NEUWAVE-12

Lund, September 1-5, 2024

Contents

Please check the Workshop Website for latest and detailed information:

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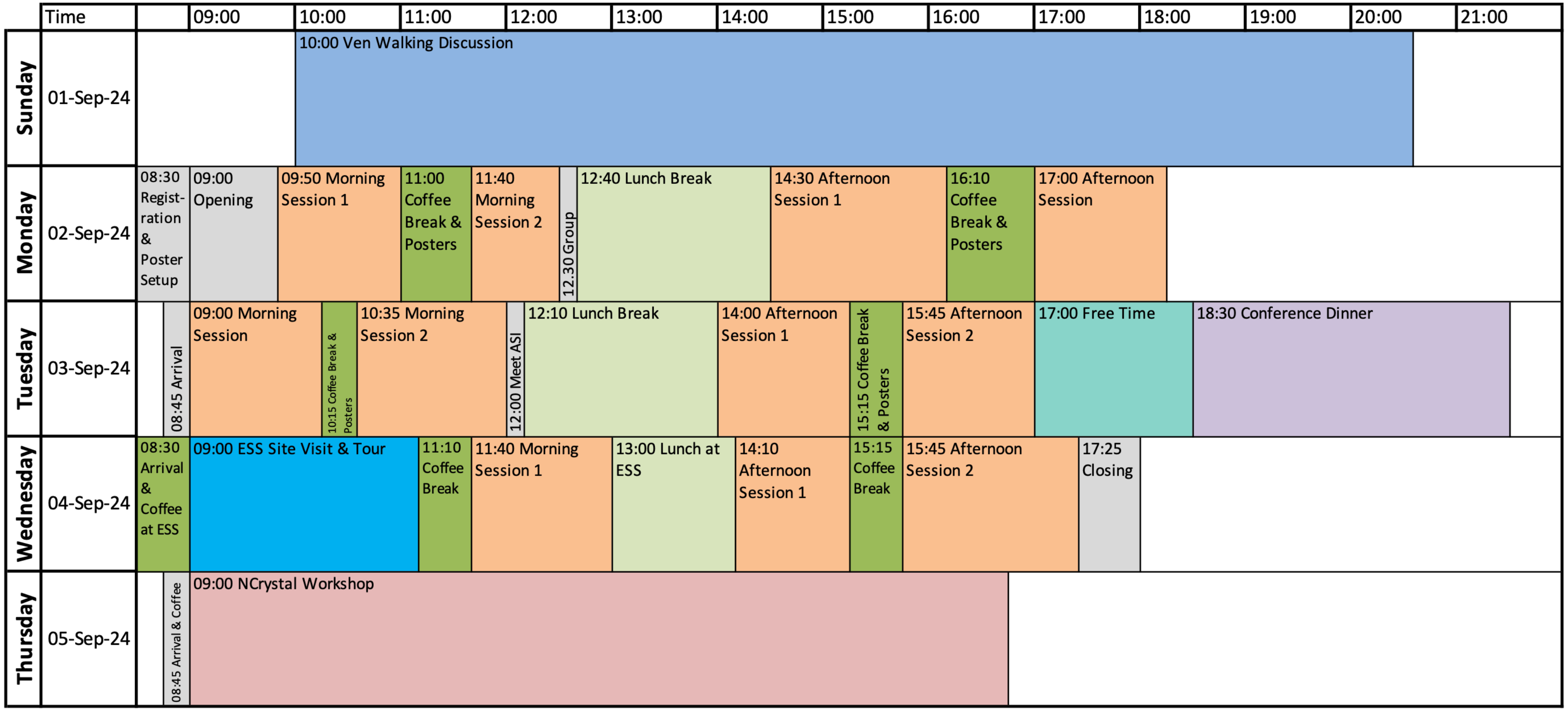
PROGRAM



	Time		09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00
Sunday	01-Sep-24			10:00 Ven Walking Discussion											
Monday	02-Sep-24	08:30 Registration & Poster Setup	09:00 Opening 09:50 Morning Session 1		11:00 Coffee Break & Posters 11:40 Morning Session 2	12.30 Group 12:40 Lunch Break		14:30 Afternoon Session 1		16:10 Coffee Break & Posters	17:00 Afternoon Session				
Tuesday	03-Sep-24	08:45 Arrival	09:00 Morning Session	10:15 Coffee Break & Posters 10:35 Morning Session 2		12:00 Meet ASI 12:10 Lunch Break		14:00 Afternoon Session 1	15:15 Coffee Break & Posters 15:45 Afternoon Session 2		17:00 Free Time	18:30 Conference Dinner			
Wednesday	04-Sep-24	08:30 Arrival & Coffee at ESS	09:00 ESS Site Visit & Tour		11:10 Coffee Break 11:40 Morning Session 1		13:00 Lunch at ESS	14:10 Afternoon Session 1	15:15 Coffee Break 15:45 Afternoon Session 2		17:25 Closing				
Thursday	05-Sep-24	08:45 Arrival & Coffee	09:00 NCrystal Workshop												

