International NR Newsletter

No. 9, December 2013

International Society for Neutron Radiology

(www.isnr.de)

NEUWAVE-5: Group foto of the participants – remarkable pillows were set!

Content

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Editorial

As a year draws to its close one is overwhelmed by reviews of the year. There are private ones like Christmas letters send to relatives and very close friends and there are public ones like in newspapers and in the increasing number of TV shows. While the first are of real relevance for some persons, the latter mainly aims in showing all the adversities and catastrophes of the year (as tragic as they were), thus giving one the impression that one has survived only by fortunate coincidence.

Nethertheless I also will bother you with a brief review of the year 2013 from the point of the International Society for Neutron Radiology (ISNR). Fortunately I must not start with a report on any sad news.

In 2013 two main events within the field of ISNR took place: NEUWAVE-5 (the fifth workshop on NEUtron WAVElength dependent Imaging) and NINMACH 2013, a new conference bringing together neutron methods and archeology and cultural heritage. You can read reviews on both meetings in this newsletter.

When having a look to the website of our society (www.isnr.de) you will probably notice that it has changed in look and content. The reason for this was an external attack of the site, which fortunately was recognized by the provider. As a result the websites were locked for some time and I decided a completely new set up taking into account some of your suggestions. It is not complete, yet, and some functionality is still missing (e.g. the search property on the list of members). It will still take a lot of time and work to complete it and I apologize for the delay. All contributions and comments are still highly welcome and will be considered, if possible.

A "hot topic" this year was and still is the terminology used by our community. In several publications of the last years the term *neutron imaging* showed up, while the *neutron radiography* seemed to be eschewed. What is the reason for this? A radiograph performed in the way as in the last years should be still a radiograph, shouldn't it? Why changing the terminology? This only resulted in some confusion and already had given some sleepless nights to some of our members. So what is meant by *neutron imaging*? In extensive discussions we tried to set up a draft definition to answer this question: *The term neutron imaging summarizes all advanced techniques using neutrons as a probe which are currently under development and not yet certified for industrial and commercial use*. Taking into account this definition and the definitions used for the other terms (see www.isnr.de/index.php/neutron-radiology/terminology) we can overcome the confusion shown up this year. But it is essential that both, authors and referees, act on the same base. This might be the list of terms as stated on our webpage and which has to be extended and / or specified further. This will probably be a topic for the upcoming WCNR-10 in Grindlwald, Switzerland, next autumn. As the organization of the World Conference of Neutron Radiography (WCNR) is one of the main purposes of the ISNR, it is THE event of our community in 2014 and I hope that many of you will be able to join it.

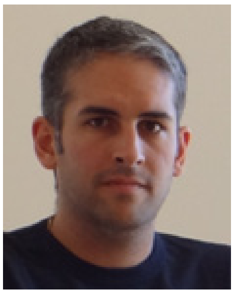
Many of our members have been very active in the last years in setting up, improving or upgrading their facilities. In this newsletter three groups from three different continents report on their activities demonstrating the ongoing efforts to apply neutrons in general and neutron imaging in particular to get more non-destructive insight in materials and on their physical behavior.

Hope you enjoy reading this newsletter and wishing you all a healthy, happy and prosperous New Year

Thomas Bücherl
(ISNR-secretary)

Facilities

Neutron Radiography Facility at RA-6, Argentina



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Background

Argentinian nuclear activities began around 1950 when the Comisión Nacional de Energía Atómica (CNEA) was created. In 1957 Argentina had its first research reactor locally developed, the RA-1. One of its successors is the RA-6, built in 1982. It is placed in Bariloche (part of the Argentinian Patagonia), and it was designed by CNEA and built by INVAP, a local company. RA-6 is a materials testing, open pool type, nuclear research reactor. Apart from research applications, its main purpose is to help forming new physicists, engineers and other related professionals. The RA-6 was originally designed to operate up to 500 kW of thermal power, but in 2009 its core was changed so now it can operate up to 1 MW. Many facilities of the reactor had to be redesigned because of this power improvement, being the neutron radiography facility among them.

Characteristics of the facility

The Bariloche's neutron radiography facility uses the Extraction Tube # 1 of the RA-6. This tube points radially to the nuclear core, penetrates the reactor biological shielding and ends at the graphite reflector.

