International NR Newsletter

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International Society for Neutron Radiography

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Content

Editorial 2

Words from the ISNR President 3

New Honorary Members of ISNR 4
Jack Brenizer 4
Yoshiaki Kiyanagi 5
Eberhard Lehmann 6

New and/or ongoing projects 8
Recent news about the "Cultural Heritage" Project @ ANSTO 8
The new high visibility neutron grating interferometer at ANTARES 10
News from the "PSI Neutron Microscope" 13
Status of the Energy-Resolved Neutron Imaging System RADEN at J-PARC 14
Optimization of crystal growth and materials characteristics for nuclear detection applications 17

News from the Lab 21
Software collaboration 21
NIST imaging team received an R&D 100 award 21
Neutron Radiography Activities in South Africa 22

Review on conferences and workshops 26
WCNR-11 26

News from the Board 29

NIST remembers Muhammad Arif 38

Upcoming conferences and workshops 42

Editorial

Dear colleagues,

Looking at the first page of this NR Newsletter (NR holds for Neutron Radiography) you may noticed that two things have changed compared to the last issues. No, I am not talking about the image of Sydneys world famous Opera house, nor the table of content. I want to draw your attention on the logo of ISNR and the name of ISNR itself. In both, the name radiology is changed to radiography! This is an unanimous vote of the Board of Members at its first meeting in 2018, the day before WCNR-11 started, taking into account the results of the Task Group "Terminology" (see pages 29 and 32 ff.).

WCNR-11 at Sydney was the highlight of our society in 2018. Talking to many participants I noticed a broad agreement that the quality of the presentations, both oral and posters, reached a new quality. Thus, if you did not have the chance to participate the conference you really missed impressive improvements in the various fields of applications in neutron imaging. The next chance to meet the ISNR community for intensive discussions and exchange of experiences will be at ITMNR-9 in Buenos Aires, Argentina 12-16 October 2020. Note this date and don't miss it (again).

For the content of this NR Newsletter, all Board Members were asked to contribute and we still have a few topics left for the next issue. However, the NR Newsletter shall not act as a forum of the Board Members only, presenting the work performed at their facilities or by themselves only, but is intended as a forum for information exchange between all members of ISNR and other interested persons. Therefore you shall not be passive but becomie an active member of ISNR. If you have new results or applications, interesting notices, upgrades of your facilities …. just summarize this information by a few sentences (or more) and send it to me for publication in the next issue (secretary@isnr.de). Photos are welcome, too. Additionally, please feel free to distribute this NR Newsletter to any interested person. A growing community most probably will be connected to further improvement in the field of neutron imaging and the opening of new fields of applications.

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

Wishing you all the best – and become active!

Thomas Bücherl

Words from the ISNR President

It is my pleasure to welcome all new members of the ISNR to our community and to thank the new ISNR Board for volunteering to serve. ISNR membership has grown to 362 members representing 41 different countries performing an ever-expanding range of techniques and applications. The presentations and posters at the recent WCNR-11 conference on 2-7 September, 2018 in Sydney, Australia exhibited many significant developments in our quickly-advancing field. This is truly an exciting time in our community, and there is much reason for optimism.

The rich history of the neutron radiography community includes an early emphasis on nondestructive examination for practical industrial applications. With the development of digital systems came development of new imaging techniques and their use for more scientific applications. Today, neutron imaging has become well-accepted as a scientific research tool with neutron diffraction and X-ray methods. Unfortunately, many industrial applications have yet to embrace the advancements that digital systems offer because of a lack of standards, as existing standards only technically apply to film-based methods. Seeing a need for digital neutron radiography standards, ISNR began exploring development of new standards some years ago. The prospect of new standards and an entrance of digital systems for industrial applications is an exciting area for future advancement within our field.

Another reason for optimism lies in what is often a source of pessimism. The dwindling number of neutron sources and its implications for our field are often discussed with some sense of despair. It is true that the number of neutron sources for neutron beams is dwindling as reactors age and shut down, making neutron imaging techniques available at fewer facilities in fewer regions of the world, restricting access to these techniques for science and industry. There are, of course, some large facilities with bright neutron sources and very successful neutron imaging user facilities that are beacons of success for our community and, with some exceptions, these facilities look like they will continue operating with longevity. But broad access to neutron imaging techniques would benefit the community more than concentrating capabilities at a few large facilities. Accelerator-based neutron sources provide neutron fluxes too low for many modern techniques, often over-promising and under-performing the source strength. Recent advances in accelerator sources have increased brightness sufficiently to make them viable for industrial applications of neutron radiography. The potential of this new generation of accelerator-based sources is exciting for the neutron imaging community, as widespread deployment of these sources coupled with new standards for digital neutron imaging systems may initiate a revitalization of industrial applications using neutron imaging techniques.

The ISNR is actively fostering advancement of our community through several focused Task Groups (TG). The TG to write our constitution has finalized its work due to the hard work of Les Bennett and Markus Strobl, and the updated ISNR constitution is now available on the ISNR website (www.isnr.de). The TG on Terminology led by Markus Strobl has developed a well-thought-out report, also available on the ISNR website, that discusses in detail various core terms used in our community, some of which have been the topic of significant controversy (neutron radiology/radiography/tomography/imaging). Personally, technical accuracy and consensus are of upmost importance. The report from the Terminology is a good step in the right direction, and I plan to work through the ASTM committees to incorporate the ISNR's work in this area into ASTM's glossaries. Also, based on enthusiastic interest at WCNR-11, the ISNR is forming another TG on Fast Neutron Imaging that will be led by Michael Schulz, the Head of the Neutron Imaging Group at Technische Universität München. Other ISNR TG's have produced significant contributions in recent years, which you can read about on the ISNR webpage (www.isnr.de).

Lastly, I would encourage you to consider attending upcoming conferences and perhaps submitting your work for presentation and publication. The 10th Workshop on NEUtron WAVElength dependent imaging (NEUWAVE-10) will be 26-29 May, 2019 at Paul Scherrer Institut, and will feature discussions of the latest advancements and applications of neutron Bragg-edge imaging, imaging detector technology, other energy-resolved imaging methods and neutron imaging facility developments (https://indico.psi.ch/event/6899/). A conference that may be of interest to some in our community, the 4th International Conference on Tomography of Materials and Structures, will be held in Cairns, Australia in 22-26 July 2019. Also, the International Topical Meeting on Neutron Radiography (ITMNR-9) will be held in Buenos Aires in 2020.

The 12th World Conference for Neutron Radiography (WCNR-12) will be hosted by Idaho National Laboratory in 2022. Dr. Hassina Bilheux from Oak Ridge National Laboratory has accepted the position as Deputy to the ISNR President and will work with me and the ISNR Board to make WCNR-12 a success. Planning for WCNR-12 is already well underway, and I am looking forward to seeing all of you in 2022.

I offer my encouragement and many thanks to all of you who are actively working towards the advancement of our neutron radiography/imaging community.

Aaron Craft

New Honorary Members of ISNR

AT WCNR-11 in Sydney three deserved members of ISNR were awarded Honorary Membership for their outstanding contributions in the field of neutron radiology throughout her career. The nomination was evaluated and accepted by the Board at the Board Meeting in Beijing 2016.

Jack Brenizer

When I started my first attempts in neutron radiography (with film methods) around 1994 there was a meeting of a European working group on Neutron Radiography, where American and Canadian partners were also be invited. It took place at BAM (Bundesanstalt für Materialprüfung) in Berlin for three days with about 10 participants only, among them Jack Brenizer.

Other prominent persons of that meeting I remember were J. Domanus (Riso, Denmark), persons from Petten (Netherlands), Saclay (France) and C. Fischer (HMI Berlin). They all had already much more experience than me – and I watched very carefully and with certain respect their presented details of studies.

On a trip to USA, where I represented Switzerland in the program for the reduction in fuel enrichment for research reactors, about one year later, I met Jack a second time at his beam line of the Virginia University research reactor. I was very impressed by the radioscopy setup with video camera systems and light amplifiers in front.

Unfortunately, this reactor was closed short time after – including the beam line for the real-time inspection of materials there. This was the reason why Jack returned to his initial education site – the Penn State University, where a professorship position was offered to him. At the same time, he got the access to a neutron imaging facility again because the reactor at Penn State continued running – until today. Maybe, Jacks activities at that reactor, in particular for neutron imaging, have been a strong argument to maintain the operation on good level into the present time – and in future.

Later, we established a deeper contact for the preparation of conferences, exchange of knowledge and also performed private visits in both directions. In particular, he organized the "4th International Topical Meeting on Neutron Tomography" in 2001 with great success at Penn State and published the proceedings in good time.

Jack was very active in the approach to standardize and to advertise neutron imaging in the U.S. and on te international level by his own studies and memberships in related committees. Before he retired in 2016, he was in Oak Ridge active as advisor for the upcoming neutron imaging facilities at ORNL.

I was always impressed by his enthusiasm and optimism, supporting students and coworkers with pleasure.

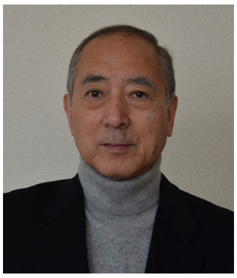
Eberhard H. Lehmann

Jacks answer to the laudation:

I am honored to receive the International Society of Neutron Radiography Honorary Membership Award. I thank the individual members who prepared my nomination and the Board members who supported it for this award. It is especially meaningful to receive this distinguished recognition from your colleagues who are intimately familiar with your efforts and accomplishments in neutron radiography and imaging. I made my first neutron radiograph in 1982 using the beam and simple collimator that we put together for a proof of principle experiment. In that year we also acquired a "real-time" neutron radiography camera – a time when the use of film was the gold standard and dynamic neutron imaging was limited by the video cameras and computers of the time. These early experiments were the beginning of a three decade long effort to use and improve neutron imaging techniques. Throughout my career I was fortunate to be able to interact with most of the world's leading neutron radiography and imaging researchers and practitioners – in developing new techniques, in ASTM and ISO standards and in exploring new applications. Additionally, I had the privilege to have excellent students who conducted their graduate research in neutron imaging.

The interactions and friendships made through our mutual interests in neutron imaging are valued as much as any of my accomplishments. Again, I want to express my sincere gratitude and say thank you for honoring me with this ISNR award. I hope all of you have an enjoyable and valuable WCNR-11.

Yoshiaki Kiyanagi



Yoshiaki Kiyanagi is a pioneer in the development of pulsed neutron imaging and its application for engineering and material science.

He was born on January 1st, 1949 in Hokkaido (Japan) and studied at Hokkaido University, where he graduated from the Department of Nuclear Engineering in 1961 and got his PhD in 1993. He became an assistant professor, lecturer, associate professor and finally full professor of Hokkaido University. He had been the division head of the Nuclear radiation source engineering and educated many students and researchers. One of his contributions to scientific research is concerning the accelerator neutron source. He performed a lot of experiments at the Hokkaido University Neutron Source (HUNS) to obtain valuable experimental data which cannot be obtained by numerical simulations. With sufficient experimental data he has designed and developed a low-energy neutron moderation system. The ability of this system has been highly evaluated and employed by many institutes, like J-PARC in Japan, SNS of Oak ledge National Laboratory in the USA, and ISIS of Rutherford-Appleton Laboratory in UK.

He has developed the Accurate Neutron-Nucleus Reaction measurement Instrument (ANNRI) in the J-PARC. For this development, he won a technology development award from the Atomic Energy Society of Japan. He has also developed the pulsed neutron transmission spectroscopy, which gives spatial distribution of crystal structure in materials. For this development, he won a paper award from Japanese Society of Metals and Materials.. Then he became a project leader to develop the pulsed neutron imaging facility (RADEN) in the J-PARC. The construction of RADEN was finished in 2014 and at present we can perform various kinds experiments at the J-PARC.

When he was a high school student, he began Japanese martial art, "Kendo". Kendo is a traditional Japanese fencing. Normally we are using a Bamboo sword for practice instead of a real Japanese sword. So, he got great interest in the manufacturing process of the Japanese swords and started his investigation on the crystal structure of Japanese sword using pulsed neutron imaging. He is now Prof. Emeritus of Hokkaido University and X'ian University in China, and President of Japanese Society for Neutron Science. He is still actively developing an accelerator neutron source for radiation therapy equipment at Nagoya University.

For his great contributions in our society, the honorable membership award was given to Prof. Yoshiaki Kiyanagi.

Yasushi Saito

Eberhard Lehmann

Eberhard Lehmann was born in Leipzig in Eastern Germany on 16th July 1952 where he also studied physics graduating on the topic of "Molecular dynamic calculations of proteins" in 1974. He received his PhD at the East German Academy of Science in East Berlin in 1983 with his thesis entitled: "Cross-section data of construction materials for the fast breeder reactor by reactivity measurements". In the years between 1976 and 1990 Dr Lehmann was active in research in reactor physics for fast breeders based on calculations of reactor parameters with different reactor codes and experimental work at different reactor stations in several countries of the Eastern hemisphere.

With the fall of the Berlin Wall and the Iron Curtain the Western world opened for the young physicist. He emigrated to Switzerland where he could apply his expertise and experience from 1991 to 1995 at the research reactor SAPHIR of the Paul Scherrer Institute.

1991 to 1995 as reactor physicist at the research reactor SAPHIR of the Paul Scherrer Institute. Given responsibility for core design and in particular neutron applications, he took his opportunity in the latter field and established the Swiss activities in neutron imaging starting in the mid 1990ties still at the SAPHIR reactor, which, however, was shut down in 1994.

As a reactor physicist without a reactor Dr Lehmann took his chances in the new spallation source project SINQ at PSI to establish neutron imaging at the new source. In an environment strongly dominated by neutron scattering, driving the source with applications of fundamental research in magnetism Dr Lehmann established a neutron imaging beamline, which became the reference for neutron imaging user service at large scale neutron sources in Europe and maybe even the world. Together with Burkhard Schillinger from TUM he introduced digital neutron imaging and tomography in Europe.

The user program at his neutron imaging instrument proved successful and Dr Lehmann was never tired to promote the technique nationally and internationally, to find fields of applications also beyond the main stream of non-destructive testing and established simultaneously a vivid scientific user program as well as a profitable service for industry.

He formed a group of experts contributing to nearly all fields of technical developments and applications as well as industrial service, which became a model for many state-of-the-art user instruments and imaging groups at large scale neutron sources as established today.