Monday, 2 September 2024 @AF Borgen

Registration and Poster setup (08:30 - 09:00)

Opening (09:00 - 09:50) – Chairperson: Robin Woracek

09:00	Welcome and Logistics	WORACEK, Robin
09:10	Welcome to ESS and its future Science	FRAGNETO, Giovanna
09:30	Poster Pitches	

Morning Session 1 (09:50 - 11:00) – Chairperson: Burkhard Schillinger

09:50	**M1**: Progress in wavelength resolved imaging at PSI	STROBL, Markus
10:15	**M2**: Pulsed neutron imaging activities at RADEN in J-PARC	SHINOHARA, Takenao
10:40	Poster Pitches	

Coffee Break & Posters 1 (11:00 - 11:40)

Morning Session 2 (11:40 - 12:30) – Chairperson: Nikolay Kardjilov

11:40	**M3**: Commissioning the VENUS beamline: preliminary results	BILHEUX, Jean
12:05	**M4**: Recent advances in neutron imaging at FRM II	SCHULZ, Michael

Group Photo!! (12:30 - 12:40)

Lunch in Lund restaurants (12:40 - 14:30)

Afternoon Session 1 (14:30 - 16:10) – Chairperson: Takenao Shinohara

14:30	**M5**: Non-destructive reconstruction of bulk microstructure and interlayer diffusion in wire-arc additive manufactured materials	TREMSIN, Anton
14:55	**M6**: Study on deformation twinning in Magnesium and its alloy: Combined neutron Bragg-edge imaging and diffraction	SU, Yuhua
15:20	**M7**: Strain and texture mapping using Frame Overlap Bragg Edge Imaging (FOBI) at SINQ	SORIA, Sergio
15:45	**M8**: Crystallographic texture quantification employing Bragg edge neu-tron imaging experiments.	MALAMUD, Florencia

Coffee Break & Posters 2 (16:10 - 17:00)

Afternoon Session 2 (17:00 - 18:15) – Chairperson: Jean Bilheux

17:00	**M9**: Targeted residual stress in electrical steel – Towards novel electric drives	NEUWIRTH, Tobias
17:25	**M10**: Optimization of experimental parameters to minimise edge effects for metal surface neutron imaging studies	ULLAS MIRASHI, Vicky
17:50	**M11**: Phase contrast imaging at NEXT. A test experiment on the potential of this method for Historical Metal Artefacts: marks and strain	GRAZZI, Francesco

Tuesday, 3 September 2024 @AF Borgen

Arrival (08:45 - 09:00)

Morning Session 1 (09:00 - 10:15) – Chairperson: Stefanos Athanasopoulos

09:00	**T1**: Advancing Energy-Resolved Neutron Imaging at ISIS: Current Status and Future Plans	MORGANO, Manuel
09:25	**T2**: Enhanced Neutron Imaging at the HIPPO Diffraction Instrument	VOGEL, Sven
09:50	**T3**: ODIN @ESS - Commissioning and First Science	WORACEK, Robin

Coffee Break & Posters 1 (10:15 - 10:35)

Morning Session 2 (10:35 - 12:00) – Chairpersons: Michael Schulz; Markus Strobl

10:35	**T4**: Using pyrolithic graphite crystals as secondary source in neutron imaging	SCHILLINGER, Burkhard
11:00	Open Discussion	

Company Intro: Amsterdam Scientific Instruments (12:00 – 12:10)

Lunch in Lund restaurants (12:10 - 14:00)

Afternoon Session 1 (14:00 - 15:15) -- Chairperson: Meimei Wu

14:00	**T5**: Multimodal neutron investigation of sodium-ion batteries as a diagnostic tool to track battery operation and failure mechanisms	BATTAGLIA, Domenico
14:25	**T6**: Operando visualization of current flow in energy devices using polarized time-of-flight neutron imaging.	QVISTGAARD, Cédric
14:50	**T7**: Polarised neutron imaging at ILL	SANS PLANELL, Oriol

Coffee Break & Posters 2 (15:15 - 15:45)

Afternoon Session 2 (15:45 - 17:00) – Chairperson: Anton Tremsin

15:45	**T8**: Characterization of beryllium for neutron reflector applications at HIPPO	DI JULIO, Douglas
16:10	**T9**: Overview of Laue Three-dimensional Neutron Diffraction Tomography and its Applications	SAMOTHRAKITIS, Stavros
16:35	**T10**: Next Steps for a Bragg Edge Round Robin	RAMADHAN, Ranggi

Free time (17:00 - 18:30)

Conference Dinner at Hos Talevski i Stadsparken (18:30 - 21:30)

Wednesday, 4 September 2024 @ESS

Arrival and Coffee at ESS (08:30 - 09:00)