Collimation

An aluminum tube allows properly placing a collimator and filter into the extraction tube. Following the beam direction, the first part of the tube hosts the collimator. The collimator consists of three parts: a convergent cone made of borated polyethylene (it hosts the sapphire filters), a cadmium disc and a divergent cone made of lead. After the collimator, the aluminum tube has a floodable middle section and finally there is beam shaping section. The beam shape at the sample position is a square of 20 cm side. By design, the ratio between the source to sample longitude (L) and beam aperture (D) is fixed to 100 (L/D = 100). At the sample position, the thermal neutron flux is of $2.4 \cdot 10^{6}$ cm^{-2} s^{-1}.

Imaging equipment

The detection system uses a scintillation screen made of $^{6}LiF/ZnS$ doped with Ag, it is 20 cm x 20 cm and was made by Applied Scintillation Technologies. The light is reflected out of the beam path by a set of two front surface mirrors in order to protect the CCD camera from the radiation. A condensing lens (Schneider Kreuznach Xenon, f = 0.95) focuses the image onto the camera. The installed camera is a Penguin 600 CLM from Pixera Corporation. It has a maximum resolution of 2776 pixels x 2074 pixels and provides digital depth of 16 bits.

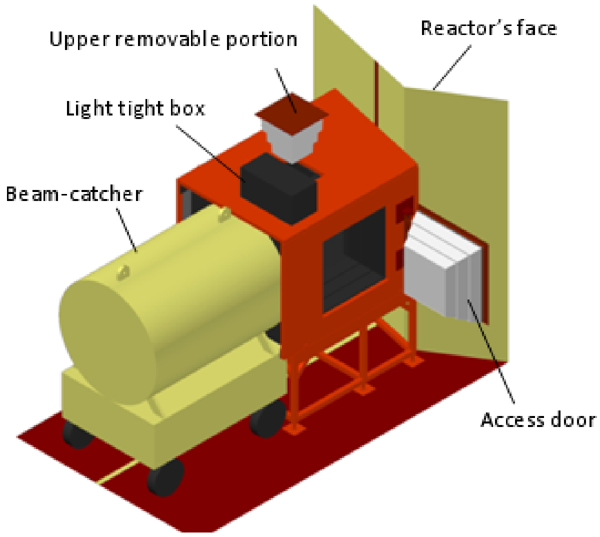


Figure 1 Model of the neutron radiography facility.

Shielding and sample chamber

In order to protect the users from the radiation and to extend the lifespan of the camera, a shielding has been incorporated. Surrounding the path of the beam, the shielding consists of 30 cm thick walls of wax loaded with boron, followed by 2.5 cm thick lead walls, all embedded in steel housing. For ending the beam, a heavy concrete cylinder of 130 cm length by 90 cm in diameter is used. The sample chamber allows placing objects of 40 cm x 40 cm x 40 cm. A shielded door gives access to the sample chamber. Finally, to allow the possibility of imaging longer objects, portions of the roof and floor of the chamber can be removed (Fig. 1).

Current work and future prospect

A characterization process of the facility is currently being performed. This includes, as a first step, to measure the neutron fluxes at the sample position and the dose rates at the surroundings of the facility. With these results the shielding is being optimized.

Objects belonging to the cultural heritage have been imaged at this facility as also a hydrogen-storage device developed in this institution (Fig. 2).

Once experienced has been gained with this technique, our intention is to move toward a three dimensional imaging system.

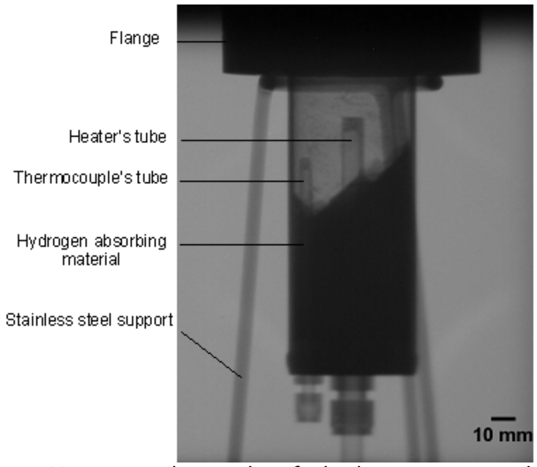
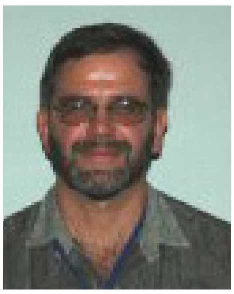


Figure 2 Neutron radiography of a hydrogen-storage device.