This included to add a second instrument dedicated to neutron imaging with cold neutrons just 10 years after the first one at SINQ. The new instrument ICON became a front runner in many modern developments utilizing monochromatic neutrons or other energy resolved techniques. Most notable grating interferometric imaging was pioneered by the ever growing group, which by the end of his career as an employee at PSI and group leader of the Neutron Imaging and Activation Group NIAG operated the two dedicated imaging beamlines NEUTRA and ICON, but also officially utilized up to 50% of two further instruments, BOA, a polarized testbeamline and POLDI, a time-of-flight diffractometer. In addition, his group is one of the driving forces and partners of the European Spallation Source (ESS) in establishing neutron imaging with a day-one instrument (ODIN) and to provide the software for imaging data analyses. Dr Eberhard also led his group from being a part of the Neutron Source Division to being a valuable and respected part of the Laboratory for Neutron Scattering and (now also) Imaging, which also underlines the successes in his time to prove the potential of neutron imaging not only for non-destructive testing but far beyond in material science and other fields of science, equivalent to (other) scattering techniques.

Dr Eberhard Lehmann was not only in his active career a tiredless ambassador and forefighter of neutron imaging in particular at large scale facilities, an advisor to nearly all major imaging instrument projects at large scale sources but is still a very active and engaged member of the ISNR. After being a yearlong member of the board with the organization of the last world conference in Switzerland (WCNR-10, 2014) he became president and served between 2010 and 2014.

After his retirement in July 2017 he remains being an active member of the community, still serving on the ISNR board and as advisor in instrumentation projects, continuing his own research and being an ambassador of neutron imaging at large scale facilities.

Markus Strobl

New and/or ongoing projects

Recent news about the "Cultural Heritage" Project @ ANSTO

Science and technology have increasingly been applied to the characterization and the conservation of heritage materials. Due to the manifold nature of cultural heritage, studies in archaeometry and conservation science always require an interdisciplinary approach and the use of multiple analytical techniques. The need of non-invasive characterization methods has challenged the limits of archaeometric research, prompted the technological advance and the establishment of powerful analytical tools. Now these instruments have become an essential prerequisite both for planning conservation intervention and for unraveling the untold story of cultural heritage materials.

The investigation of cultural-heritage artefacts became part of ANSTO (Australian Nuclear Science and Technology Organization) research since the 1980s. Over the years, the application of the scientific analytical tools available at ANSTO has increasingly grown to study a wide range of heritage materials. Since the neutron scattering instruments came online in the 2000s, and were subsequently complemented by the DINGO neutron imagining facility, the user community from the field of cultural-heritage, archaeology, and conservation science has significantly broadened.

In order to promote the access to the suite of nuclear methods available across ANSTOs campus, a strategic scientific research project on Cultural Heritage has been initiated in 2015. Significantly, the neutron imaging beamline DINGO at the Australian Centre for Neutron Scattering (ACNS) has been successfully applied in a series of forensic investigations conducted in close collaboration with Australian museum institutions and universities.

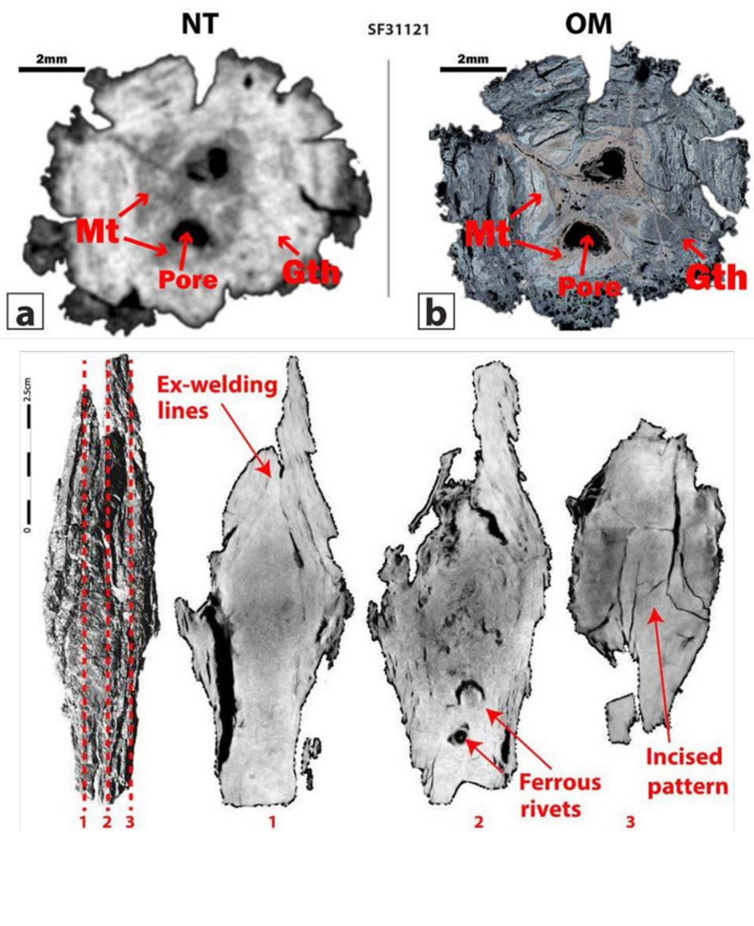


Figure 1: On the top, comparative investigation of corrosion products by NI (a) and OM(b). Magnetite/ maghmite (Mt) and goethite (Gth)are highlighted. At the bottom, structural inhomogeneities evidenced by NT.

One of the most recent studies focuses on the ancient ferrous artefacts from the archeological site of Saruq al-Hadid, U.A.E. investigated by a combination of non-invasive and invasive techniques: neutron tomography (NT) performed at DINGO beamline, optical microscopy (OM) and SEM-EDS. Despite the severe degradation of the objects, NT allowed the detection of various features associated with the mechanisms of degradation and working (manufacturing, recycling) of the ferrous artefacts. Most importantly, NT enabled the identification of the former welding lines attesting to the ancient, almost 3,000-years-old, blacksmithing techniques. This data combined with results from OM and SEM-EDS provided a new insight into the socio-technological aspects underlying the choices in the fabrication of Saruq al-Hadid objects, and the broader aspects of the early Iron Age iron-working in the Ancient Near East. [1]

Figure2: Group photo of the first ANSTO-AINSE workshop on Nuclear Techniques for Cultural Heritage taken outside the OPAL reactor at ANSTO (June 2018).

Finally, the 1st ANSTO-AINSE workshop on Nuclear Techniques for Cultural Heritage was held from the 12th to the 15th of June, 2018, at ANSTO's Lucas Heights (Sydney, NSW) campus. During the four-day program, a comprehensive introduction to the relevant analytical tools that are available at ANSTO for cultural-heritage research was provided. ANSTO staff presented detailed overview of applications for each analytical instrument with presentations tailored to novice-to-intermediate users from the disciplines of cultural heritage, conservation science and archaeology to provide an in-depth insight into the use of ANSTO facilities and related research opportunities. Feedback received from the attendees after the school was overwhelmingly positive, and we look forward to the next ANSTO-AINSE workshop on Nuclear Techniques in Cultural Heritage in 2020.

F. SALVEMINI
(Australian Nuclear Science and Technology Organization, Sydney, Australia)
I. STEPANOV
(Ariel University, Israel)

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The new high visibility neutron grating interferometer at ANTARES -Performance and Applications-

Neutron grating interferometry allows to resolve material or magnetic structures in a range from 100 nm to 20 µm by analysis of ultra-small-angle neutron scattering (USANS). This makes it an ideal supplement for standard neutron imaging, as resolving of structures normally too small for imaging becomes possible. Recently we rebuilt the neutron grating interferometer (nGI) used at the ANTARES beamline at the Heinz Maier-Leibnitz Zentrum (MLZ) [1], significantly improving its performance.

The upgraded interferometer has several advantages compared to currently used interferometers. The advantages are (i) the ability to adjust the ratio between flux and visibility, (ii) the decreased minimal distance between sample and detector, (iii) the increased visibility and (iv) the greater accessible correlation length range. The most important characteristic here is the increased visibility, as it is directly linked to the signal-to-noise ratio in the data [2]. The visibility of the upgraded setup is 0.746 over the whole field of view (FoV) of the detector system (71 mm x 76 mm), which is to our knowledge the highest visibility achieved on such a large FoV. While a similarly large visibility (0.69) has been previously reported the FoV was only 10 mm x 10 mm at a wavelength of 5 Å [3].

Reaching such a high visibility required a change of the interferometer geometry and a novel fabrication process of the absorption gratings [4]. Fig. 1 presents a schematic view

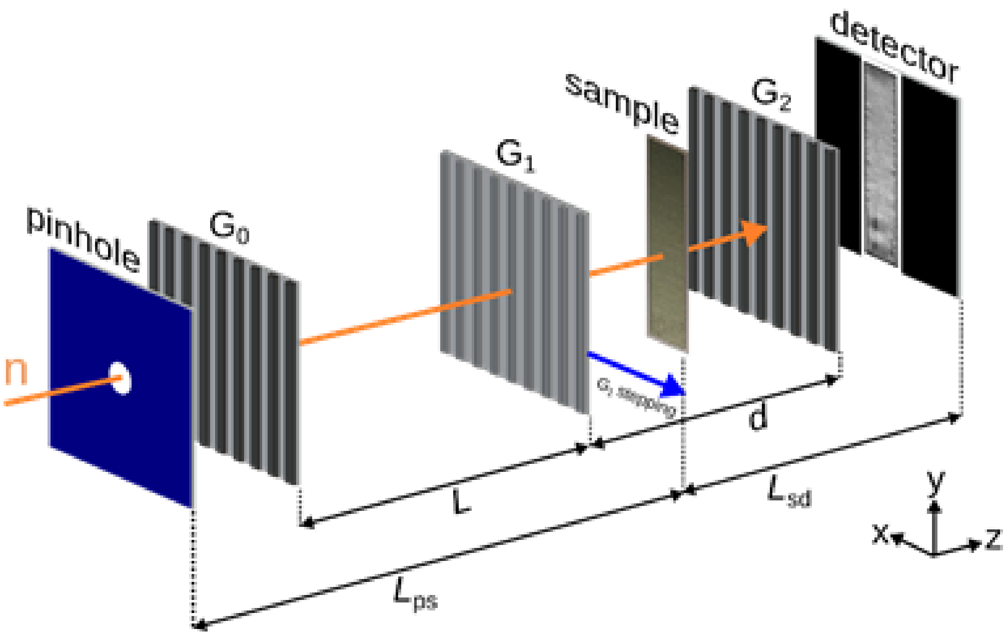

Fig. 1 Sketch of the nGI-setup. The setup consists of two absorption gratings (source grating G0 and analyzer grating G2) and a phase grating G1. Here the sample is generally placed between G1 and G2. Partially adapted from [5].

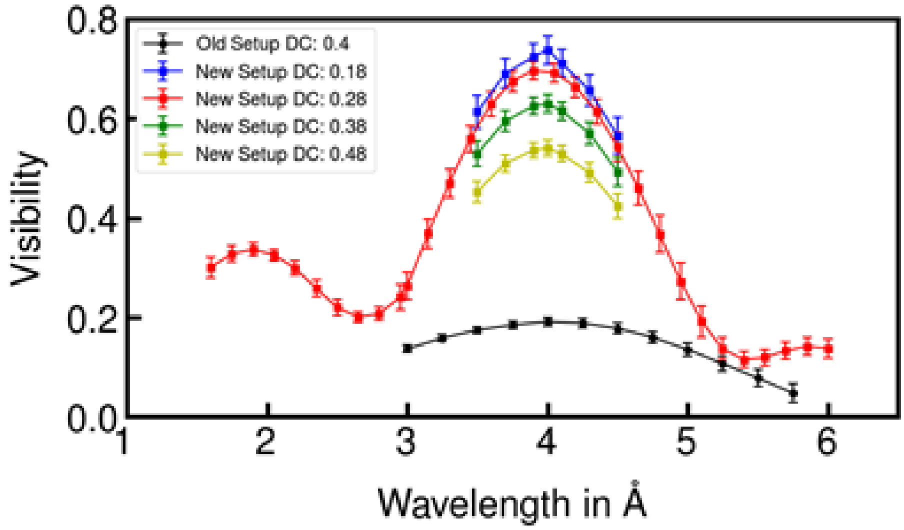

Fig. 2 Visibility of the nGI versus the wavelength for different setups. The visibility has been extracted by averaging over the central 80% of the visibility map. The error bars correspond to the standard deviation of the visibility.

of the upgraded nGI. The nGI is constructed as an asymmetric Talbot-Lau-interferometer, which consists of two absorption gratings (G0 and G2) and a phase grating (G1).

We reached the maximum visibility of 0.746 at a wavelength of 4.0 Å using a G0 duty cycle (DC) of 0.18. In contrast, the previous setup had a maximum visibility of 0.196 at a wavelength of 4.0 Å and a DC of 0.40. In Fig. 2, the dependence of the visibility on the neutron wavelength is presented. The graphic includes results for different duty cycles of G0 and of the old setup. The comparison shows that the performance of the new setup is superior at all wavelengths.

The massive increase of the peak visibility from 0.196 to 0.746, as compared to our old setup, allows performing experiments with less noise while keeping the exposure time the same or even decrease the needed exposure time without increasing the noise in the acquired data.

In the following, we will show some first results acquired with the new grating interferometer. Energy efficiency is a primary concern in electrical engines. With nGI it is possible to analyze the local magnetic properties of electrical steel sheets, which are used in most electrical engines based on the scattering of neutrons on domain walls. By analysis of these properties, more efficient production processes can be developed. The case we are looking at is the usage of internal stress as a means of guiding the magnetic flux inside the electrical steel sheet. Due to the magneto-elastic effect, the internal stress leads to a decrease in the magnetic domain mobility. This in turn causes a decrease in magnetic flux in areas affected by internal stress.

Conventionally the guiding of the flux is performed by cutting holes in the electrical steel sheet, which however lowers the mechanical durability. In the case of high-speed electrical engines, this may lead to a mechanical failure. Therefore, the possibility of guiding the magnetic flux without decreasing the mechanical stability is investigated.