ESS Visit and Tour (**bring ID, wear long trousers**) (09:00 - 11:10)

Coffee Break (11:10 - 11:40)

Morning Session 1 (11:40 - 13:00) – Chairpersons: Thawatchart Chulapakorn; Manuel Morgano

11:40	Open Discussion	
12:10	**W1**: Enhanced epithermal neutron imaging applied to Heritage and Planetary sciences	MARCUCCI, Giulia
12:35	**W2**: White Beam and Monochromatic Neutron Imaging and the reconstruction of the casting process of ancient bronzes: an overview of results and interpretation	CANTINI, Francesco

Lunch at ESS (13:00 - 14:10)

Afternoon Session 1 (14:10 - 15:15) – Chairperson: Søren Schmidt

14:10	**W3**: Event-type neutron imaging detector development at RADEN	PARKER, Joseph
14:35	**W4**: Advancements in Imaging Detectors Based on Event Mode Data Acquisition	LOSKO, Adrian
14:55	**W5**: Comparative Study of Scintillator Performance for Event-Mode Neutron Resonance Imaging	HIRSH, Tsviki

Coffee Break (15:15 - 15:45)

Afternoon Session 2 (15:45 - 17:25) -- Chairpersons: Sven Vogel; Sylvia Britto

15:45	**W6**: Material characterisation through neutron resonance absorption spectrosco-py: advances in 2D quantitative isotopic mapping at the ISIS neutron and muon source	SCHERILLO, Antonella
16:10	**W7**: Neutron Thermo Tomography	KARDJILOV, Nikolay
16:35	Open Discussion	

Closing (17:25 - 18:00)

Thursday, 5 September 2024 @LINXS

Arrival and Coffee at LINXS (08:45 - 09:00)

Please refer to https://indico.ess.eu/e/NeuWave-12 for details and schedule about the workshop.

OPEN DISCUSSION SESSIONS

The goal of Neuwave is to foster active and engaging discussions, which is why we have planned three Open Discussion sessions. Each session will be led by two chairpersons who will work closely together to structure the discussions effectively.

We encourage participants to think about possible themes and come prepared to engage. Possible discussion topics may include, but are not limited to:

- **Making Advanced Techniques More Accessible to New Users**
- **Impressions from the Site Tour:** Does the layout of ESS meet the needs of the imaging community?
- **Event Mode Data Processing:** Improving event mode data processing, calibrating pulse shape discrimination parameters, integrating AI for event detection, and handling multi-modal characterization
- **Collaboration Opportunities:** Identifying areas for collaboration, such as sample environments, and proposing actions to facilitate these collaborations
- **Data Analysis Pipelines:** Developing flexible and expandable data analysis pipelines for Bragg-edges and resonances, including common pipelines for CT and nGI, and community projects for improved user accessibility
- **Diffraction Simultaneity:** Benefits and funding strategies for adding additional diffraction panels for simultaneous data collection and calibration
- **Round Robins and Calibration:** Ensuring new beamlines and detector configurations produce quantitative results, and compiling best practices for calibration and background reduction
- **Future Directions:** Exploring collaborative opportunities and future developments in neutron imaging and related fields
- **Current and Future Hot Topics:** Identifying where wavelength-resolved imaging could make an impact
- **New imaging beamline at ESS**: Who is interested to join a consortium?
- …

ORAL PRESENTATIONS

M1: Progress in wavelength resolved imaging at PSI

Markus Strobl[a]

[a]*Paul Scherrer Institut, Villigen, Switzerland*

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This presentation will give an overview of wavelength resolved imaging methods and instrumentation developed and pursued at the instruments of the Applied Materials Group at PSI. It will focus on such methods, techniques, applications and results not covered in other contributions. Recently added capabilities from a new velocity selector, and new double crystal monochromator at ICON as well as the addition of a chopper system for our pioneering approaches for time-of-flight imaging at a continuous source will be discussed. New contrast modalities such as inelastic scattering contrast, polarized dark-field imaging as well as multi-directional dark-field contrast will be presented together with outstanding applications in material science [1].

References

[1] M. Strobl and E. Lehmann (eds), Neutron Imaging - From applied materials science to industry, IOP Publishing Ltd 2024 Online ISBN: 978-0-7503-3495-2 • Print ISBN: 978-0-7503-3493-8

M2: Pulsed neutron imaging activities at RADEN in J-PARC

Takenao Shinohara[a], *Daisuke Ito*[b], *Keisuke, Kurita*[a], *Yasushi Saito*[b], *Yoshiaki Kiyanagi*[c], *and RADEN team*

[a]*Japan Atomic Energy Agency, Tokai, Ibaraki, Japan,* [b]*Kyoto University, Kumatori, Osaka, Japan,* [c]*Hokkaido University, Sapporo, Hokkaido, Japan*

