanned the full range of the neutron imaging field, including sessions on non-destructive testing & standards, facility overviews, advanced techniques, material science applications, engineering applications, facility upgrades, software & machine learning, energy & environmental applications, new facilities, nuclear engineering applications, cultural heritage, detectors, neutron grating interferometry & dark field imaging, and neutron optics. A total of 65 oral presentations were given in a single auditorium between Monday and Thursday. A total of 72 poster presentations were shared in two lively sessions following lunch on Monday and Tuesday. The American Society for Testing & Materials International (ASTM International) Subcommittee E07.05 that develops standards for neutron radiography held the semi-annual meeting co-located at WCNR-12. Notably, the subcommittee is pursuing new standards focused on digital neutron imaging techniques, and the meeting at WCNR-12 enabled broader engagement from the community than typically available. The conference also included a special plenary session focused on the exciting new VENUS instrument at the Spallation Neutron Source at Oak Ridge National Laboratory, which included presentations on state-of-the-art technologies and approaches, representing in many ways a culmination of the technical developments and lessons learned in the nearly 70-year history of neutron imaging. The conference dinner was held Thursday evening at the Experimental Breeder Reactor 1 (EBR-1), a national historical landmark known as the world's first nuclear power plant. Attendees had the unique opportunity to tour EBR-1, gaining insights into its historical significance and groundbreaking contributions to nuclear energy. However, the evening took an unexpected turn when a fierce windstorm swept through, causing quite a gust of excitement. Despite the blustery conditions, spirits remained high as participants weathered the storm, making the dinner event a whirl-wind of memorable moments. Conversations were filled with a breath of fresh air, as the wind of change seemed to blow through the discussions. The unruly weather couldn't dampen the enthusiasm of the attendees, who breezed through the evening with remarkable resilience. In the end, the storm provided an atmospheric backdrop to an otherwise illuminating and breezy gathering at EBR-1. Forty-four attendees toured Idaho National Laboratory on Friday, June 7, 2024. Three groups rotated between the TREAT facility, the Hot Fuel Examination Facility where the Neutron Radiography Reactor is located, and the Irradiated Materials Characterization Facility.

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Workshop report – The development and use of scientific software

by ANDERS KAESTNER & JEAN BILHEUX

The development and use of modern neutron imaging techniques involve not only the design of instrument components, but also integral computational efforts required to obtain scientific information from the acquired raw data. The availability of reduction and analysis tools is essential for scientific progress in the field, as many experimentalists have limited capacity to implement high-quality workflows. There are different aspects of the computational efforts, ranging from scientific core algorithm development to technical data processing and management workflows. Interoperability is another aspect that is becoming increasingly important due to user mobility between neutron facilities. For them, it is essential to be able to use their data from different sources in the same way, without having to learn yet another tool suite. Interoperability includes the use of standard data formats, or at least the ability of tools to read data from different sources. The development of scientific software for neutron imaging is primarily carried out on an institute-by-institute basis, with varying degrees of engagement ranging from single-person initiatives to dedicated developer teams. There are also a few collaboration projects between institutes. The neutron imaging community is relatively small, and the developer community is even smaller; therefore, it is important to share experiences and results to grow both communities. It is also common for junior scientists with little experience in software development to be assigned to develop new methods. Their focus is, with full right, to promote their own scientific progress. This is an unfortunate combination and is often not ideal for the broader use of their outcome. It is often hard to bridge the gap between creative code and sustainable open-source tools due to limited resources. Therefore, we should provide minimal, easy-to-follow guidelines to reduce the gap.