Hence, we analyzed how induced internal stress changes the magnetic field inside an electrical steel sheet. As an example, we show data from an electrical steel sheet embossed by a flat 3 mm diameter punch. As reference, a non-embossed steel sheet of the same thickness (350 µm) and material (97.6%wtFeSi) was used. The embossing depth was approxi-

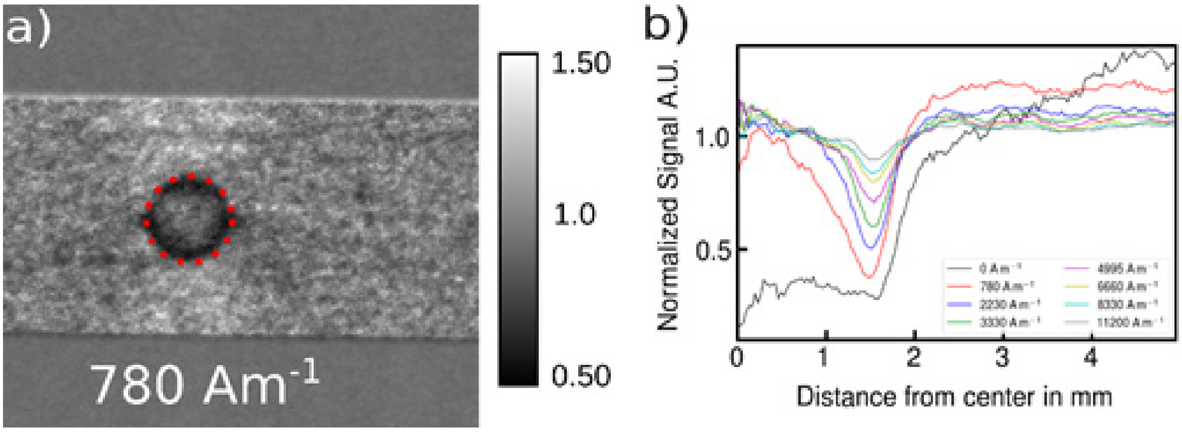

Fig. 3 a) Normalized signal of an embossed electrical steel sheet to a non-embossed reference. An external magnetic field of 780 Am-1 is applied to both sheets. Shown in b) is a radial plot originating from the center of the embossing. It can be seen that due to the chosen shape of the stamp (flat, 3 mm dia. punch) the stress is confined to a small area.

mately 20 µm. The sample and reference were measured at a correlation length of 1.865 µm. They were magnetized by a magnetic yoke with magnetic fields ranging from 0 A/m to 11200 A/m. After acquiring the data the sample was normalized to the reference to directly visualize the difference of the magnetic flux caused by the embossing. In Fig. 3 a) the normalized image at an applied magnetic field of 780 A/m is presented. A signal below unity denotes a lower magnetic flux than in the reference, while a signal above unity denotes a higher magnetic flux. The area of the embossing is marked by the red circle. In Fig. 3 b) a radial plot from the center of the embossing is presented for different magnetic field strengths. Due to the chosen shape of the punch the stress is confined to a small area located around the edge of the punch, which is denoted by the lowest signal in this area. Away from the edge, the signal rises rapidly to unity. Due to the low embossing depth and therefore small applied internal stress high magnetic fields overcome the decreased mobility. This results in the signal getting closer to unity for high magnetic fields.

Work funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - HA 4395/22-1; SCHU 3227/2-1; VO 1487/31-1

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[2]Chair of Biomedical Physics, Department of Physics and Munich School of Bioengineering, Technical University of Munich, Garching, Germany

News from the 'PSI Neutron Microscope'

In 2018, the instrumentation for the high spatial resolution neutron imaging, known as 'PSI Neutron Microscope' (NM) [1], has experienced another rather busy year.

Within the SINQ 2018 call for proposal with the deadline in February, NM attracted 16 proposals that combined for the total of 70 requested days of beamtime. As is usual for neutron imaging instruments, the scope of the proposal topics has been very broad. To name just a few, they covered as distant fields as the porosity distribution in additively manufactured high-Z materials, the investigation of dynamic investigations of skin formation on polymer suspension droplets, and the assessment of novel high-resolution scintillators. Above that, there have been two highlights that are notably worth mentioning at least shortly. First, the high resolution capability of NM enabled the observation of the cavitation phenomena inside the orifice of a single-orifice Diesel injection nozzle [2], and, even more recently, NM has been successfully used for the first high resolution image of hydrogen distribution within the highly-activated Zircaloy cladding from a Swiss nuclear power plant [3].

Apart from the user program there were several further notable developments. On the technical side of the NM, the light output of the isotopically-enriched 157-gadolinium oxysulfide scintillator screens were further improved and the publication about this enhancement has appeared recently here [4]. As the 'Neutron Microscope project' was officially completed in November and Pavel Trtik has been earlier in the year 2018 appointed the beamline scientist and the temporary beamline responsible for NEUTRA [5], the isotopi-

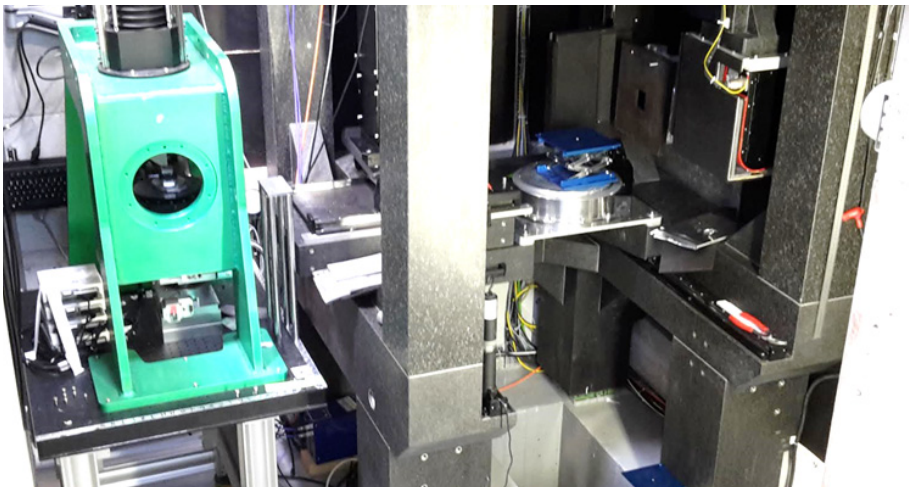

Fig. 1 'PSI Neutron Microscope' installed at ILL-D50 beamline

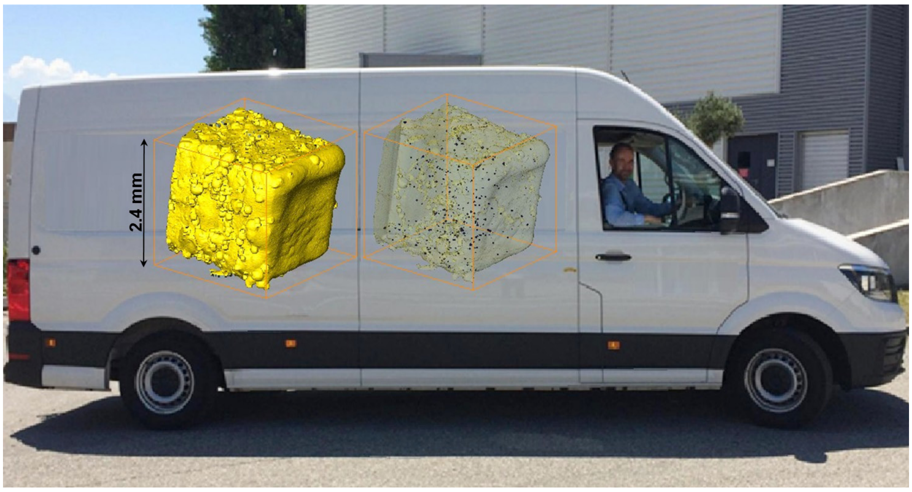

Fig. 2 Pavel Trtik driving a van away from ILL on a sunny July day with NM being freshly released from ILL radiation safety officers and with rather unique neutron microtomographic datasets (image courtesy of Dr Michel Kenzelmann LNS/PSI). On the van side 3D renderings of a sample of additively manufactured gold alloy and its closed porosity (in black).

cally-enriched 157-gadolinium oxysulfide screens –originally developed in-house PSI- will be in the future further developed (in collaboration with PSI) and marketed by the company RC Tritec [6]. Also, the first prototype of the Neutron Microscope (NM1.01) [7] has been purchased by ANSTO for DINGO beamline and further collaboration between the institutes is envisaged. Likewise, there has been a further interest in the purchase of NM from other research institutes.

Another of 2018 highlights of PSI Neutron Microscope occurred even before the official start of the SINQ neutron production. Courtesy of Dr Duncan Atkins, Pavel Trtik was invited to ILL (Grenoble, France) within the framework of ILL industrial beamtime to test the NM at high flux neutron source. As much as the NM has been designed as self-contained piece of instrumentation that can be (and regularly is) transferred between individual beamlines at SINQ with ease, this has been the NM's "maiden voyage" outside SINQ.

As will be reported in the WCNR-11 proceedings paper [8] (provided successful peer-review process), NM was installed at the newly-built D50 beamline for 5 days at the end of June/beginning of July. The first neutron images were being taken only 6 hours after the start of the set up and the combination of the high flux at ILL-D50 and the high spatial resolution of NM led to the acquisition of a number of high contrast-to-noise tomographies of relevant static samples.

The ILL journey has proven that the NM can be installed in (and also released from – see Figure 2) other neutron facilities rather easily. Therefore, the upcoming 18 months (i.e. the entire 2019 and first half of 2020) are surely one of the most convenient times for similar endeavors to be performed, as no neutrons will be available due to an upgrade of neutron guides at SINQ. Neutron Imaging and Applied Materials Group (NIAG/PSI) have already registered several enquiries for a short-to-medium term installation of NM from other neutron facilities worldwide, however NIAG are open to further proposals in this matter. From that perspective, the SINQ-neutronless-period might be for the NM a bit busier time than what could have been originally foreseen. In any case, the NIAG is already now looking forward to comeback of neutron production at SINQ and to welcoming both the new and the regular users.

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Status of the Energy-Resolved Neutron Imaging System RADEN at J-PARC

It has been 4 years since RADEN started its operation in November 2014. RADEN is the world-first pulsed neutron imaging instrument constructed in a MW-class spallation neutron source facility, with which the energy-resolved neutron imaging (ER-NI) experiments, such as Bragg-edge imaging, resonance absorption imaging and pulsed polarized neutron imaging, can be conducted with a good wavelength/energy resolution effectively

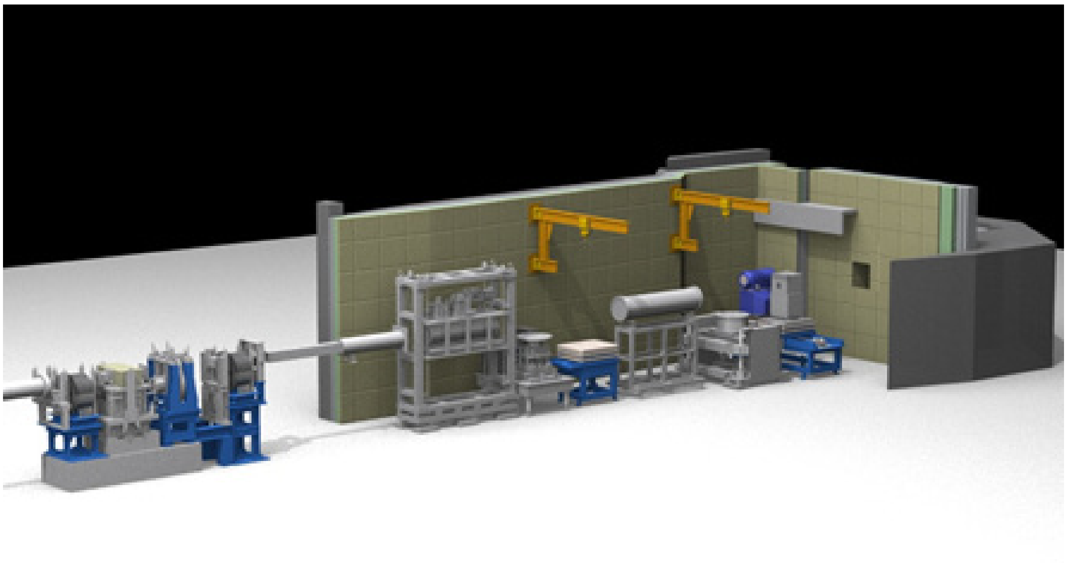
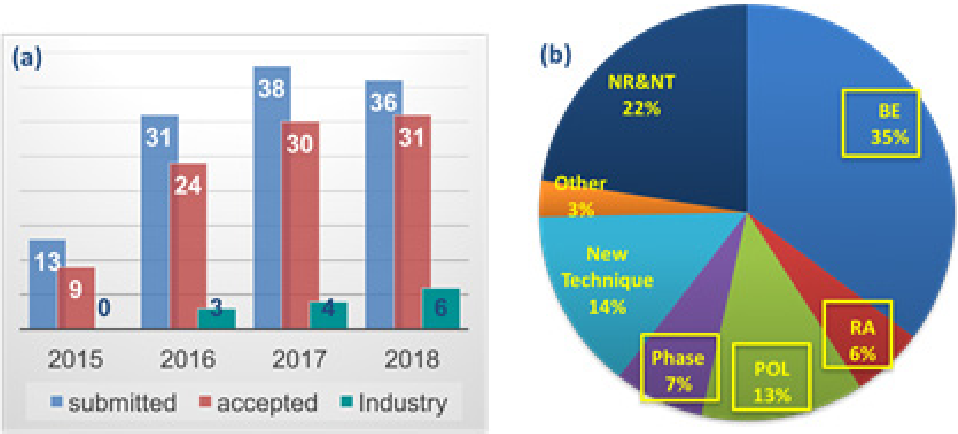


Fig. 1 Illustration of RADEN instrument.

[1]. After the Great East Japan Earthquake in 2011, the Japanese neutron imaging environment has changed drastically, because the biggest neutron imaging facility at JRR-3 was forced to stop and a lot of users have gone. Hence, RADEN has another role than to conduct ER-NI experiments to support and to rebuild neutron imaging society in Japan by providing the place to perform conventional neutron radiography/tomography experiments.