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The Energy-resolved neutron imaging system, RADEN [1], has been constructed in J-PARC MLF in 2014 and started the user operation in 2015, and we will soon celebrate the 10th year from the successful first neutron beam extraction in RADEN. So far, we continued developments on energy-resolved neutron imaging techniques using time-of-flight (TOF) analysis and on the devices related to neutron imaging. Accordingly, now RADEN becomes a unique instrument that can cover Bragg edge, resonance absorption, polarimetry, and grating interferometry imaging techniques with wavelength/energy resolution. Regarding the application, more than half of proposals submitted to RADEN use TOF technique, especially Bragg edge imaging, and remaining proposals are mostly special neutron radiography/tomography experiments, such as high-resolution imaging and in-situ/in-operando imaging, which are difficult to conduct in other neutron imaging facilities in Japan. Especially, this situation becomes more obvious after the successful operation restart of the Japanese research reactor, JRR-3, in 2021, which was suspended more than 10 years due to fitting the new regulatory standard created after the Great East Japan Earthquake in 2011. Thus, the major neutron imaging facilities in Japan are all in operation, and hence, cooperation and distinction among facilities became even more pronounced, and by taking advantage of their features, it allows us their efficient use in a wide range of experiments.

Recently a new neutron imaging instrument in MLF was proposed, which views the coupled hydrogen moderator of JSNS to obtain higher neutron flux with moderate wavelength resolution, to compensate RADEN. In addition, because Kyoto University Research Reactor (KUR) is scheduled to be shut down in May 2026 due to the deadline for returning spent fuel to the United States, the Japanese government authorized a project to construct a new research reactor at the site of the fast breeder reactor "Monju" in Fukui prefecture to be a base of neutron science in western Japan on behalf [2]. We are proposing to install two neutron imaging instruments in this new research reactor each of thermal and cold neutron beams.

In the presentation, we will discuss the current status of RADEN and what we learned through the 10-year operation, in addition, our future prospects on RADEN and Japanese neutron imaging activity.

References

[1] T. Shinohara, et al., Rev. Sci. Instrum. **91**, 043302 (2020)
[2] https://www.jaea.go.jp/04/nrr/en/

M3: Commissioning the VENUS beamline: preliminary results

Jean Bilheux, Hassina Bilheux, Harley Skorpenske, Greg Guyotte, Bogdan Vacaliuc
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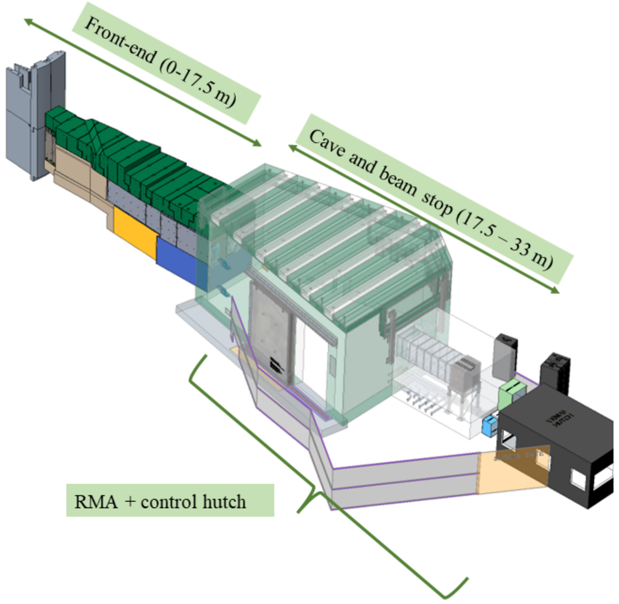
The VENUS hyperspectral imaging beamline is currently being commissioned at the Oak Ridge National Laboratory Spallation Neutron Source after several years of construction. The beamline provides collimation ratios varying from 400 to 2000. It is equipped with choppers, a cadmium filter, and two collimators to reduce background in the instrument cave. While the flight tubes located in the front-end are evacuated, the cave flight tubes are filled with helium to minimize the thickness of the aluminum window near the sample area. VENUS is optimized for Bragg edge and resonance imaging, with a 20 x 20 and 4 x 4 cm^2 field-of-view, respectively. VENUS is equipped with three detectors: the ANDOR charge-coupled device (CCD) iKon-XL 230, the QHY scientific Complementary Metal Oxide Semiconductor (sCMOS) sensor 6060, the microchannel plate Timepix detector (with a maximum field-of-view of 2.8 x 2.8 cm^2). A microchannel plate Timepix 3 detector is also being commissioned. Figure 1 displays the general layout of the beamline with the front-end area (where optical components, the filter, and choppers are located), the cave and beam stop, the radiological materials area (RMA), and the control hutch. During routine operations, the cave, RMA and control hutch are accessible.



The instrument commissioning focuses on the performance of the beamline components, the study of the moderator, the acquisition and data workflows, calibration measurements, and early scientific results. Some of these preliminary results are presented here.