SANRAD facility, South Africa

General activities



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Successful application and participation of Mabuti Radebe in an IAEA-CRP on materials research where he as PhD candidate, together with PSI and Helmholtz-Berlin, drives the initiative for the establishment of protocol and test samples to characterize neutron imaging facilities which have digital detector systems. Individual work within the scope of the CRP on protocol for the quantification of porous media and thus the establishment of standard testing procedures which will include the effective usage of QNI scattering software.

Necsa participates also in the IAEA-CRP for cultural heritage which was established in 2012. The goals for Necsa is the establishment of a international database on the web page of the International Society for Neutron Radiology (www.isnr.de) where all activities and references of published papers on archaeology, palaeontology and other objects in cultural heritage origin will be listed. Another goal is the establishment of an exhibition on cultural heritage artifacts either at Necsa (which is located within the Cradle of Human Kind) or at the DITSONG museum in Pretoria, showcasing the effective implementation of imaging with radiation principles applied to the scientific field of cultural heritage studies.

Collaboration with Helmholtz-Berlin and FRM II in the knowledge transfer and establishment of an Autoradiography facility at Necsa is planned. .

SANRAD facility in South Africa due for major upgrade

November 2012 sees the closure of the SANRAD facility (Fig. 3) located at beam port #2 of the SAFARI-1 nuclear research reactor. After more than 10 years of high quality output and the historic first reported neutron tomography to be performed in Africa and the Southern Hemisphere in 2003, the facility is now due for a total and massive upgrade, an initiative that started in 2005 with an IAEA review expert visit from Dr. Burkhard Schillinger (FRM II, Germany) and Reynaldo Pugliesi (IPEN, Brazil) to make recommendations for an upgrade. Through MCNPX simulations of the new facility by Dr. Florian Gruenauer (Germany), based upon these recommendations and that was completed in 2009, funding from the South African Government was obtained in 2011 and full design, based on the principles of the ANTARES facility in München, Germany, could proceed (see simulated layout of the facility in Fig. 4). Through a memorandum of understanding between Necsa and FRM II, knowledge transfer on manufacturing and design criteria add to the relative quick progress of activities in 2012.

Figure 3 *Old SANRAD facility*

A project manager at Necsa, Mr. Tankiso Modise was appointed to drive and manage the initiative for the new built and it can now be reported that certain deadlines and goals were achieved to date e.g. design drawings and all materials for the upgrade were completed and purchased, the mockup test facility with the manufactured empty shielding boxes were erected to study the process of installation and to obtain the exact fingerprint of the facility for the beam port floor of SAFARI-1 to be prepared, the 1st wave of documents for approval by the South African National Nuclear Regulator was created and submitted and the frontal chamber of the beam port was flooded with water to allow for a 6 month decay of the old collimator before extraction from the biological shield of the reactor.

Figure 5 shows the mock-up facility on the manufacture workshop floor with shielding boxes stacked together to eventually, be filled with high density concrete mix, have a