After the hot commissioning, RADEN started to accept user programs from JFY 2015, and 94 proposals in total have been conducted through JFY 2018. The number of proposals from industrial users is still small, but it is certainly increasing year by year (Fig. 2). More than half of the proposals use wave-length/energy analysis. Especially, new application studies of ER-NI, e.g., in-situ observation of liquid/solid interface and segregation of elements during the single-crystal growth process [2] and applications of tomography techniques to visualize the three-dimensional distribution of strain in a steel sample using Bragg-edge analysis [3] or of both magnetic field strength and direction in a solenoid coil with TOF polarimetric imaging [4], have been successfully carried out. On the other hand, most of industrial application studies using conventional radiography/tomography techniques, and observation of batteries, mechanical objects, concretes, liquid flow in an air-conditioner, etc. have been done. But application of ER-NI to industrial objects is also producing interesting achievements. The magnetic field in a driving electric motor and the leaked field from an electric transformer have been observed by using the pulsed polarized neutron imaging technique (Fig. 3) [5]. Degradation of Li ion batteries was analyzed using Bragg-edge imaging. Since the Li ion transfer from cathode to anode causes a structural change in anode material, the Bragg edge shifts depending on the state of charge (SOC) of the battery. Consequently, spatial distribution of SOC can be visualized under charge-discharge operation by means of ER-NI. Regarding the technical development, we are improving the performance of imaging detectors, especially the counting-type detector system with fine time resolution, which is important for energy-resolved neutron imaging experiments using pulsed neutrons. The current μNID detector can provide a good spatial resolution up to 100 μm with an active area of 10 cm x 10 cm without sacrificing the neutron beam intensity due to their limited count rate. The improvement is continuing to achieve much higher count rate capacity over 20 Mcps.

Now, RADEN is under user operation and is being continuously upgraded. The detector performance improves year after year, and we will continue the development in order to achieve finer spatial resolution and higher count rates. The application of ER-NI tech-



Total proposal number

Proposals classified by technique (from 2015 to 2018A)

Fig. 2 (a) Yearly trends in proposal numbers for RADEN, (b) Percentage of proposals classified by imaging techniques. (BE: Bragg-edge, RA: resonance absorption, POL: polarization analysis.)

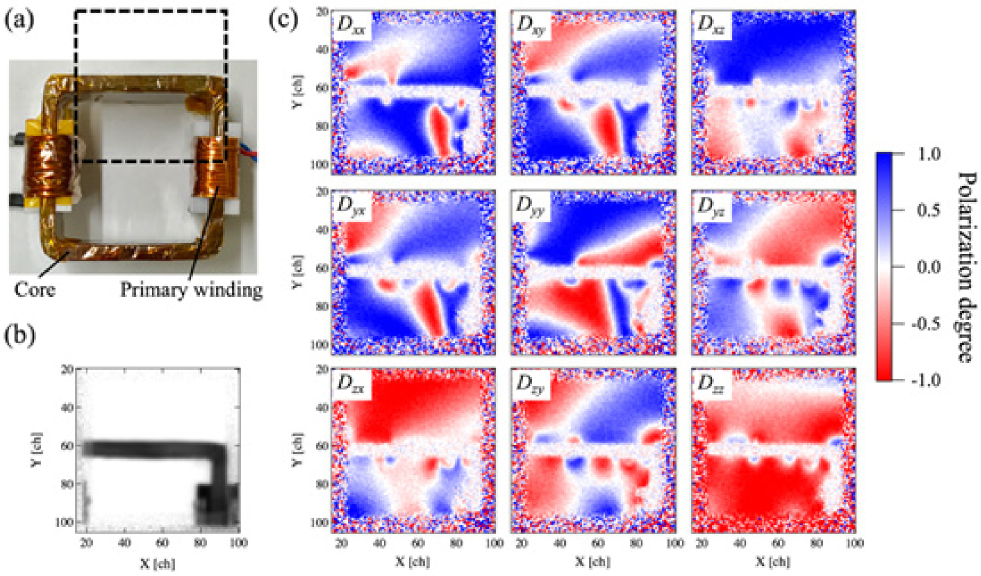


Fig. 3 (a) Photograph of the model electric transformer. The dashed square indicates the FoV. (b) Neutron radiograph of the transformer. (c) Polarization images for the spin rotation matrix elements (wavelength = 2.51 Å). [5]

niques has started to spread widely in both scientific and industrial disciplines. In-situ or in-operando observation experiments are expected to be very important subjects for RADEN, because they can utilize the advantages of neutron imaging. We are going to improve the RADEN instrument and prepare an easy-to-use environment to promote these kinds of application studies.

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Takenao Shinohara

Optimization of crystal growth and materials characteristics for nuclear detection applications

Capabilities and performance of many gamma and neutron detection devices are often determined by the characteristics of materials used for the initial conversion of incoming radiation into a detectable signal (e.g. photons, as in the case of scintillators, or electrons/holes in semiconductors). Discovery of very promising materials, typically performed on powder or small crystal samples, needs to be followed by the development of crystal growth techniques in order to produce materials with volumes sufficient for radiation absorption. In many cases, most efficient detection is achieved with materials grown in the form of a single crystal as light scattering and charge trapping occurring at the grain boundaries substantially degrade the performance of detection devices. It is the development of crystal growth recipes, which in many cases becomes the most difficult, long and expensive part of novel material transition from the discovery phase into large scale production for detection devices. Although there is a large number of growth techniques that have been developed to this date, in many cases growth conditions are optimized by a trial and error approach due to the lack of in-situ diagnostics during crystal growth. The single growth process can take days to weeks, making the trial and error approach very costly and time consuming. The Bridgman growth method [1], for example, widely used for the growth of hygroscopic or highly reactive materials, does not allow direct measurements of material characteristics during the growth as these materials are usually grown in a vacuum-sealed container and introduction of physical probes into that container unacceptably tampers the growth process. Conventional non-destructive testing methods based on X-rays also cannot be implemented here since the materials are designed to absorb high energy photons. Our collaboration has employed neutron imaging techniques in order to provide in-situ diagnostics on the materials during crystal growth, which can be used for the optimization of growth conditions, improving the yield and performance of resulting crystals. The ability of neutrons to penetrate the furnace, the container and the materials themselves, which are opaque to conventional X-ray techniques, make them unique probes for such diagnostics. Energy resolved neutron imaging (Fig. 1), in particular, enables investigation of some crystallographic properties (e.g. uniformity of single crystal, identification of multiple grains, presence of different solid phases) through Bragg scattering measured in transmission mode, identification of defects (e.g. voids, cracks, inclusions) through neutron attenuation, as well as mapping of the elemental composition and phase separation in both melt and grown crystal for the elements which have sufficiently large neutron resonance absorption cross sections. All these can be done simultaneously in one experiment at a pulsed neutron imaging beamline, where neutron transmission spectra can be acquired in a broad range of energies (meV to tens of keV) through the neutron time of flight technique (Fig. 1). Recent development of bright pulsed neutron imaging beamlines at spallation neutron sources and fast neutron counting detectors [2] enables these measurements to be done in real time, which in crystal

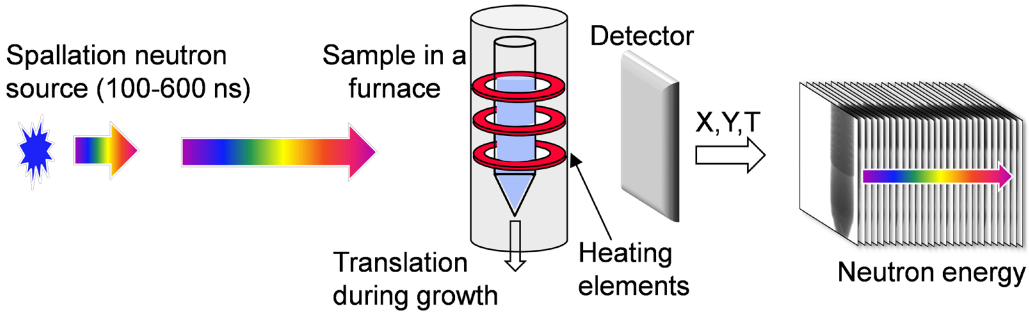


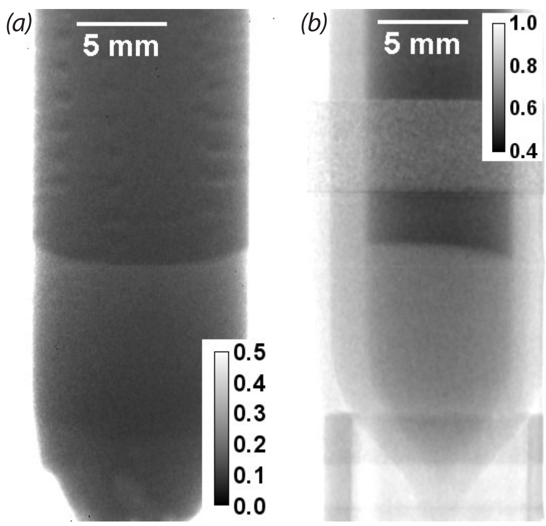
Figure 1. Energy resolved neutron imaging of Bridgman crystal growth process. Neutron transmission spectra is measured in each pixel of the imaging data set, all energies at the same experiment.

growth terms can be tens of minutes as these processes are usually inherently slow (with typical crystal growth speed being 1 mm/hr).

After initial proof-of-principle ex-situ measurements, where we investigated the uniformity of crystal structure, the elemental composition and melting properties of various gamma scintillator and semiconductor materials [3], we continued with in–situ crystal growth by a vertical gradient freeze technique (a sub-type of Bridgman method) implemented in a single-zone clam-shell furnace [4]. These experiments, conducted at J-PARC and Los Alamos National Laboratory, demonstrated that the location and shape of the interface between liquid and solid phases can be imaged for the materials with sufficient segregation coefficient of one constituting element, Fig. 2. The shape of the interface needs to be optimized for the crystal growth in order to minimize the defect accumulation as crystal growth proceeds. A convex shape is preferred as it leads to expulsion of all the defects towards the exterior wall of the container. After almost a century of applications of the Bridgman method, this approach provides for the first time real time feedback for the optimization of growth conditions to maximize yield in unparalleled efficiency. Furthermore, the method uniquely provides validation of simulations such that the synergy between experiment and theory enables novel avenues to further optimize the process.

Introduction of booster heater in our new furnace (a very compact heating element with heat input localized in a small section) enabled us to control the shape of interface, as predicted by the thermal simulation modeling performed within our collaboration. Neutron imaging allowed visualization of the shape in real time, enabling optimization of furnace parameters to reach the desired convex shape, as shown in Fig. 2.

Figure 2. White beam neutron radiographies of crystals grown by a Bridgman technique. Location of the interface between solid and liquid phases can be clearly seen from these images due to substantial variation of elemental composition due to segregation. (a) Concave interface: BaBrCl:5%Eu sample during growth by a Vertical gradient Freeze method. (b) Convex interface under optimized furnace settings: CsI:0.5%Eu crystal grown in a 5-zone furnace, shown in Fig. 3. The legend indicates sample transmission values.



Not only the shape of the interface can now be monitored for a given sample position within the furnace, but also the dynamics of the interface can now be visualized by our diagnostics technique. As the sample container is translated through the furnace during Bridgman growth, the location of interface can shift as heat extraction from the hot zone is also changed with the sample translation. The heat conduction of a particular crystal material and its container define the specifics of heat extraction and therefore need to be optimized for each growth recipe. A real time control system (with feedback time constant on the scale of a minute, sufficient for crystal growth processes) can be developed now with the help of neutron imaging diagnostics. It was observed in our recent experiments in a newly built 5-zone furnace (Fig. 3), that for certain materials (such as CsI:0.5%Eu sealed in a quartz ampule) the location and the shape of the interface remains constant with a ~7 cm sample translation, which may be not the case for other materials.

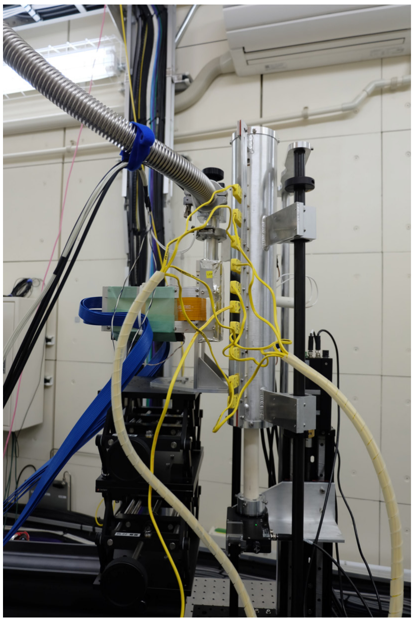


Figure 3. Photograph of our 5 zone furnace developed specifically for neutron imaging experiments, with the distance between the grown sample and the detector minimized in order to reduce image blurring.

In addition to location and shape of the interface energy-resolved neutron imaging allows quantification of elemental composition for the elements, which have sufficiently high attenuation cross section. An example of such quantification map of BaBrCl:5%Eu sample is shown in Fig. 4.

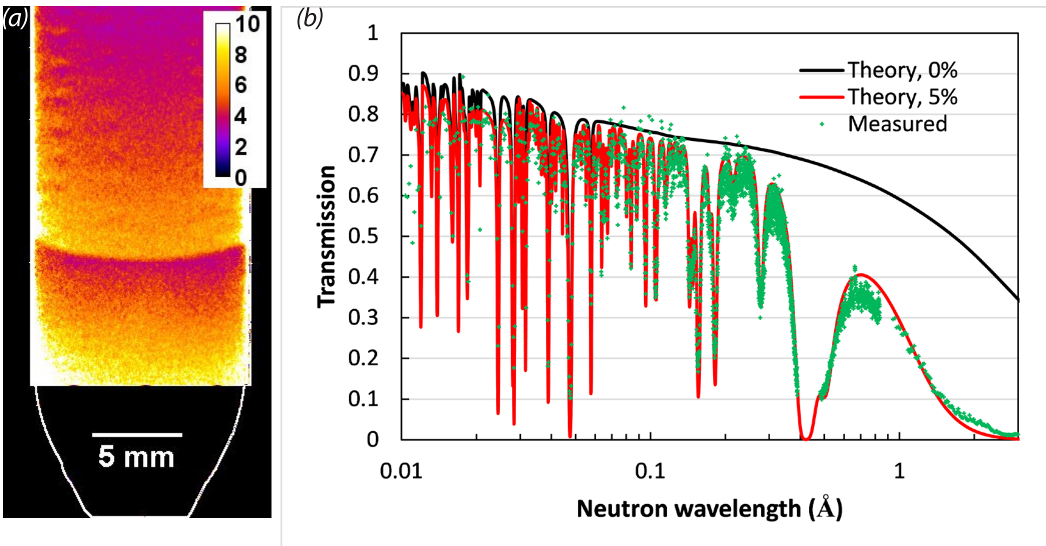


Figure 4. (a) Eu concentration map of BaBrCl:5%Eu gamma scintillator measured in-situ during crystal growth. The concave interface location is clearly seen due to Eu segregation. Each pixel in that image represents the concentration of Eu averaged through the sample thickness, as indicated by legend. The concentration is reconstructed by fitting theoretical transmission (calculated from known cross sections of elements) into the measured spectrum in each pixel. (b) Calculated (solid lines) and measured (crosses) neutron transmission spectrum of BaBrCl:5%Eu sample shown in (a). Quantification of Eu concentration is possible by fitting theoretical transmission curves into measured spectra.