Figure 1. *VENUS general layout, showing the front-end area, the cave and beam stop, the radiological materials area (RMA) and the control hutch.*

This research used resources at the Spallation Neutron Source, a DOE Office of Science User Facility operated by the Oak Ridge National Laboratory.

M4: Recent advances in neutron imaging at FRM II

Michael Schulz

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The neutron imaging group at FRM II, Garching operates the two neutron imaging facilities ANTARES and NECTAR. ANTARES provides a cold neutron spectrum, which gives high sensitivity for even small changes of composition in a sample and is used for neutron imaging with high spatial resolution as well as advanced techniques such as imaging with polarized neutrons or neutron grating interferometry (nGI). The instrument NECTAR is a unique facility that provides a fast fission neutron spectrum that allows the investigation of even very bulky samples and shows contrast complementary to X-rays or gammas. Additionally, thermal neutrons and gamma radiography are also available at NECTAR in a multi-modal approach.

While FRM II has not been running due to repair works for an extended period of time, we have performed many upgrades to our instruments and have performed many experiments at other facilities to support ongoing internal and user projects such as the development of event-mode neutron imaging detectors, studying the defect evolution in additively manufactured samples, investigating the process of freeze drying with neutron imaging or using neutron grating interferometry to track the magnetic domain behavior in electric steel under tensile stress. Moreover, we have proposed to install the additional and complementary neutron imaging instrument FLASH-NT on a cold neutron guide end position at FRM II in the framework of an upgrade program.

In our contribution, we will give an overview of recent achievements and activities of the neutron imaging group at FRM II and show the new experimental possibilities users will have at our instruments.

M5: Non-destructive reconstruction of bulk microstructure and interlayer diffusion in wire-arc additive manufactured materials

A.S. Tremsin[a], E. Eimer[b], S. Ganguly[b], T. Shinohara[c], K. Oikawa[c], W. Kockelmann[d]*

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Energy-resolved neutron imaging provides unique opportunity to investigate bulk microstructure and elemental composition, all in one non-destructive measurement, providing neutron transmission spectra can be measured in a wide energy range [1]. The existence of bright pulsed neutron beams and fast neutron counting detectors enable reconstruction of sample characteristics within several centimetre areas with ~0.1 mm resolution measured all at the same time.

We present the results of experiments where Al alloy samples were produced by wire-arc additive manufacturing (AM) technique [2]. Interdiffusion of materials between the deposition layers was investigated through neutron resonance absorption, while the microstructure was revealed through Bragg edge imaging. Several samples were used in this study, some with rolling applied to individual layers during manufacturing process. Both as-built and heat treated samples were investigated. The analysis of neutron resonance absorption enabled quantitative reconstruction of Ag and Cu elemental composition within different layers of AM printed materials.

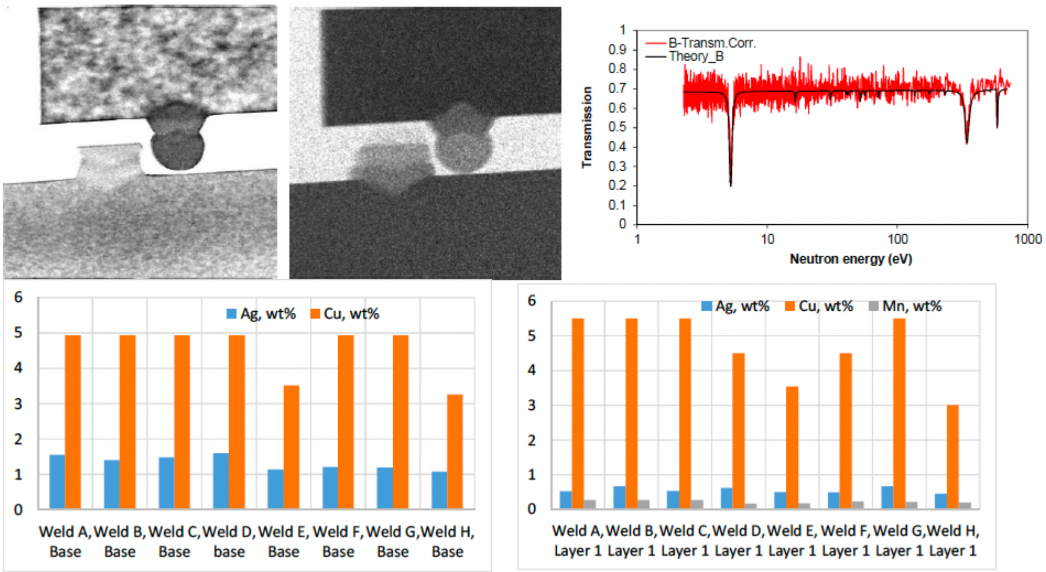

Fig. 1 (a) Narrow-band neutron tramsmission image near 200 Bragg edge for unrolled (top) and rolled specimens. **(b)** Resonance absorptoin image around of same specimens near Ag resonance. Concentration of Ag in baseplate, first and second layers is reconstructed quantitatively by the analysis of resonance attenuation spectra, such as shown in figure **(c)**. **(d), (e)** Reconstructed concentration of Ag and Cu in baseplate and in layer 1 for different specimens.