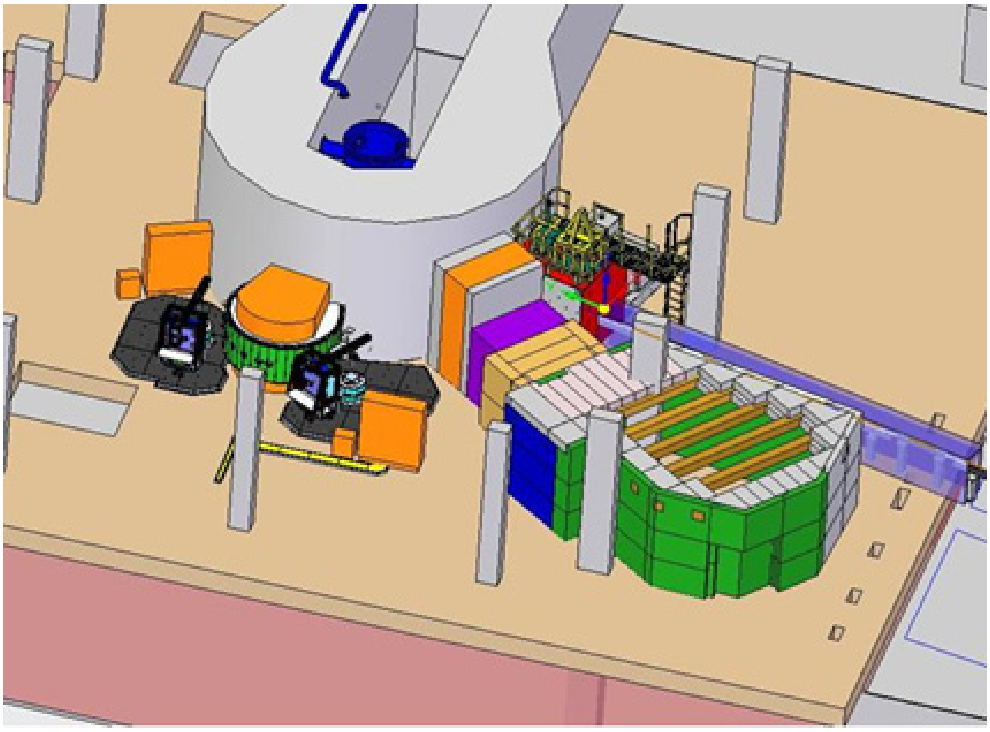

Figure 4 *Simulation of the SANRAD facility*

mass of 500 tons. The upgrade entails an experimental capability expansion of the neutron imaging techniques from hosting only a thermal neutron station but to add also a fast neutron- and fission gamma-ray capability to the list at L/D ratios of 250, 400 or 800. Neutron and gamma filters to be selected depending upon the application and need for certain beam qualities are Bi, Sapphire and Be. Due to an expected high neutron flux ($1 \cdot 10^9$ cm^{-2} s^{-1}) at an L/D of about 70, dynamic studies is thus possible. It is envisaged that the facility will be fully commissioned and characterized by December 2013 to start operations as a user based facility in Jan 2014.

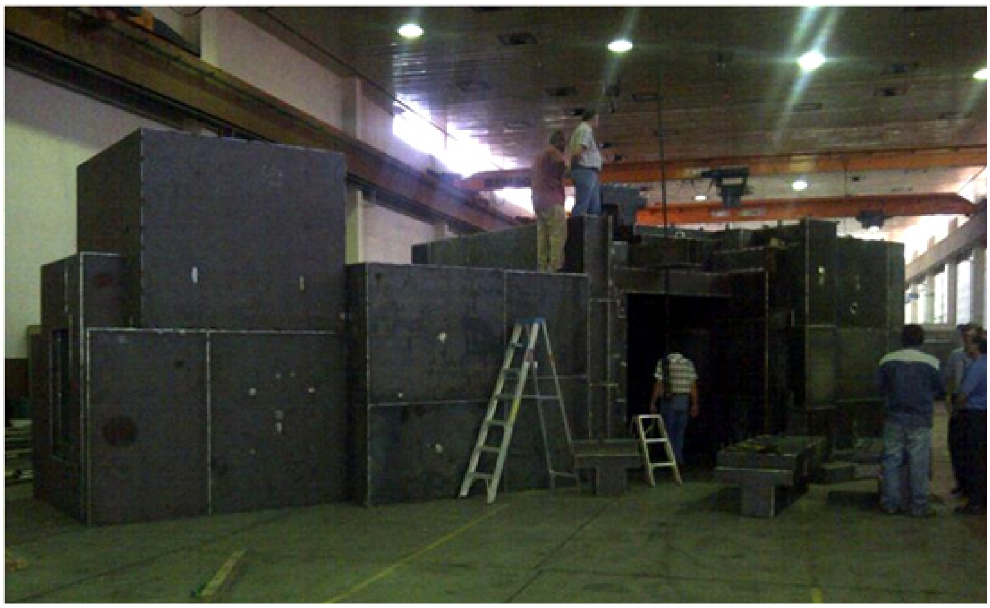

Figure 5 Mock-up facility at the manufacturing workshop at Necsa

ANTARES

The Upgrade of the Neutron Imaging Beam Line ANTARES at FRM II

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Introduction

The imaging beam line ANTARES at FRM II was one of the first beam lines at FRM II to come to operation in 2004 and has since then been one of the most intense imaging facilities in the world. Many successful experiments have been performed at ANTARES in various fields of scientific research and industrial application, which have profited largely from the high flux and good collimation. However, due to the construction of a new neutron guide hall in the east of the FRM II reactor building the beam port SR4b at which ANTARES was located had to be cleared for the installation of a neutron guide to deliver cold neutrons into this new hall. Therefore, the old ANTARES beam line was dismantled and almost completely rebuilt at the neighboring beam port SR4a. Taking this redesign of the beam line as an opportunity to improve the concept of the ANTARES beam line resulted in a major upgrade of the neutron imaging facility at FRM II now providing even better performance and higher flexibility.