Complementing neutron diffraction experiments on the HIPPO beamline at Los Alamos Neutron Science Center demonstrated how the crystal properties of grown materials can be studied with the help of neutron diffraction [6]. Crystal cracking, for example, observed previously for BaBrCl:Eu crystal in neutron imaging experiments [4] was hypothesized to be spatially correlated to the variation of Eu concentration. That hypothesis was confirmed by the neutron diffraction measurements where it was determined that the coefficient of thermal expansion and the lattice parameter of this material varies with different levels of Eu doping concentration, leading to localized stresses in the crystal with non-uniform doping distribution.

In summary, energy-resolved neutron imaging and diffraction enable novel diagnostic methods, which can be very helpful for the optimization of crystal growth techniques and lead to efficient introduction of novel materials for a wide variety of applications. The yield of synthesized and grown crystals, their quality and performance characteristics can be improved by the combination of in-situ diagnostics and real-time control based on the process simulation. We plan to continue exploring the new capabilities of neutron imaging and diffraction for the development of advanced materials within our collaboration, possibly combining it with other diagnostic techniques.

Acknowledgements

The authors would like to acknowledge the support of this research by the U.S. Department of Energy. We also acknowledge the access to beamline facilities at Lujan Center at LANSCE, Los Alamos, Japan Proton Accelerator Research Complex and ISIS Neutron Source at the Rutherford Appleton Laboratory, UK.

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News from the Lab

Software collaboration

In order to improve the software collaboration between the various institutions, we must be able to measure the quality of the tools developed. The only way to do so is to make sure we all used the same testing data sets, called Standards. I started to create a github account where I put a few standard images I'm already using to test some of my python scripts. Just like during an experimental setup change masks have to be used to determine the resolution of the new setup, those images can be used to test a new gamma filtering algorithm for example, the profile of an image and make sure x is x and y is y (imageJ and matplotlib do not seem to agree for example on the orientation of an image).

Jean Bilheux
https://github.com/JeanBilheux

NIST imaging team received an R&D 100 award

NIST's Simultaneous Neutron and X-ray Tomography (NeXT) system was among the 100 best innovations in 2018 as reviewed by the R&D 100 magazine, see: https://www.rd100conference.com/awards/winners-finalists/year/2018/. NIST's tomography system using neutrons and X-rays can improve the estimate of a sample's composition due to the complementary interaction of the two probes with the sample. Tomography is a widely utilized non-destructive method to determine the structure of complex samples. One field of study that makes intensive use of non-destructive 3-dimensional imaging is porous media in which one typically wishes to observe the distribution of a hydrogenous material within a mineral matrix. Our system exploits the fact that X-rays primarily interact with material through the electron cloud while neutrons primarily interact with material through the strong nuclear force. When applied to porous media, the combination of X-ray and neutron image contrasts is highly advantageous, as X-rays have high sensitivity for the mineral matrix, while neutrons have high sensitivity for the hydrogenous components. Thus, by combining the image data sets from both probes, a more complete understanding of a multi-phase sample can be obtained. In particular, one is able to conduct more robust segmentation of complex materials to improve structural or flow models. Typically, neutron and X-ray imaging would be implemented in a serial configuration where the sample would be imaged with one technique followed by the other. Problems arise when investigating samples that slowly evolve with time or stochastic processes as samples will not be identical for each imaging mode as scans can take around 12 h to 24 h or more to complete, so only average information can be extracted from the data. To overcome these issues while facilitating improved material identification and volume registration, simultaneous, dual-mode, neutron and X-ray imaging is necessary.

The primary limitations of the NeXT system are time and spatial resolution, primarily dictated by the available neutron intensity. At present, the best spatial resolution achievable with the NeXT system is 20 micrometers with a field of view of 16 mm x 14 mm, requir-

ing about 12 hours of acquisition time. Larger fields of view with coarser resolution and reduced acquisition time are straightforward to realize through exchange of the lens that images the scintillation light onto the digital camera.

The NIST NeXT system acquires truly simultaneous neutron and X-ray tomography which is necessary for many research topics, such as multiphase flow in porous materials, due to the stochastic nature of the process or the sample slowly evolving with time. Both neutrons and X-rays provide highly penetrating, nondestructive probes to investigate internal structures within an object in three dimensions which allows a sample to be placed in devices such as pressure vessels and flow cells; their complementary interaction with materials enables improved estimation of the structure of the system under study. Access to NeXT is provided free of charge for peer-reviewed open literature research allowing researchers from industry, academia, or government laboratories to benefit from the measurement technique.

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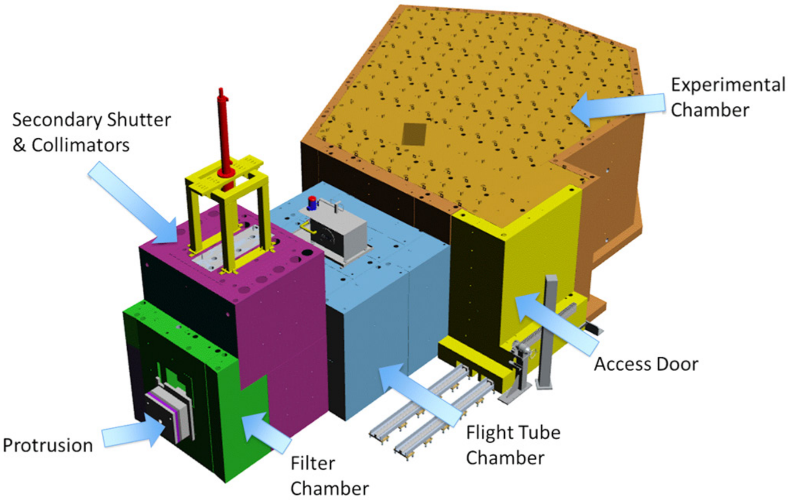
Neutron Radiography Activities in South Africa

Infrastructure Development:

The old South African Neutron Radiography (SANRAD) facility, located at beam port 2 of the SAFARI-1 nuclear research reactor, was operational from 1975 until 2013. The facility served the national and international community through the application of the various film techniques until 1996 when the first digital NRAD detection system was installed using the combination of scintillation screen, MCP and CCD technology. In 2003, SANRAD became the only NRAD facility at the time in South Africa, in Africa and southern Hemisphere equipped with a tomography capability. This was achieved in collaboration with



Dr Eberhard Lehmann and colleagues from PSI, Switzerland. Through an IAEA expert mission in 2005 by Dr Schillinger (TUM, Germany) and Pugliesi (IPEN-CNEN/SP, Brazil), a proposal on the total upgrade was accepted followed by a MCNP-X simulation completed in 2009 of the new INDLUVO facility by Dr Florian Gruenauer (Germany). Since then, Necsa's engineering efforts were hampered and a delay was experienced on the progress due to personnel change on the engineering side on the project as well as the intervention of the NNR on the safety classification of the casted shielding blocks. The Fukushima Daiichi nuclear disaster (2011) and the resulting seismic evaluation of all nuclear plants including SAFARI-1, with the additional INDLUVO shielding of 600 tons added to the beam port floor on the SAFARI-1 structure, had to be undertaken which placed another delay on the finalization of the design. However, major effort is currently underway to complete the processes for the upgrade towards a more versatile INDLUVO NRAD facility which entails filtering of the radiation beam into predominant thermal neutron, fast neutron and gamma-ray beams respectively. Ongoing activities for the past 4 years entails various engineering aspects, modelling, control and instrumentation, as well as required documentation as prerequisite for the National Nuclear Regulator to approve construction and implementation. Hot commissioning of the new facility is planned for end of 2020.

As South Africa is a country rich of fossils, the ongoing initiative is taking momentum in support of the Cultural Heritage community to implement chemical and mechanical fossil preparation laboratories at Necsa for the neutron and X-ray beam lines to be accessed and used in the non-destructive tomography analysis of breccia and fossil materials. The pilot chemical preparation facility is ready for the first test run in early 2019. The initiative is in collaboration with the South African palaeoscience community including the University of the Witwatersrand, University of Johannesburg as well as the Cultural heritage collections initiative of Department of Science and Technology.

Human Resource Development:

Although no local neutron radiography/tomography could take place since decommissioning of the old SANRAD facility in 2013, a user's office is implemented since 2015 to manage researchers using the micro-focus X-Ray tomography facility, a facility complementing INDLUVO. This Users Office is currently off-line but will be activated for online applications and management once the INDLUVO facility is operational and user ready.

Four of the five instrument scientists from the Radiography&Tomography section at Necsa pursued their PhD studies over the past years:

- Dr. Frikkie de Beer obtained his PhD from the University of North West, Potchefstroom in Engineering Sciences on 31st July 2018 entitled: "Neutron and X-ray Tomography Research Facilities for Applied Research in South Africa" which describes the design and development of such national facilities for both neutrons and X-rays at the South African Nuclear Energy Corporation SOC Ltd. (Necsa) and the subsequent building of capacity for research support to users of a number of disciplines. http://hdl.handle.net/10394/30900
- Mr. Lunga Bam has submitted in Dec 2018 his PhD in Geology at the University of Stellenbosch entitled: "Use of X-ray CT for the mineralogical and textural characterisation and analysis of iron ores with implications for mineral processing". It is envisaged that the study and research will continue using the new INDLUVO NRad facility for complementary knowledge generation and for Necsa to provide complete neutron and X-ray tomography services as analytical techniques to the geoscience research community and mining industry.
- Mr. Robert Nshimirimana is enrolled for PhD in Mathematics at the University of Pretoria entitled: "Optimization of radiography using multi-objectives particle swarm optimization" to be submitted early 2019.
- Mr. Mabuti Radebe, former Necsa colleague who left Necsa since April 2018, is enrolled at the University of the Witwatersrand, Johannesburg, for a PhD to be submitted to the faculty of Science entitled: "Establishment of Characterization Methods for Spatial Resolution of Neutron Digital Radiography and Tomography Setups" . Mr. Radebe's PhD study is an international contribution to address the global need to establish performance characterization criteria and methods including experimental and analysis protocols for digital neutron radiography and tomography instruments.

International Collaborations and Ongoing Research

The following international activities, other than attending the ISNR series of conferences, were undertaken whereby international neutron beam line facilities were utilised and collaborations with other institutes were established. To continue to enhance South African neutron radiography/tomography research and collaborations in positive manner while upgrading the SANRAD facility to a new INDLUVO facility the following interactions are recorded:

UK – ISIS

The Rutherford Appleton Laboratory (UK) has invited two Necsa scientists for collaborative research and training related experiment and data analysis at the ISIS pulsed neutron and muon source, which includes participating in the commissioning of the new neutron radiography facility (IMAT).

South Korea - KAERI

South Africa was invited by KAERI, Korea, under the SA-Korean bilateral agreement to conduct neutron radiography experiments using the beamline facility at HANARO research reactor on agriculture research, gave a presentation at the workshop on neutron radiography organized by KAERI and attended the 14th International Symposium on Characterization of Metals and Nanostructured Materials by Neutron and X-ray Synchrotron Scattering (NeXS 2018) in Korea.

USA - NIST

The progress in South Africa on the technology and utilisation of fuel cells is growing rapidly due to the beneficiation of Pt, an abundant natural resource in South Africa and the rapid growth of fuel cell technology in South Africa. In collaboration with HySA (Hydrogen

South Africa), a beneficiary and stakeholder of the Department of Science and Technology, beam time has been obtained during 2015 and 2018 at the NI of NIST, USA. Research has been conducted to understand and visualise electrolysis, the process when a fuel cell is operational in reverse. The long term goal is to establish a research capacity for fuel cell research at the new INDLUVO facility.

European Commission BrightnESS-2 program: European Spallation Source (ESS)

The South African Department of Science and Technology (DST) interacted through the regular meetings of the Group of Senior Officials (GSO) on Global Research Infrastructures, to which the European Commission nominated ESS as a pilot case study and an example of ESFRI project in order to provide insight to European best practices in terms of expanding global scientific and technical partnerships. The goal of the DST is to establish a bilateral collaboration framework between ESS and South Africa with Necsa and iThemba LABS to be the only neutron related national institutions involved with neutron research activities. The collaboration was approved for 2019 – 2021 and South Africa is engaged in Work Package-2 : "A strategy to deliver neutrons for Europe and beyond" as a precursor to long term collaboration with ESS. The only 2 neutron beam line facilities in South Africa are located at SAFARI-1. The diffraction (Dr. Andrew Venter) and radiography (Dr. Frikkie de Beer) sections are engaged to deliver on 2 workshops in South Africa with the aim to develop a plan / strategy for SA to become involved in collaboration with ESS with the ultimate goal to enhance current initiatives and create new interest in neutron sciences and technology in SA.

European Commission ERASMUS + Capacity-building in Higher Education: Bakeng se Afrika

Necsa is a partner in collaboration with 3 national universities (Univ Pretoria; Stellenbosch University; Sefako Makgatho Health Sciences University and 3 European universities (Univ of Bordeaux - France; Univ of Coimbra – Portugal; Catholic Univ Leuven – Belgium) from 2019 - 2021. The goal is to establish an online data server at Necsa for archiving 3D tomography data (X-rays and eventually also neutron 3D CT data) to be made available to the national and international research community through a proper management system and protocol. This will benefit inter alia the palaeoscience community in the long term to have access to 3D neutron and X-ray fossil data for research.