References

[1] A.S. Tremsin, J.V. Vallerga, Radiation Measurements 130 (2020) 106228.

[2] J.R. Hönnige, et al, Additive Manufacturing 22 (2018) 775

M6: Study on deformation twinning in Magnesium and its alloy: Combined neutron Bragg-edge imaging and diffraction

Y.H. Su[a], T. Shinohara[a], J.D. Parker[b], K. Oikawa[a], T. Kai[a], W. Gong[a], S. Harjo[a], H. Sato[c], Y. Kiyanagi[c]

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Neutron Bragg-edge imaging, offering high spatial resolution for visualizing crystallographic information, has become a useful tool for material research. Magnesium (Mg) and its alloy, as one of the light structural materials, have been widely applied in various industries. Deformation twinning plays an important role in the deformation processes of Mg alloys with a hexagonal-close-packed (HCP) structure. Our study focuses on understanding the mechanisms of deformation twinning in Mg and its alloy using neutron Bragg-edge imaging and diffraction techniques. Two types of samples were designed: Pure Mg with coarse grains, for direct observation of deformation twins using energy/wavelength-dependent neutron transmission imaging; and Mg-6Zn alloy with fine grains, for extracting the volume fraction of deformation twins via Bragg-edge transmission spectra analysis. Rectangular-shaped pure Mg and Mg-6Zn (6 wt.% Zn) alloy samples were prepared. Compression tests were carried out using a loading machine with different strains. Ex-situ pulsed neutron transmission imaging experiments were conducted at BL22 RADEN of the MLF/J-PARC [1]. A μNID detector was used to obtain 2D neutron Bragg-edge spectra of the samples after compression [2], and GUI-RITS software was used for Bragg-edge spectral analysis [3].

As shown in Fig. 1, the transmission spectra of the Mg-6Zn sample along the compression direction exhibit evident changes with increasing strain, especially for the three prominent Bragg edges. The height of the {0002} edge increases with strain, while the {10-10} edge decreases simultaneously, indicating texture evolution due to twinning. The volume fraction changes of {10-12} <10-11> twins were quantitatively assessed through Bragg-edge spectral analysis. Additionally, direct visualization of twin formation and growth during compression of coarse-grained pure Mg was achieved using wavelength-dependent imaging. Comparative analyses with in-situ neutron diffraction data from BL19 TAKUMI, MLF/J-PARC, will also be presented.

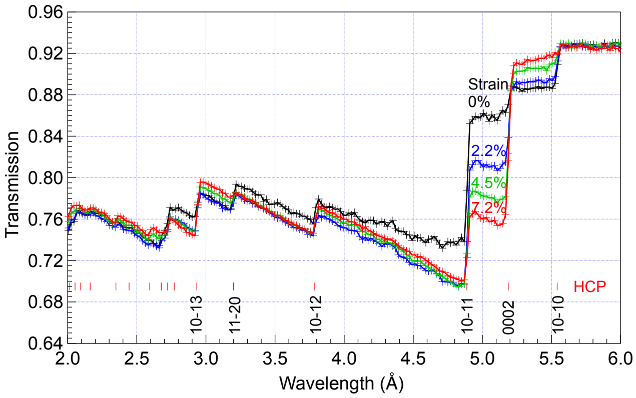

Figure 1 Bragg-edge spectra of the Mg-6Zn sample.

References

[1] T. Shinohara *et al.*, Rev. Sci. Instrum. **91**, 043302 (2020)

[2] J.D. Parker *et al.*, JPS Conf. Proc. **22**, 011022 (2018)

[3] K. Oikawa *et al.*, J. Phys. Conf. Ser. **2605**, 012013 (2023)

M7: Strain and texture mapping using Frame Overlap Bragg Edge Imaging (FOBI) at SINQ

S.R. Soria[a,b]*, F. Malamud*[a]*, M. Busi*[a] *, M.Strobl*[a]

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Recent advances have been made at SINQ, the neutron source of the Paul Scherrer Institute in Villigen, Switzerland, in applying the Frame Overlap Bragg edge Imaging (FOBI) method for non-destructive internal strain measurements [1]. This method employs a multiple slit chopper with a pseudorandom pattern, allowing neutron pulses with different wavelengths to arrive at the detector simultaneously. The overlapping spectra prevent direct conversion to wavelength, so a coded source imaging technique is used to disentangle the overlap between different pulses [1]. This approach compensates for flux reduction by increasing the duty cycle, thereby reducing measurement times. FOBI has been successfully employed at POLDI (Pulse OverLap DIffractometer), the Time-Of-Flight (TOF) diffractometer at SINQ, for texture determination and strain mapping in various metallic alloys produced by additive manufacturing.