The new beam line concept

An improved concept was developed for the new ANTARES beam line. A key design feature was to provide – among new possibilities – identical beam conditions as on the old ANTARES so users can directly compare new measurements with old ones. The beam is

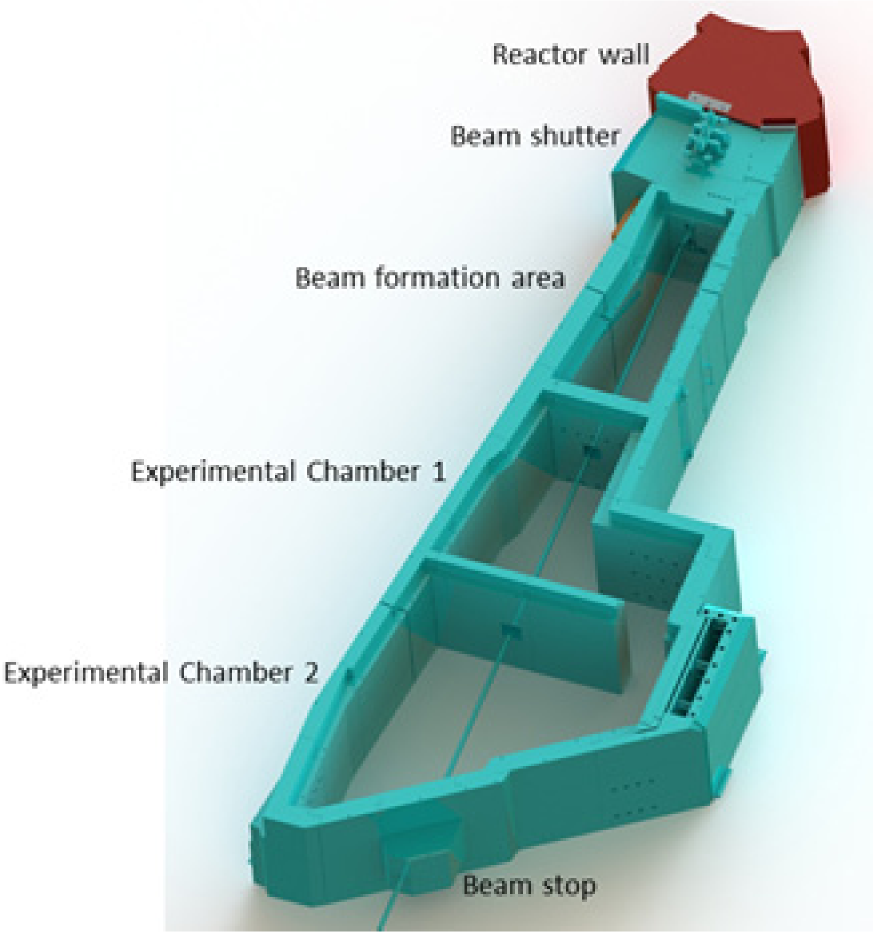

Figure 6 ANTARES Beam Line Layout

now accessible over the entire length of the instrument as shown in Fig. 6. The first shielding block connecting to the biological shielding houses a massive instrument shutter and a collimator drum which allows the selection of six different collimators with pinhole sizes between 2mm and 70mm. Furthermore, three chambers were installed along the beam path separated from each other by massive shielding walls to reduce the fast neutron and gamma background.

The first chamber in beam direction offers the possibility to flexibly install all kinds of beam forming devices. It hosts a fast shutter to reduce activation of the sample and a filter selector wheel with different crystals to shape the spectrum and reduce the fast neutron and gamma background. Furthermore, a velocity selector is installed and a double crystal monochromator as well as neutron optical periscopes to avoid direct sight to the beam tube will soon follow. Also devices provided by the user can be mounted in this separately accessible chamber.

Following the beam formation area is the first experimental chamber, where experiments with high flux on smaller samples can be performed. The maximum beam size in this area is approx. 20x20cm providing a flux as high as $1.6 \cdot 10^9$ cm^{-2} s^{-1} for the largest pinhole. This renders this position ideal for stroboscopic or fast imaging of moving processes. Moreover, using smaller pinholes the collimation ratio L/D can be increased from 100 over 200, 400, 800 and 1600 even up to approx. 3000. Due to the small beam size in this chamber and the fact that the beam dump is located further downstream in the next chamber the background for high resolution or monochromatic imaging on small samples is significantly lower than at the old ANTARES beam line. The roof was elevated in a small area to accommodate the standard FRM II cryostats which do not fit into the last chamber.