Hosting of a National Conference at Necsa:

Necsa is to host the 4th National Conference on Imaging with radiation (IMGRAD 2019) from 16 – 17 Sept 2019 at its venue at Pelindaba near Pretoria. This is the 4th bi-annual conference in the series preceding conferences held in 2013 at Necsa, 2015 at University of Stellenbosch and 2017 at University of the Witwatersrand in Johannesburg. The aim of the IMGRAD-series of conferences are to share knowledge and to bring together all experts (non-medical diagnostic) on micro-focus X-ray radiography/tomography, neutron tomography and Gamma-ray imaging in South Africa who utilizes these penetrating radiation techniques in many kinds of applications. IMGRAD2019 will create a platform for discussion of issues of national importance where penetrating radiation imaging technology makes a difference in society, particularly quality of living, and benefits the South African research community. Researchers and post graduate students have a platform where they can display their work and showcase research opportunities, possibilities and achievements. The non-destructive nature of penetrating radiation as probe being applied in various fields of applied sciences (e.g.: Geosciences; Anatomical Sciences; Engineering; Palaeosciences; etc) will be covered.

Frikkie de Beer

Review on conferences and workshops

WCNR-11

Conference

ANSTO, the Australian organization for nuclear science and technology hosted that meeting of the experts in modern neutron imaging this year in "early spring" with temperatures between 15 and 20 °C. Although the destination was quite far from most places of the world, more than 120 participants made the trip to "down under".

The request for oral presentations was so high, that for the first time parallel sessions were held on one day of the meeting. Almost all contributions were given in high technical and content quality. The best evidence was the high participation in all sessions, including the two poster session in later afternoon.

It was a clever decision made by the main organizer Ulf Garbe to use the lecture hall of the "Australian National Maritime Museum" for the conference, situated just in the bay of the Darling Harbor. Located in the middle of the vivid city of Sydney but accessible from all hotels on foot, a good technical infrastructure was provided.

With the neutron imaging facility DINGO at the research reactor OPAL, ANSTO is enabled to provide a competitive user program in neutron imaging for the region. Several highlights of recent studies at DINGO were presented during the meeting.

The conference has demonstrated clearly that neutron imaging is nowadays a well-established and promising technology with high potential for applications in different branches of science and in industry. Although the number of prominent strong neutron sources is declining (shutdown of BER-2 (HZB, Germany), Orphee (Saclay, France), several new installations for neutron imaging are on the way to be realized (ILL (France), Kjeller (Norway), Buenos Aires (Argentina), …) or recovered after shutdown phases (HANARO (South Korea), SAFARI (South Africa)) - and upgrades are on the way (INL (USA), CARR (China), HOR (Netherlands)).

Surprisingly, quite high interest came up for the imaging with fast neutrons. Obviously, the high penetration power of these neutrons make the technique quite interesting for inspections of very bulky objects. A key question is for better scintillator screens with more efficient light conversion and higher spatial resolution. For this purpose a "topical team" was formed to support further development.

Several techniques, started some years ago in a pioneering manner (tomography, grating interferometry, high speed imaging, imaging with resolution around 10 micro-meters, imaging with polarized neutrons) are now routinely established in a few labs and part of their user program.

The problem of data handling and analysis is valid on an increasingly high level since the acquisition rates are on the GByte to TByte range nowadays. In order to support the users in a most efficient manner, infra-structure and analytical tools have to be established more.

One highlight of the conference was a ship cruise in the harbor bay for the celebration of the conference dinner with beautiful views onto the famous Harbor Bridge and the Sydney Opera House at night. This was also the opportunity to hand over the certificates of the “ISNR Honorary Membership” to Jack Brenizer (USA), Yoshiaki Kiyanagi (Japan) and Eberhard Lehmann (Switzerland).

The decision for hosting the 12th World Conference on Neutron Radiography” was not easy. According to the rules of the ISNR, the participants have voted in a democratic manner before the current conference ends. Three candidate countries presented their offer: India, Japan and USA. The competition won Idaho National Laboratory (USA) and Aaron Craft was elected as the new ISNR president. We hope for another intense and successful meeting in 2022 in the American mountains.

Ulf Garbe (ANSTO)
Eberhard Lehmann (PSI)

Elections

At the end of each WCNR President, Vice-President, Secretary and a new Board of Members were elected. The day before voting the three candidates for President from India (Venkatraman Balasubramaniam), USA (Aaron Craft) and Japan (Yasushi Saito) had the opportunity to make a bid in five minutes presentations. The candidates for Vice-President, Secretary and Board Members were based on nominations during the first days of WCNR-11.

All ISNR members participating WCNR-11 had one vote for President, Vice-President and Secretaery, respectively, and up to 10 votes for Board Members.

The ballots were counted by Ulf Garbe, Dan Hussey and Thomas Bücherl. The counting was repeated two times to assure a correct result. In the case of the vote for President a third counting was performed, but the difference between first and second by only one vote was confirmed in each counting. The results are shown in the tables. The table with the results of the voting for Board Members shows several special features: First, Nikolay Kardjilov and Burkhard Schillinger, both from Germany, had equal votes, but only one candidate from Germany was allowed, as stated by the constitution. Nikolay Kardjilov, Member of the previous Board, withdrew. Thus Burkhard Schillinger was elected. Second, according to the number of votes Anders Kaestner was elected, but Pavel Trtik from Switzerland, too, had more votes and thus become the representative for Switzerland. Aaron Craft and Markus Strobl are elected for President and Vice-President, respectively, which do not count towards the Board Member limits for their countries. Third, there was only one candidate for Secretary.

Table 1: Results of the voting for President.

Rank	Name	Country
1	Aaron Craft	USA
2	Yasushi Saito	Japan
3	Venkatraman Balasubramaniam	India

Table 2: Results of the voting for Vice-President.

Rank	Name	Country
1	Markus Strobl	Switzerland
2	Michael Schulz	Germany
3	Joseph Bevitt	Australia

Table 3: Results of the voting for Secretary (only one candidate).

Rank	Name	Country
1	Thomas Bücherl	Germany

Table 4: Results of the voting for Board Members (only elected and canceled candidates are shown in the order of votes).

Nr	Name	Country	Remark
1	Winfried Kockelmann	United Kingdom	
2	Dan Hussey	United States of America	
3	Burkhard Schillinger	Germany	Burkhard and Nikolay had equal votes; Nikolay withdrew
-	Nikolay Kardjilov	Germany	
4	Anton Tremsin	United States of America	
5	Pavel Trtik	Switzerland	
6	Takenao Shinohara	Japan	
7	Jean Bilheux	United States of America	
8	Floriana Salvemini	Australia	
-	Anders Kaestner	Switzerland	only one member from Switzerland
-	Aaron Craft	United States of America	elected for President
9	Yasushi Saito	Japan	
-	Markus Strobl	Switzerland	elected for Vice-President
10	Frikkie de Beer	South Africa	

Short curriculum vitae (CV) of all new Board Members are presented in the section "News from the Board".

Thomas Bücherl

Ad-hoc meeting „Fast Neutron Imaging (FNI)"

At WCNR-11 the topic "Fast Neutron Imaging (FNI)" gained high interest. An "ad-hoc" meeting with about 20 persons participating, was initiated. The minutes of that meeting are available via our webpage (http://www.isnr.de/index.php/information/fast-neutron-imaging-fni).

It was decided to hold a dedicated meeting in 2019 to define the current state of knowledge, to look on technical improvements (mainly scintillator technology) and further applications. Since the number of facilities is quite low, the foreseen audience will be not more than 20 persons.

The MLZ/TUM experts accepted to take over the organization and hosting part of the meeting to be scheduled for the 2nd part of 2019 in Garching next to Munich, Germany.

Thomas Bücherl

News from the Board

Two Meeting of the Board of Members took place in 2018, one on the day of the welcome reception of WCNR-11, the second on the penultimate day of WCNR-11. The main results are summarized next.

New Constitution adopted

At the first Board Meeting discussion on the new Constitution, being on-line for more than a year for comments, took place. Finally the new Constitution was accepted unanimously by vote of the Board of Members. The Board gave props to Les Bennett and Markus Strobl for their work and closed the Task Group "Constitution" (02.09.2018).

Guidelines for applying for hosting WCNR and/or ITMNR adopted

In addition to the revised Constitution Guidelines for applying for hosting WCNR and/ or ITMNR were worked out by the Task Group "Constitution" with the aim to make the application, pre-selection and voting of candidates as transparent and traceable as possible. The resulting Guidelines were discussed at the first Board Meeting and accepted unanimously by vote of the Board of Members.

Name of ISNR changed

Discussions on the results of the Task Group "Terminology" and the name topic, which have been published on the ISNR webpage already in Beijing at ITMNR in 2016, were followed by extensive discussion on the terms "radiology" versus "radiography". As a result the name "International Society for Neutron Radiology" was changed to "International Society for Neutron Radiography" . This was accepted unanimously by vote of the Board of Members.

Logo adopted

As a result of the changed name of ISNR the logo of ISNR was adapted by Dan Hussey.

Revised logo of the International Society for Neutron Radiography

Hassina Bilheux appointed as Deputy President

As stated by the constitution, the President of ISNR can appoint a deputy immediately following the election. Aaron Craft asked Hassina Bilheux (Oak Ridge NationalL Laboratory) and she has accepted the appointment as Deputy President and is happy to help with planning WCNR-12. Aaron is confident that together with her contributions, the contributions of other board members together with event planners from his institution WCNR-12 will be a success.

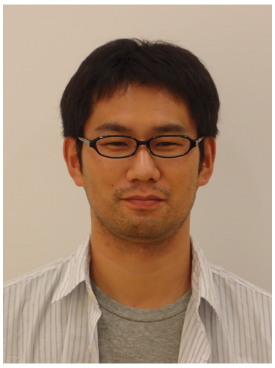
New Board Members

Aaron Craft is an R&D Scientist in the Advanced Post-Irradiation Examination Department at Idaho national Laboratory (INL) where he serves as the principle investigator on numerous projects involving x-ray and neutron radiography and tomography. He is also the group lead for the Beamline Examinations for Applied Materials Science (BEAMS) workgroup, a team of nine colleagues working on neutron and X-ray examination techniques. Dr. Craft received his BS and MS degrees in Nuclear Engineering from Missouri S&T in 2007 and 2009, respectively, and his PhD in Nuclear Science & Engineering from Colorado School of Mines in 2013. In his PhD work, he designed and installed an inexpensive neutron beam at a 1 MW research reactor and demonstrated its capabilities using a micro-channel plate detector and traditional neutron radiography with film. His work at INL focuses on developing digital imaging technologies for examination of highly-radioactive irradiated nuclear fuels, but the BEAMS workgroup is also expanding the range of applications of these techniques at INL to include geology, archaeology, paleontology, industrial research, energy storage, and material processing. Dr. Craft is also an active member of the American Society for Testing and Materials (ASTM) committee for neutron radiology and X-ray methods. He is leading development of new standards applicable to digital neutron radiography techniques, for which there are no existing standards, and is also actively involved in ASTM committees for terminology and X-ray computed tomography.

Jean Bilheux obtained his PhD in Physics from the University of Versailles-Saint-Quentin France in 2003. After a short post-doc at the Physics division in Oak Ridge he moved up the hill to the freshly built Neutron Spallation Source where he moved his focus from hands on experiment to computing development. After playing with IDL and Matlab for a few years, he decided to focus on python for implementing tools and notebooks to instrument staff and users. His main goal is to facilitate the life of the users coming to the neutron imaging beam lines by providing easy to use and intuitive tools. Outside works, Jean loves spending his time in the air (gliders, single engine planes and paramotor), running after a soccer ball or hitting a small yellow one. Jean is married to Hassina (instrument scientist on the neutron imaging beam lines at SNS and HFIR) and father of 2 children.

Floriana Salvemini is a scientist at the Australian Centre for Neutron Scattering |ANSTO, Australia. Since 2014 she is co-responsible for the operation and development of the neutron imaging instrument DINGO at the OPAL research reactor. She received a PhD in Applied Physic from the University of Florence in 2014. During her PhD she was based at the Institute of Complex System (ISC) – National Research Council (CNR) in Sesto Fiorentino where she carrying out her research on the development of methodological approaches for non-invasive characterization of metal artefacts of historical, archaeological and industrial interest, through neutron diffraction and imaging techniques. In 2014 she joined ANSTO during the commissioning of the neutron imaging instrument, and since then she is actively involved in the establishment and broadening of the user community. Her scientific interest includes the investigation of Heritage materials through a non-invasive approach by means of neutron-, synchrotron- and accelerator-based techniques. From 2015 she is the coordinator of the scientific research project on Cultural Heritage at ANSTO.

Burkhard Schillinger is a senior scientist and instrument responsible at the Heinz Maier-Leibnitz Zentrum at the FRM II reactor and faculty for physics E21 of Technische Universität München, Germany. He developed one of the first cooled CCD camera neutron detectors for his Masters Degree in 1993, and produced the first 3D neutron computed tomography in Europe in 1996 during his Ph.D. work. He has participated in the development of many neutron imaging techniques like stroboscopic imaging. He built several imaging facilities at the old FRM reactor in Munich, and developed and built two generations of the ANTARES facility for neutron imaging at the FRM II reactor. He advised many neutron imaging facilities in the world and initiated the NEUWAVE workshop series on neutron wavelength dependent imaging.



Takenao Shinohara is a senior scientist at the J-PARC Center of Japan Atomic Energy Agency, Japan. He is responsible for the energy-resolved neutron imaging system RADEN instrument at the Materials and Life Science Facility (MLF) of J-PARC. He received his PhD degree from Keio University in 2005. In his PhD work, he studied magnetic properties of nanoparticles and found out the ferromagnetic ordering in the surface of non-magnetic pure metallic nanoparticles. From 2003 he worked at RIKEN as Post Doc researcher, and developed neutron optical devices, such as neutron lenses and neutron prisms based on a perfluoropolymer. After he moved to JAEA in 2006, he worked as a member of the small angle neutron scattering instrument group, designing and building the optical system of SANS instrument at J-PARC. Since 2010 he is working on pulsed neutron imaging and has led the design and construction work of the RADEN instrument. His scientific interests include magnetic imaging using pulsed polarized neutrons, magnetic materials, and development of neutron techniques and devices.