In this work, we present the application of strain and texture mapping using the FOBI method at POLDI in multi-material lattice structures produced by laser powder bed fusion. Additionally, we study the internal strain during in-situ lap shear tests on different combinations of dissimilar materials joined by friction stir welding.

References

[1] M. Busi et al. Frame Overlap Bragg edge Imaging. Scientific Reports 10 (2020) 14867.
[2] C.P. Martendal et al. Effects of beam shaping on copper-steel interfaces in multi-material laser beam powder bed fusion. J. Mater. Process. Tech. 327 (2024) 118344
[3] S. Sumarli et al. Neutron Bragg edge imaging for strain characterization in powder bed additive manufacturing environments. J. Mater. Res. Tech. 21 (2022) 4428-4438.

M8: Crystallographic texture quantification employing Bragg edge neutron imaging experiments.

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The capabilities of Bragg edge imaging to characterize microstructure features of relatively large polycrystalline objects with good spatial resolution have been extensively proved over the years. However, the quantitative analyses of the signature of crystallographic texture in the spectrum remain a challenge. A prediction of transmission spectra with respect to known ODFs has been proven to be achievable for different types of materials [1], [2], [3], [4]. In particular, we have developed two theoretical approaches to model and evaluate the effect of texture in the neutron transmission spectra, based either on decomposing the ODF in individual orientations [2] or by expanding the ODF in Fourier series [5], [6]. Both methods produced excellent predictions for materials with different crystal symmetries with the former being better suited for sharp textures and large-grained materials, and the later for smooth textures and fine-grained materials.

However, the inversion problem to obtain a full description of crystallographic texture from a number of transmission spectra of different projections represents a more difficult task. Recently we have proposed a novel approach and applied it successfully, in a first step, to homogeneously textured materials [7].

Here, we will present experimental results of the application of the inversion method for the estimation of the ODF from the transmission spectra measured along several samples directions. Besides this, we will show the application of the direct methods to predict the wavelength-resolved neutron transmission spectra from known ODFs, and compare them with measurements performed at different neutron facilities using time-of-flight techniques.

References

[1] F. Malamud,et.al, Journal of Applied Crystallography, vol. 49, no. 2, pp. 348–365, Apr. 2016, doi: 10.1107/S1600576716000443.

[2] F. Malamud, et.al. Journal of Applied Crystallography, vol. 56, no. 1, Feb. 2023, doi: 10.1107/S1600576722011323.

[3] F. Malamud et al., Journal of Applied Crystallography, vol. 47, no. 4, pp. 1337–1354, Aug. 2014, doi: 10.1107/S1600576714012710.

[4] L. L. Dessieux, et. al. "Nuclear Instruments and Methods in Physics Research Section B, vol. 459, pp. 166–178, Nov. 2019, doi: 10.1016/j.nimb.2019.09.010.

[5] M. A. V. Alvarez and F. Malamud, Journal of Physics, 2022, doi: 10.1088/1742-6596/2605/1/012023.

[6] M. A. Vicente Alvarez, et.al. Journal of Applied Crystallography, vol. 54, no. 3, pp. 903–913, Jun. 2021, doi: 10.1107/S1600576721003861.

[7] M. A. Vicente Alvarez, et,al. Journal of Applied Crystallography, vol. 56, no. 6, pp. 1721–1731, 2023, doi: 10.1107/S1600576723008877.

M9: Targeted residual stress in electrical steel – Towards novel electric drives

Tobias Neuwirth[a], Simon Sebold[a], Ines Gilch[b], Phillip Stöcks-Morgan[b], Wolfram Volk[b], Nora Leuning[c], Michael Schulz[a]

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Slowing and stopping the ongoing rapid climate change necessitates the reduction of CO2 emissions and, therefore, fossil fuel consumption. Transportation, particularly motorized private transport, contributes significantly to fossil fuel consumption. Here, transitioning to battery electric vehicles (BEVs) is an option to reduce the consumption of fossil fuels, assuming a CO2-free electricity production. Compared to conventional vehicles, BEVs have a reduced range due to a lower energy density in the battery. Next to the development of higher capacity batteries, an avenue for a higher range is to improve the efficiency of the electric drive. In our DFG-supported project, we investigated the improvement of electric drives by targeted residual stress.

Electric drives, i.e. synchronous motors, used in BEVs require the careful guidance of the magnetic flux in the rotor. The rotor comprises a stack of non-oriented electrical steel (NOES) sheets. Conventionally, material is removed from the sheets to create flux barriers. These removed areas are called cutouts and reduce the mechanical strength and, hence, the achievable rotational speed of the drive, which affects its power density and efficiency. Here, we showed that residual stress introduced by embossing, a local forming process, locally reduces the magnetic permeability. Inverse magnetostriction describes the change of magnetic permeability due to residual stress. The locally reduced permeability displaces the magnetic flux from these regions and concentrates it in other areas. Neutron grating interferometry (nGI), an advanced neutron imaging technique, is uniquely capable of mapping the magnetic flux displacement with high spatial resolution in the bulk of electrical steel, as shown in Fig. 1.