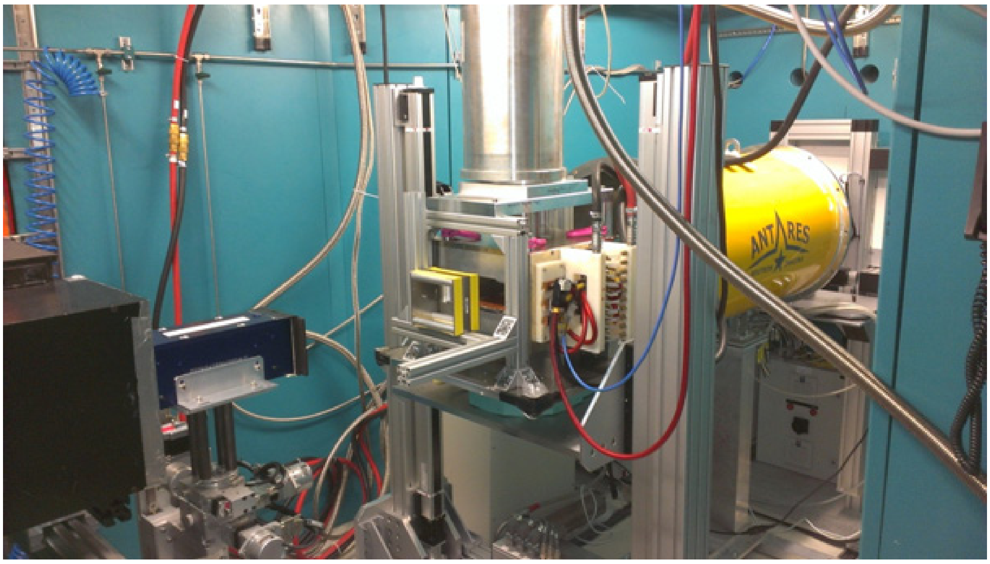

Figure 7 The new ANTARES Beam Line with a complex setup for polarized imaging using a cryostat and magnet.

The third and last chamber provides, among others, conditions identical to the old ANTARES with a maximum beam diameter of up to 35x35cm and a massive sample manipulation stage to handle even large and heavy samples. A separate detector with a variable field of view of up to 40x40cm is installed at this sample position.

Both experimental chambers offer a rail system installed in the floor which provides flexible and accurate positioning of all devices like flight tubes, sample manipulation stages, detectors, etc. along the beam direction.

A new, reusable shielding material based on iron powder, boron and paraffin oil cast into steel containers was developed which provides a better shielding of fast neutrons and gammas while having the same density as heavy concrete. This allowed us to decrease the thickness of the walls and therefore to increase the interior size of the beam line without exceeding the floor weight limit. The new ANTARES beam line now offers ample space for even complex sample environment (e.g. power supplies, cryostats or gas handling systems for fuel cells) to be installed at both of the sample positions.

The new features described above render the new ANTARES facility one of the most flexible and powerful imaging beam lines worldwide. We offer a variety of different detectors with different fields-of-view which provide a resolution of up to 25µm and time resolution for repetitive processes in the µs range.

The field of applications at ANTARES is vast and covers, among others, archaeology, geology, biology, fuel cells, construction materials, stroboscopic imaging of fast processes but also fundamental research on magnetism or the structure of superconducting vortices.

After approximately three years from starting to dismantle the old ANTARES beam line, the new instrument is now back in operation and you are most welcome to submit proposals for new experiments through the FRM II User Office online system.

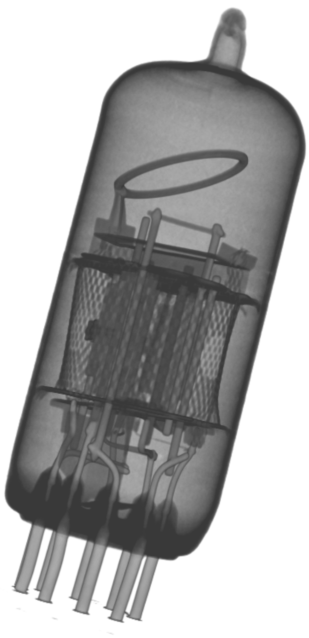

Figure 7 Tomograph of a tube. Data were measured at the new Neutron Imaging Beam Line ANTARES.