Pavel Trtik received his diploma from the Faculty of Civil Engineering, Czech Technical University in Prague, Czech Republic. After receiving his Ph.D. degree from Advanced Concrete & Masonry Centre at the University of Paisley, Scotland, he worked as postdoc at ETH Zurich and research scientist at Swiss Federal Laboratories for Materials Science and Technology (EMPA) in Dübendorf, Switzerland. Throughout this time, his research interest was focused on the construction (in particular, cement-based) materials and has been a frequent user of synchrotron and neutron imaging facilities. In 2012, he joined the Neutron Imaging and Activation Group (currently Neutron Imaging and Applied Materials Group) in Paul Scherrer Institut (PSI), Switzerland, where he has led the 'Neutron Microscope' project, in which the user-facility for the high spatial resolution neutron imaging (sub-5 micrometres) has been developed. At PSI, Pavel's research interests naturally broadened to the fields of the high-spatial and high-temporal resolution neutron imaging on the instrumentation side, and to the areas for which these techniques provide useful tools (e.g. nuclear materials, etc.) on the material science side, respectively. In early 2018, he was appointed a beamline scientist at NEUTRA beamline. Apart from the scientific position at PSI, Pavel is also linked with his 'alma mater' - the Czech Technical University in Prague - where he holds a position of Associate professor.

Hassina Bilheux obtained her Ph.D. in Physics from the University of Versailles-Saint-Quentin-en-Yvelines, France, in 2003. Her Ph.D. research was performed at the Physics Division of the Oak Ridge National Laboratory on electron cyclotron resonance ion sources. After a post-doctoral research appointment at the Physics Division, Dr. Bilheux joined the ORNL Neutron Sciences Directorate in 2005. She is responsible for neutron radiography and computed tomography capabilities at both the Spallation Neutron Source and the High Flux Isotope Reactor. Her expertise includes neutron technology development and image processing and analysis. Dr. Bilheux is interested in applying advanced imaging techniques in the fields of materials science (such as energy and additive manufacturing), geosciences and biological applications at the Spallation Neutron Source VENUS imaging beamline (to be operational in 2022).

Anton S. Tremsin is a Full Research Scientist at Space Sciences Laboratory (SSL), UC Berkeley. He received his PhD in 1992 from Russian Academy of Sciences and his M.Sc. in 1898 from Moscow Institute of Physics and Technology, then joined X-Ray Astronomy group at Leicester University in the UK as an Honored Royal Society Postdoctoral Fellow in 1994 and continued his research at Space Sciences Laboratory from 1996 till present date. After joining the Experimeental Astrophysics Group at SSL Dr. Tremsin has been working on the development of high resolution instrumentation for detection of photons/electrons/ions/neutrons for very diverse fields including space-based astrophysical instrumentation, detectors for synchrotron and neutron sources, fast imaging devices with sub-ns timing resolution for biomedical research, geological sciences, and many others and was a PI on multiple projects funded by NASA, US Department of Energy, US National Science Foundation and others. At the present time Dr. Tremsin leads the development of novel techniques for non-destructive testing with neutrons in materials science, nuclear energy, synchrotron instrumentation and other fields. Several detectors built at the University of California at Berkeley have been established over recent years as user instruments at several neutron imaging facilities, including ISIS spallation neutron source in the UK, Oak Ridge and Los Alamos National Laboratories in the USA and recently Paul Scherrer Institute in Switzerland.

Task Groups

TG "Constitution"

The Task Group "Constitution" has completed work with the unanimously decision of the Board of Members at the Board Meeting in Sydney, Australia, September 02, 2018, on the draft constitution, published in the NR Newsletter (No. 12, March 2017) and on the ISNR webpage.

The Board of Members expressed their special thanks to Les Bennett (convener) and Markus Strobl for their work on the revised version of the constitution and closed the Task Group.

TG "Terminology"

The published compilation on terminology for neutron imaging in the NR Newsletter (No. 12, March 2017) and on the web was put to the vote during the Board Meeting in Sydney, Australia, September 02, 2018. With one abstention from voting it was accepted and is now published on the ISNR-webpage (http://www.isnr.de/index.php/information/activities/tg-terminology). It covers High Level Terms and Context for Neutron Radiology, Neutron Radiography and Neutron Imaging and gives interesting insight in the etymology on the individual terms.

All members of ISNR are encouraged to use these definitions in their publications and presentations to avoid misunderstandings and disputes sometimes caused by different interpretations of terms.

The Task Group (convener Markus Strobl) will continue work now defining more specific terms. New collaborators are welcome!

A comprehensive scheme for neutron imaging classification

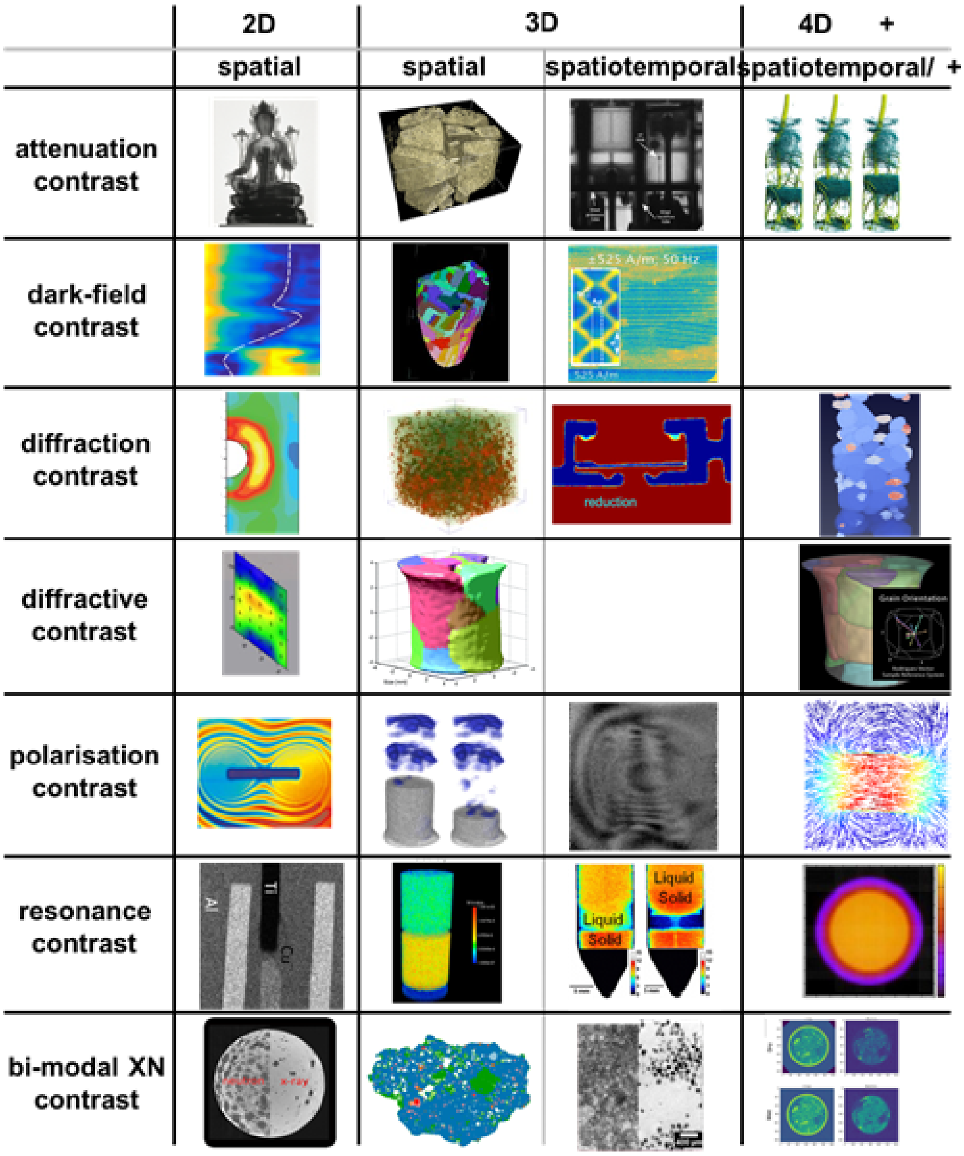
The fast development of neutron imaging and imaging methods in this millennium has lead to ambiguous terminology and presentation of our abilities and methods. As ISNR we have reacted and have given ourselves a well-defined terminology for the first time for the very needs of the neutron imaging community, but also regarding the context with other relevant methods and user communities. With the definition of high level terms as presented in this issue we have made a good start. However, in particular methodical developments have lead to the situation where a simple hierarchical classification and terminology is not applicable anymore to describe specific measurements and techniques. We therefore work on a modular list of concise terms and potentially rules to describe specific measurements and the methods applied on different levels of detail. On a relatively high level I would like to here propose a classification scheme based on the most important characteristics of our measurements and results, namely (i) the dimensionality of resolution in time and space (and potentially other dimensions) as well as (ii) the specific contrast modality. This leads to a two dimensional scheme, which is represented below and populated with pioneering and illustrative examples of corresponding measurements. A few fields will stay still empty as applications have not or could not have been realized or communicated yet.

Markus Strobl (PSI)
markus.strobl@psi.ch)

TG "Characterization and Standardization"

The ISNR Task Group (TG) for Characterization & Standards was well-served under the leadership of Nikolay Kardjilov with significant contributions from Anders Kaestner. They developed a number of phantoms to measure spatial resolution and engaged the International Atomic Energy Agency to pursue round robin testing of some prototype test objects. Another round robin test series has begun for a new set of samples based on this work. Drs. Kardjilov and Kaestner will continue working on these efforts with Aaron Craft, which will now lead this TG and integrate the existing efforts with the work he is pursuing through the American Society for Testing and Materials (ASTM). Work is progressing and developing at a rapid pace.

Aaron Craft just returned from the bi-annual ASTM meeting for Committee E07 on Nondestructive Testing, where he and some other colleagues serve on the X-ray and neutron radiology committees. The E07.05 Committee on Neutron Radiology is developing a new standard to measure basic spatial resolution with a line-pair gauge that will be applicable to neutron radiography with both film and digital methods. A first prototype was fabricated and tested through a round robin series that included seven facilities, the results of which were reported in WCNR-11. Based on the lessons learned from these first tests, a second prototype gauge has been designed. Once fabricated, the new prototype gauges will be distributed for a second series of round robin testing. If you are interested in participating in the round robin testing of the new gauge, please contact Aaron Craft.



References from left to right, top to bottom:

- *Courtesy of E. Lehmann; A. Kaestner et al. Solid Earth, 7 (2016) 1281; B. Schillinger et al., Physica B 385–386 (2006) 921; C. Toetzke, et al. Sci. Rep. 7(1) (2017)*
- *R. P. Harti et al. Sci. Rep. 7:44588 (2017); I. Manke et al., Nat. Com. 1, 125 (2010); R. P. Harti et al., Sci. Rep. 8, 1 (2018);*
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- *https://next-grenoble.fr/ ; A. Fedrigo et al., J. Imaging 4, 72 (2018); F. Sun et al., Applied Surface Science 399 (2017) 359; courtesy of A. Kaestner;*

While at the ASTM Meeting, Aaron Craft also discussed with colleagues there about some of the concepts developed by Anders Kaestner, including: a Siemens star, an edge specimen for calculating MTF, and a discrete resolution device for computed tomography (CT). Aaron also discussed with experts the Fourier Ring Correlation that has been proposed by Pavel Trtik for determining spatial resolution. The Siemens star and the edge specimen for MTF are useful samples for determining spatial resolution, and the ASTM Committee is interested in developing standards for neutron radiography based on these objects.

A standard for MTF currently exists in E1695 for X-ray CT, and colleagues from the ISO Community are working with the ASTM community to update this standard. Unfortunately, there is not an ASTM standard through E07.01 (X-ray method) for measuring MTF using an edge specimen in simple 2D radiography, likely due to lack of consensus for the process to determine the presampled edge spread function. Fortunately, the E07.05 (neutron method) committee generally develops consensus more readily than the larger X-ray committee, and consensus is the most important factor when developing new standards. It may very well be that the neutron community develops a standard for measuring MTF for 2D radiography before the X-ray community.

Aaron Craft presented some material written by Anders Kaestner on the discrete resolution CT device and by Pavel Trtik on Fourier Ring Correlation to experts on the X-ray and neutron committees. They gave some general guidance for designing the CT device, but were interested in the approach and encouraged us to develop these samples further. They were excited to learn more about the Fourier Ring Correlation approach, which seems to be a superior way to measure spatial resolution to other techniques because it does not require a separate CT measurement of a test device. Altogether, some of the X-ray community are interested to test the CT device once they are fabricated.

The ASTM E07.05 Committee on neutron radiography also updated existing ASTM standards. A new Beam Purity Indicator has been developed that uses gadolinium wires instead of cadmium wires, removing the use of this toxic material that complicates its use in some countries. The revised documentation is headed to ballot. Additionally, ASTM E545 is being updated to clarify language in Section 10 about use of a Process Control Radiograph for cases where the beam purity indicator and sensitivity indicator are not in every radiograph, which is necessary for some users with very large test objects or other restrictions.

Terminology may not be the most attractive area to some in the community, but consistent application of terminology is important for fostering a strong and vibrant field that can exchange ideas broadly and clearly. Aaron Craft is also serving on the E07 subcommittee for the Glossary (ASTM E1316, Standard Terminology for Nondestructive Examinations), where terminology issues are worked out in excruciating detail. Aaron worked with the committee on seven new terms for X-ray and general-digital imaging, six of which will be balloted in the coming months. Aaron is planning to develop some new terms to be included in the Glossary, Section H. Neutron Radiologic Testing (NRT) Terms. Aaron plans to wait to address common but controversial terms such as neutron radiology/radiography/imaging until consensus is better developed within the international neutron community. For now, Aaron plans to incorporate into the Glossary some common terms and some of the terms investigated in the thorough report developed by the ISNR TG for Terminology led by Markus Strobl, which is also available on the ISNR webpage. The glossary needs to be updated to include terms related to digital methods and should follow much the same way the X-ray community has adapted to include digital methods.

All these efforts are progressing well. It should not be too long before standards exist for digital methods and beyond...

Aaron Craft

Task Group "Computational Imaging" - ISNR – Software Report January 2019

Processing neutron data – We mostly all do the same things

Introduction

Today, it is hard to perform a successful neutron imaging experiment without using computational methods to process and analyze data. In particular, many experimenters expect to obtain quantified information from the image data. Many neutron imaging users identify themselves neither as image processing experts nor as programmers. These are, however, the skills needed to perform an analysis of imaging data from scratch. Fortunately, there are already many open source and commercial tools developed to perform a significant part of the analysis task.