Workshops to form a community

In 2025, we organized two dedicated satellite workshops. The first was a mini symposium during the International Conference on Neutron Scattering (ICNS) in June, Copenhagen, Denmark. The mini symposium was a hybrid meeting with high participation from both present and remote participants. The success of this meeting encouraged us to organize the second workshop during NeuWave 13 in October in Knoxville, USA. Both workshops had an open format, allowing participants to engage in active discussion during the talks, which ensured lively contributions. The addressed topics during both workshops were (a) contributors could present and demonstrate their tools and approaches to analyzing their data, (b) introducing modern software engineering methods to promote sustainable open-source tools, and (c) proposals for data formats. In general, we found that the workshops were well received not only by the developers who had a forum to discuss their efforts and receive feedback, but also by non-developers who gained insight into ongoing efforts across different institutes. During the software session of the 13th NeuWave workshop, the following software tools were presented: MuhRec (Anders), iBeatles (Jean), Hydration/dehydration tool (Samin), Pleiades and some ML tools (Chen), SciTiff (Christian), and Bragg-edge fitting (Tsviki). The success of the workshop is evident from ORNL's decision to convert the TIFF to SciTiff. Both ISIS and ORNL have begun testing and providing feedback on the Hydration/Dehydration tool.

Software workshop session during the 13th NeuWave in Knoxville, with more than 30 participants.

Looking forward

The past year has been a success in highlighting the efforts in the field of scientific software development for neutron imaging. Next steps would be to develop a shared strategy for leveraging our collective efforts and experiences. We would also propose integrating additional software-related workshops alongside the usual neutron imaging conferences and workshops to reduce logistical burden. A further idea would be to organize a hackathon, code camp, or similar event for a smaller group of dedicated enthusiasts. We look forward to hearing your thoughts on this matter.

Latest Concluded Neutron Imaging PhD Thesis in AMG at PSI

by Markus Strobl

Late 2024, early 2025 saw three Phd projects finishing in the Applied Materials Group at PSI. Two of the projects by Shieren Sumarli and Christos Sofras were concerning metal additive manufacturing and one, by Antonia Ruffo, was focused on remote temperature sensing in operating fuel cells through polarized neutron imaging.

PhD Shieren Sumarli

Under the title An in-situ/operando laser powder bed fusion system for advanced neutron characterization the PhD work of Shieren Sumarli involves the provision of a LPBF metal additive manufacturing device that enables in-situ and operando studies utilizing neutron imaging and diffraction techniques during 3D printing of metals [1]. In order to enable Bragg edge imaging Shieren provided a data analyses approach that allows for deconvolution of the signals from the surrounding powder bed and container in order to extract the relevant information from the printed sample material [2]. The same data analyses technique was later used to map sample temperature and ferritic phase evolution from concurrent operando inelastic and polarization contrast imaging during the manufacturing of bimetallic steel (316L) – copper (CuCrZr) samples with varying mixing ratios, which shed light on the conditions determining the resulting amount of ferritic phase in the printed material (Fig.1 a)[3].

PhD Christos Sofras

Christos Sofras explored in his PhD work the laser powder bed fusion parameters in order to create specific local crystallographic textures in TRIP and TWIP steels that would enhance or suppress transformation and twinning, respectively, for certain load conditions in defined locations of the printed parts. This required first to understand well the required textures and their evolution due to load and then the ability to locally control the printed texture [4]. Neutron imaging and in particular polarization contrast neutron imaging were eventually utilized to evaluate in-situ the local martensitic transformation for complex specimens with locally varying texture (Fig. 1b&c)[5,6].

PhD Antonia Ruffo

This PhD work aimed to explore the possibility of operando mapping of the temperature in operating fuel cells through the use of magnetic nano mediators. Assessing the local temperature in operating fuel cells remotely and, in particular, without interfering with the electrochemical process is yet a significant challenge for diagnostics. Here, the idea is to use magnetic nanoparticles, that would not interfere with the process, to utilize the dependence of their magnetic properties on temperature to probe the latter by inferring the former with polarized neutron imaging. While it proved difficult to design well suited magnetic nanoparticles a proof of concept could be established for remote temperature sensing in fuel cells through magnetic nanoparticles (Fig. 1d).