Previous conferences and workshops (reviews)

NEUWAVE-5 Workshop

ESS Lund hosted the NEUWAVE-5 Workshop (promoting energy-selective neutron imaging) in April 2013

The 5th Meeting of the NEUWAVE series took place in Lund coinciding with the initiation of the neutron imaging instrument project ODIN at the upcoming European Spallation Source ESS.

Since the first NEUtron WAVElength dependent Imaging (NEUWAVE) meeting held 2006 in Munich/Garching the compact community dealing with the advanced methods for imaging, in particular also at pulsed sources, meets regularly for dedicated workshops.

Related to the fact that advanced imaging methods, like imaging with polarized neutrons or using a grating interferometer for phase and dark-field imaging, required either a monochromatic neutron beam or wavelength dependent measurements, like in the case of Bragg edge imaging, a number of new developments has been triggered in the field. Not only different means of monochromatisation have been tested and implemented at state-of-the-art neutron imaging stations, but also method development has seen considerable progress. In this framework not at least pulsed neutron sources became especially attractive for neutron imaging. The time-of-flight (TOF) approach has not only proven highly efficient for novel methods, but also having a significant potential for methods utilizing only monochromatic beams before. In the latter case especially quantitative approaches can profit a lot. However, the TOF strategy also requires corresponding imaging detectors, providing not only high spatial resolution but also according time resolution. This provides the context in which the NEUWAVE meetings have become an important means of communication, exchange and development in the field of neutron imaging.

In parallel to the according detector development and corresponding to the significant progress of methodical development a new generation of neutron imaging beamlines at the upcoming pulsed spallation sources is a central task of this workshop.

Four different projects have been initiated meanwhile resulting in four beam line initiatives:

- ERNIS at J-PARC (Japan)
- IMAT at ISIS-TS 2 (UK)

both of which are under construction in the meantime and are expected to enter the commissioning phase in 2015, as well as

- VENUS at SNS (USA)
- ODIN at ESS (Europe, Scandinavia)

both of which are in a final design phase looking for approval and final funding to enter the construction phase.

The progress of these instrument projects but also possible novel applications and the growing scope of neutron imaging are core topics of the NEUWAVE meetings nowadays as well.

Figure 9 Neutron imagers are not only able to make impressive research and submit great proposals (e.g. as ODIN for ESS) – they also capture big fishes when required

The recent NEUWAVE-5 meeting at the ESS in Lund was highlighted by the message that the ESS Scientific Advisory Committee (SAC) has strongly recommended the ODIN project to be among the first two beam lines to be constructed at this future spallation source. Hence, the project is waiting for a corresponding final approval by the ESS Steering Committee (STC) expected in autumn this year in order to enter the construction phase.

The meeting in Lund was attended by 50 experts in the fields of neutron imaging, material research, detectors, neutron scattering and even X-ray diffraction, all dealing with topics around the mentioned projects.

However, energy selective imaging is already utilized at the world leading existing neutron imaging facilities where the energy bands are tuned by means of turbine type devices, monochromators or band filters, which triggered the above outlined developments. Correspondingly and despite the limited performance compared to the one expected at the major spallation sources important new approaches and results were obtained and reported at the NEUWAVE-5 meeting. The program hence conveyed contributions dealing with the newest results concerning e.g. strain mapping of construction materials in imaging geometry, measuring and visualizing textures and other crystalline information partly complementing transmission imaging with diffraction data, which was e.g. additionally measured by imaging devices in diffraction geometry. Applications have been addressed dealing amongst others with engineering materials, nuclear materials, cultural heritage but also fuel cell research and development.

Furthermore wavelength resolved measurements with polarized neutrons have been reported, which successfully target magnetic properties such as super-conductivity (Meissner effect) and enable direct observations, visualization and quantification of magnetic field distributions in and around samples with high spatial resolution.

A wavelength dependent analysis of refraction artifacts at the edges of materials, supporting earlier reports, has been presented and the potential to utilize those for defect analysis in structural materials has been outlined.

Last but not least also the state of detector developments for TOF imaging, which is indispensible for the novel beamlines at pulsed sources, has been presented by several groups from Europe, America and Japan. Not only prototypes and test measurements but also significant applications have been introduced in this context as well..

As common in all previous NEUWAVE workshops, the kick-off in advance to the presentations and discussions has to be a hiking tour to bring the participants together in a more relaxed atmosphere. Due to the lack of challenging mountains in the area of Lund, the hiking was replaced by fishing on the Oresund on Sunday afternoon (under blue sky and sunshine and with great success – see picture). The fishes were prepared and eaten during the reception dinner.