The computational methods in use can roughly be divided into early and specific processing. The early processing is often referred to as reduction and involves operations common for most experiments, e.g., normalization, noise and artifact reduction, and reconstruction. The specific processing which is based on reduced data aims at obtaining the information needed to make conclusions about the observed sample or process. The reduction steps require efficient tools that are capable of handling large data quantities with little interaction. The specific processing has a different character as it to some extent is of a more explorative nature based on a collection of operations. It is harder to generalize these workflows, in particular for the final stages as these are specific to each experiment category. We recommend using python for the specific analysis due to its flexibility and availability of many great libraries for data analysis and in particular image processing. These libraries provide the building blocks for specific analysis meeting the requirements of each experiment.

Open source development

Over the years, facility software development initiatives have been maintained with different levels of effort to provide workflows that solves the processing tasks at hand. This has resulted in a great variety of tools the imaging research community benefit from when they visit different facilities. Our goal is to provide a general collection of open source tools that can be used interoperably at different neutron imaging facilities. This reduces the redundant development efforts to provide the same tools essentially. We maintain a GitHub organization (https://github.com/neutronimaging) containing our development repositories and invite new developers to join us to increase the visibility of their efforts and contribute to our software tools.

Training

An important consideration about developing tools for the analysis of experimental data is to make sure that these tools can actually be used by the means of manual and training material. We are working on keeping our user manuals up to date and new this year, and we started to produce tutorial videos showing how to use these tools. A further good way to introduce workflows to the community is to provide demo sessions during schools and workshops. A major event in neutron imaging community agenda is the quadrennial World Conference on Neutron Radiography that was held in Sydney, September 2018. Before the conference, a school was held to introduce topics like CT reconstruction using MuhRec and how to work with Python to analyze neutron imaging data.

Data

Developing algorithms to solve different problems in imaging highly depends on having data available. In general, we could use any data but to be able to compare the efficiency of a new algorithm it is beneficial to use the same data. Not only development relies on data, but also training sessions and tutorials benefit from data that illustrate a workflow. Therefore, we propose to organize a database with links to well-described and citable data. Several free services are allowing you to upload data and obtain a DOI. Please, contact us if you have a data set you think would make sense to highlight in this context.

Conclusions

We aim to provide a collection of interoperable open source tools for analyzing neutron imaging data that reduces the diversity of tool a user needs to learn to work with experimental data obtained at different neutron imaging facilities. Training sessions with dedicated calibration data are essential in this mission.

A. Kaestner[1], J. Bilheux[2], C. Carminati[1], H. Bilheux[2], J. Lin[2], Y. Zhang[3], and M. Strobl[1]
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Paul Scherrer Institut, Villigen, Switzerland
[2]Neutron Sciences – ORNL, Oak Ridge, USA
[3]Nuclear Sciences & Engineering – ORNL, Oak Ridge, USA

Task Group 'Neutron Imaging at small and low intense neutron sources'

Digital neutron imaging systems have demonstrated improved efficiency by many orders of magnitude compared to film based techniques, used in the past. This higher flexibility and advantage has been used not only at the most powerful neutron imaging stations to develop more sophisticated methods, but also to bring weak sources into the business of neutron imaging.

Since neutron imaging generally has been proven a very useful universal tool for material studies, there are more and more new neutron sources which will have this technique in a "day one" instrument. Examples are ODIN at ESS, the research reactors in Argentina, Jordan and Brazil, the "high brightness source" of FZ Jülich. In addition, we have upgrade programs in Norway, South Africa, USA or South Korea which take into account modern neutron imaging systems. The reactor with lowest power is the AKR-2 at TU Dresden, Germany, where NI attempts were made successfully.

On the detector side, there are some different approaches visible:

1. Copy of proven systems (on a commercial level) using the know-how of established teams. Such an example is the MIDI-setup at PSI which has 4 in-house copies under operation and five ones delivered to different labs world-wide.

2. There is the company "NeutronOptics" operated by A. Hewat, Grenoble, which provides the same technique and devices in principle, focused on low prices. However, flexibility and resulting image quality is not the same than in the previously mentioned approach. Several systems have been delivered to developing countries, sometimes with support from IAEA.

3. Since the technique of a camera based neutron imaging detector is relatively simple in principle, there are also "homemade" systems with inexpensive cameras with quite useful performance. The camera market is still under development and future systems have to be checked whether they are adequate for neutron imaging.

The Task Group should be aware about all these initiatives and can give guidelines for best suitable options in the particular cases. The major components: neutron beam properties, beam line layout and budget have to be judged in the optimal manner.

The initiatives for new neutron source like that in FZ Jülich should be followed with interest with the aim to install the best possible imaging facility with modern techniques and challenging applications. This is important since the shut-down of prominent reactor sources in Germany, France and other countries will limit the access to neutrons for imaging in the near future.

Eberhard H. Lehmann

NIST remembers Muhammad Arif

Muhammad Arif, a NIST Fellow and former leader of the Neutron Physics Group in PML's Radiation Physics Division, died after an extended illness on Nov. 27 at the age of 64. Arif — as he was always called — was born in Madaripur, Bangladesh, as the first of four children. He attended Dacca University in Bangladesh, where he excelled in physics. He received a scholarship to study physics in the United States at Ohio University, where he

Arif on the train to explore the Fukuroda Falls during the NEUWAVE-7 workshop held in Mito City, Japan in 2015. Photo credit: Burkhard Schillinger.

earned his M.S. degree. He received a Ph.D. at the University of Missouri in 1986 in the nascent field of neutron interferometry. (Interferometry involves the superimposing of electromagnetic waves — or waves composed of matter such as neutrons — in order to extract information from the resulting wave interference.)

Arif joined NIST in 1988 as an NRC postdoctoral fellow doing precision X-ray work in Dick Deslattes' Quantum Metrology Division [1]. He frequently commented that he felt privileged to work alongside Deslattes in improving the precision of the X-ray optical interferometer known as XROI. At the time, XROI was one of the flagship projects of the Quantum Metrology Division.

Upon completion of his postdoc, Arif joined NIST's Neutron Interactions and Dosimetry Group, where his primary research focus was the construction of a state-of-the-art neutron interferometry station in the first guide hall of what is now the NIST Center for Neutron Research. Neutrons of sufficiently low energy begin to display wave-like behavior due to quantum mechanics; for this reason, experiments and techniques (including interferometry) typically used to study light waves and X-rays also have applicability for neutrons. Arif helped to pioneer neutron interferometry in a variety of areas, including tests of quantum entanglement [2], coherence restoration in quantum information, and matter-wave optics [3]. Arif played the leading role in the creation of the Neutron Interferometry and Optics Facility (NIOF) [4] in 1992, and to this day it is arguably the premier neutron interferometry facility in the world.

The scientific output of the NIOF is prodigious and spans many aspects of physics — and Arif was its tireless champion. He demonstrated the Aharonov-Casher effect with neutrons [5], which experimentally verified quantum non-locality [6]. Other notable achievements include his observation of the Fizeau effect [7] for neutrons, neutron scattering in a non-inertial reference frame [8], and a motion-induced phase shift in neutron scattering.

Arif climbing the Great Wall of China during the 2016 International Topical Meeting on Neutron Radiography in Beijing. Photo credit: Thomas Bücherl.

As improvements to the NIOF were made over the years, it became possible to use interferometry to make precision measurements of the neutron scattering length [9] of silicon and a number of low-mass isotopes. His design of these experiments was a tour de force requiring precise measurements of parameters such as isotopic purity, pressure, thickness, and neutron wavelength.

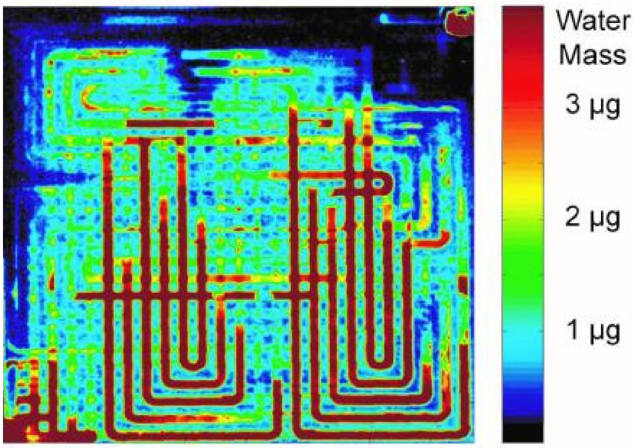
“Arif would never give up on an experiment when it didn’t work the first time,” recalls Arif’s longtime NIST colleague David Jacobson. “He knew that all groundbreaking experiments require multiple attempts before succeeding.”

Late in the 1990s, Arif realized that neutron imaging could make a substantial contribution to the development of hydrogen fuel cells [10] by providing images of the water and hydrogen within an operating fuel cell. To prove this, in 2002 he and his colleagues constructed a demonstration neutron imaging station able to take rapid time-lapse radiographs [11] of the inside of operating fuel cells.

“Arif loved to tinker with new gadgets,” says physicist Dan Hussey. “His office had several precision instruments from bygone eras — pressure meters, theodolites [12], and the like. This fascination with instrumentation parlayed into Arif’s focus on building novel neutron imaging detectors. The first of those detectors, built in 1996, was by current standards pretty limited, but it was able to reach 50-micron spatial resolution and was used to make the first measurement of the water concentration from anode to cathode in an operating fuel cell. He pushed to achieve the first real-time imaging detector, with 30 frames per second (neutron movies!). He also formed partnerships with industry to create a vastly improved detector to reach 13-micron spatial resolution. These were vital to the neutron imaging of hydrogen fuel cells.”

His vision for neutron imaging resulted in a second premier facility for the United States: the NIST Neutron Imaging Facility [13]. Neutron imaging made a huge impact in the fuel-

Posing in front of an experimental General Motors car powered by a hydrogen fuel cell rather than a gasoline engine: From left, Eli Baltic, Arif, David Jacobson and Dan Hussey. This team of NIST researchers collaborated with GM on neutron imaging of hydrogen fuel cells over a period of more than 20 years. Photo credit: David Jacobson



Fuel-cell image from NIST's first neutron radiography experiment in collaboration with GM. It shows that the anode channels (shown in red) were flooded, despite the water being produced on the cathode — a big surprise, but neutrons don't lie! Image credit: Jon Owejan

cell community. For the first time, researchers had a way to peer inside a fuel cell and see where the water was forming. Jacobson recalls that "Arif was fond of telling folks in this scientific community that `Neutrons don't lie.' Many were shocked that they had made so many mistakes in the design of their fuel cells, and the neutron images showed them exactly where they made the mistakes."

In addition to the imaging of fuel cells, Arif's neutron imaging technique was used to look inside a myriad of other systems, such as industrial casting processes, lithium-ion batteries, and biological specimens. The subsequent rapid development and successes of neutron imaging techniques led to NIST's construction of a significantly upgraded thermal neutron imaging facility in 2006 and a cold-neutron imaging facility in 2015. The NIST neutron imaging program realized a series of important technical advances that recently culminated in a new record resolution for neutron imaging of 1.5 microns.

Arif became leader of the Neutron Physics Group in 2003 and remained in the position until his illness forced him to give it up in 2017. The group flourished under his leadership, achieving world recognition not only in neutron interferometry and imaging, but also in neutron metrology and in using neutrons to carry out fundamental tests of the Standard Model [14] of particle physics. In all these areas of research, he was a tireless advocate for NIST and the importance of its mission for U.S. science and commerce.

He received numerous awards and accolades during his career, including a Department of Commerce Gold Medal Award, two NIST Bronze Medal Awards, the Arthur S. Flemming

Award, an R&D 100 Award, and a Department of Energy R&D Award. He was elected a Fellow of the American Physical Society and of the Washington Academy of Sciences, and in 2014 he became a NIST Fellow.

Arif's passions in life extended beyond physics. Of all things, he loved spending time with his daughter. He also enjoyed being in nature and traveling to many destinations, visiting over 25 countries in his lifetime. Among his favorite places to travel were Switzerland, Japan and Hawaii.

His extensive knowledge made him an excellent partner in conversation and a trusted source of guidance in matters beyond science. Those who knew him well respected his nuanced perspectives on current events and his pragmatic approach to problem solving. He had a love of gardening, kayaking, studying airplanes, dining out, tinkering with technology, all things Star Wars (as any visitor to his office could attest), and elephants. He will be remembered by friends and colleagues for his gentle personality, infectious sense of humor, and good will toward others.

Arif is survived by his daughter Sabrina, wife Mary, mother, and two brothers and a sister.

In the mountains of Switzerland while attending 2014 World Conference on Neutron Radiography: Arif (center) with his Neutron Physics Group colleagues Dan Hussey (left) and David Jacobson. Photo credit: Dan Hussey

References

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By Jeffrey Nico, Leader of the Neutron Physics Group in PML's Radiation Physics Division and Scott Dewey, Physicist in the Neutron Physics Group

Upcoming conferences and workshops

NeuWave10 2019

NEUWAVE-10

The next NeuWave meeting will taking place 26-29 May 2019 at Paul Scherrer Institut in Villigen, Switzerland.

Details can be found on the NeuWave-10 workshop page on Indico at https://indico.psi.ch/conferenceDisplay.py?ovw=True&confId=6899

Please note that it is intended to return to the well thought initial format of the NeuWave workshops initiated by B. Schillinger, having less presentations and more time to discuss. Details are still considered on how to best enable this, but certainly it is considered to have a poster session, to thus also enable attendance of colleagues without an oral presentation. We strongly encourage presentations to be summarized per group, or at least significantly different topics per group.

Details of the social program are yet to be fixed, but as usual we will start with a walking discussion on Sunday 26th May in the surroundings of PSI.

The scientific program shall last till Wednesday 29th May early afternoon. Afterwards there shall still be opportunity to visit our instruments and installations.

Please do not hesitate to contact the organizers in case you have any questions.

In the name of the organizing committee
R. Bercher, A. Kaestner, C. Carminati, E. Polatidis, M. Morgano
Markus Strobl

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

FNI-1
First Workshop on Fast Neutron Imaging
autumn 2019, TU München, Garching, Germany

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

Other Conferences

TN-2019
II Argentine Conference on Neutron Scattering
09.-10 May, 2019, Buenos Aires, Argentina

ICTMS 2019
International Conference on Tomography of Materials & Structures
22-26 July 2019 | Cairns, Australia
http://ictms2019.org/index.php

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

Tosca
Tomography for Scientific Advancement, 6 - 8 March 2019 in Florida, USA
https://www.rms.org.uk/discover-engage/event-cal-
endar/tosca-north-america-2019.html
(usually includes neutron tomography contributions)

... 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.

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