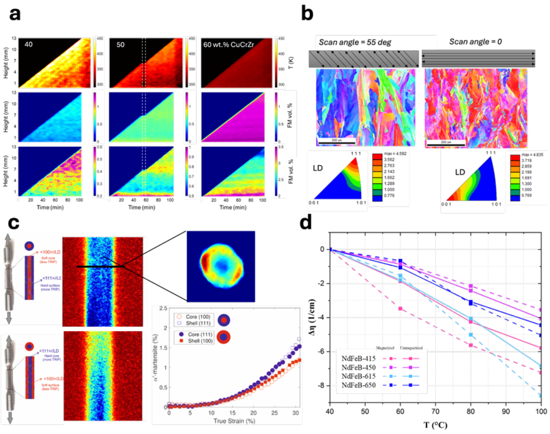

Figure 1: *(a) operando temperature and phase maps of LPBF of three different 316L/CuCrZr mixtures [3]; (b) LPBF tailored textures in TRIP steel for supporting and suppressing martensitic phase transformation [4]; (c) TRIP steel LPBF manufactured dogbone samples with tailored local texture and polarized neutron imaging evaluation of corresponding locally enhanced and suppressed martensitic transformation [6]; (d) temperature dependent depolarization coefficient extracted from polarized neutron imaging of magnetic nano-particles in gas diffusion layer of polymer electrolyte fuel cell;*

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Images from WCNR-12

by Aaron Craft

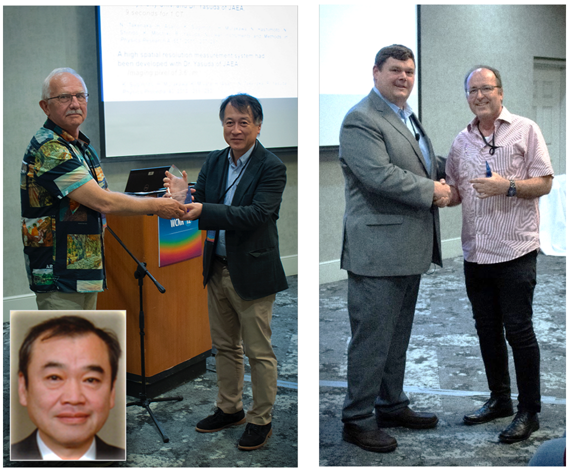
Conference attendees enjoyed an excursion to Yellowstone National Park on Sunday, June 2, 2024. This group photo was taken along the Madison River at the west entrance.

Collage of conference attendees.

Dr. Michael Schulz fielding questions from the audience.

Dr. Tobias Neuwirth was awarded Best Poster for his work on “Study of failure mechanisms in additively manufactured steel samples using grating interferometry and Bragg edge imaging.”

Dr. Mohammad Samin Nur Chowdhury was awarded with the Best Presentation for his work on "Fast hyperspectral reconstruction for neutron tomography using sub-space extraction." His efforts reduced the number of projections for a tomography data set from 1,200 radiographs to just nine while maintaining the same image quality.



ISNR Honorary Membership, the highest award given by the Society, were given to two deserving members: Prof. Nobuyuki Takenaka, Emeritus Professor of Kobe Uni-versity and Dr. Thomas Bücherl from the Technical University Munich. (Left) ISNR Honorary Member Eberhard Lehmann presenting the Honorary Membership Award to Prof. Nobuyuki Takenaka (unable to attend in person), accepted by Professor Hitoshi Asano. (Right) ISNR President Aaron Craft presenting the Honorary Mem-bership Award to Thomas Bücherl.

Attendees visiting the Hot Fuel Examination Facility at INL's Materials & Fuels Complex, the world's largest inert-atmosphere hot cell, which is the starting point for post-irradiation examination of nuclear fuels. The NRAD reactor beneath the hot cell is used for neutron imaging of irradiated nuclear fuels.

Participants enjoying the TREAT facility, a pulsing reactor at INL's Materials & Fuels Complex where experimental nuclear fuels are tested at powers up to 19,000 MW to determine how they perform in over-powered and under-cooled conditions, ultimately informing the safe operating envelope for new nuclear fuels.

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