NEUWAVE-6 will be organized in 2014 again by the institute which initiated and hosted already the first meeting – FRM-2 at TU Munich in Garching.

Eberhard H. Lehmann, Paul Scherrer Institut, CH; president ISNR
Markus Strobl, ESS Lund, Sweden

NINMACH 2013

The NINMACH 2013 (Neutron Imaging and Neutron Methods in Archaeology and Cultural Heritage Research) conference was a new format, explicitly designed to initiate as well as to extend the application of neutron techniques in archaeology and cultural heritage. About one hundred archaeologists, conservators and scientists met at the Technische Universität München (TUM), Garching, Germany, in September 2013, and informed by a number of interesting and informative lectures on the latest developments in the fields of neutron activation analyses (NAA), prompt gamma activation analyses, neutron scattering, neutron radiography, neutron computed tomography, and other methods applied in archaeology and cultural heritage.

More information was presented at a poster session which took place together with a Bavarian "Brotzeit". The conference dinner at the Bavarian State Brewery Weihenstephan, which is told to be the oldest still existing brewery, with a beer tasting gave further possibilities for discussions, forming new contacts or just having fun. At the closing ceremony it was decided to resume this successful format of the conference in spring 2015 in Garching again, and at the Budapest Neutron Centre in Hungary in 2017.

As an additional program a welcome hike to the Herzogstand was organized the day before the conference started. Those who joined this tour and crested were rewarded by a breathtaking outlook. During the conference the possibility was given to either tour the FRM II, the Neue Pinakothek or the department of restoration of the Bavarian State Archaeological Collection. The visit of the latter gave insight in the daily business of cultural heritage preservation and restoration but also in exciting actions like a salvage excavation of a grave of a chieftain from the Hallstatt period (Fig. 10 and 11). The presentations were given thus lively and enthusiastic that we nearly lost track of time.

Thomas Bücherl

Figure 10 Excavation block of a grave of a chieftain from the Hallstatt period

Figure 11 Pieces of bowls and pots (grave goods)

ITMNR-7 Wrap-up

The Seventh International Topical Meeting on Neutron Radiography, held in Kingston, Ontario, with a Workshop in Algonquin Park, June 16-24, 2012, saw over 80 participants present and participate in formal sessions and workshop discussions. The website has now been closed as of December 1; however, John Rogers has kindly placed some information on his RadSci website, **www.radsci.co.uk**.

The submitted papers are in their final stages of review to be readied for publishing early in the new year.

The Local Organising Committee wish to thank all of those who participated and encourage them and ISNR colleagues to attend the next meeting, The World Conference, WCNR-10, in Switzerland in 2014.

Les Bennett, Paul Hungler, Bill Lewis (& spouses)

Announcement: 10th World Conference on Neutron Radiography

October 5-10, 2014, Grindelwald (Switzerland)

The 10th World Conference on Neutron Radiography (WCNR-10) will attract scientists active in the field of neutron imaging either as designers and/or operators of facilities or as users of such installations. During the conference the latest methodical developments, instrumentation layout and improvements and new applications will be presented and discussed. The official language of the conference is English. The WCNR-10 is hosted by the Neutron Imaging and Activation Group at Paul Scherrer Institut, Switzerland.

You are now welcome to submit your abstracts for WCNR-10. The call is open until March 3rd, 2014. More information and instructions can be found on the conference web site **www.psi.ch/wcnr10**, please select menu item "Call for abstracts". For further questions, please contact Anders Kaestner (email: wcnr10@psi.ch).

Anders Kaestner
On behalf of the WCNR-10 organizing committee

Upcoming Conferences

Conference on Industrial Computed Tomography 2014
February 25-28, 2014, Wels (Austria)
www.3dct.at/ict2014

NEUWAVE-6
April 6-10, 2014, Technische Universität München, Garching (Germany)
burkhard.schillinger@tum.de

XII School of Neutron Scattering(SoNS)
April 30-May 9, 2014, ETTORE MAJORANA FOUNDATION
AND CENTRE FOR SCIENTIFIC CULTURE, Erice (Italy)
www.sonsfpricci.org

American Conference on Neutron Scattering
June 1-5, 2014, Knoxville, Tennessee, USA
www.mrs.org/acns-2014

10th World Conference on Neutron Radiography
October 5-10, 2014, Grindelwald (Switzerland)
www.psi.ch/wcnr10

11th European Conference on Non-Destructive Testing (ECNDT)
October 6-10, 2014, Prague, Czech Republic
http://www.ecndt2014.com

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