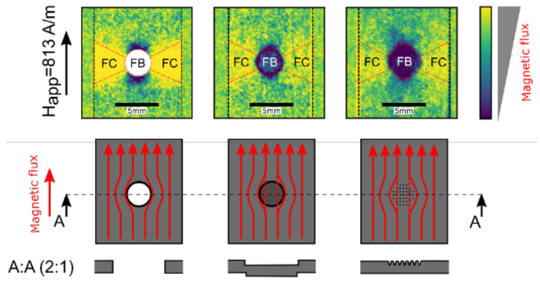

Fig. 2: Magnetic flux guidance in NOES achieved by conventional cutout (left) and novel embossing techniques, macro (middle) and sequential micro (right).

In our contribution, we will present how polychromatic and energy-resolved nGI allowed us to verify the magnetic flux guidance by mapping the dependence of magnetic domain size and orientation on material parameters and applied magnetic field. Further, we will present our current DFG-supported industry transfer project. Here, we are working with our collaborators from mechanical and electrical engineering and an industry partner to use the previously gained insights to build more efficient electric drives using residual stress to guide the magnetic flux.

M10: Optimization of experimental parameters to minimise edge effects for metal surface neutron imaging studies

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Our understanding of corrosion and material degradation of steel materials can significantly improve by combining imaging with electrochemical characterisation. Neutron imaging is a non-destructive powerful technique suitable for imaging metal surfaces. It is useful to conduct attenuation-based studies and it is highly sensitive to light elements (hydrogen). However, the influence of neutron-optical artifacts (e.g., edge effects) occurring at the air-metal interface restrict us from characterising surface corrosion films (FeCO3) on X65 steel forming in carbon dioxide environments. Edge effects (a refraction phenomenon) are influenced by wavelength, sample geometry, sample-to-detector distance, surface inclination and sample composition as different materials have variable refractive indices [1-3]. We studied ways to overcome edge effects in neutron imaging by optimising experimental parameters at IMAT. In particular, we thoroughly investigated and optimized the operating wavelength range to analyse X65 steel material. Energy-resolved imaging was chosen for this investigation as it offers flexibility to study the effects of specific, smaller and larger wavelength ranges after data collection.

It was observed that edge effects are less pronounce in the lower neutron energy range, in the region of Bragg edges, whilst stronger edge effects are evident after the Bragg cutoff. Our study was validated using other materials such as nickel, lead, copper, for which similar trends were found. Thus, we suggest that to improve the surface imaging analysis of metals, like X65 steel, the selection of appropriate wavelength range is important to reduce edge effects.

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M11: Phase contrast imaging at NEXT. A test experiment on the potential of this method for Historical Metal Artefacts: marks and strain

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Polychromatic phase-contrast imaging is based on the contrast enhancement in transmitted neu-tron beams and allows to measure features within a sample of homogeneous composition but exhibiting a different microstructure induced by mechanical actions. The different plastic defor-mation of adjacent areas within a sample generates a small difference in the refraction of the neutron beam crossing the differently strained areas. An interference pattern (following the mor-phology of the strain vs no strain border) becomes visible at specific conditions related to the strain level and to the sample-detector distance. In this way, it becomes possible to map the pres-ence and shape of mechanically stressed areas, which can be of strong interest in several research fields.

Our goal is to exploit this method to visualize no-longer-visible manufacturing or signature marks on historical metal artefacts as armour pieces, weapons and artistic bronzes. In historical metal artefacts it is common that either over-polishing, patination, or mineralization of the surfaces al-tered or erased the presence of unique distinctive marks. However the footprint mechanically impressed on the metal substrate still survive and can be revealed by this method.

Such a technique was exploited by us in several successful experiments at the CONRAD-II neutron imaging beamline at Helmholtz Zentrum Berlin (HZB) [1], analysing armours from Renaissance time and produced in Italy and Germany, in collaboration with the Wallace Collection London [2].

Here we present our first test experiment on a set of iron and copper sheets, purposely chiselled, thermally treated and mechanically polished in different ways. The measurement performed on the NEXT beamline shows the great potential of this method in such experimental station where even a phase contrast tomography was successfully performed.

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T1: Advancing Energy-Resolved Neutron Imaging at ISIS: Current Status and Future Plans

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Energy-resolved neutron imaging is effectively applied using time-of-flight methods at pulsed sources, with spectral ranges and pulse widths of an instrument given by the type of moderator. The imaging instrument IMAT [1] views a coupled cold liquid hydrogen moderator on TS2 at ISIS and is operated as a user facility for more than six years. About half of the projects on IMAT make use of energy-resolved and energy-selective neutron imaging: for strain mapping using Bragg edge analysis, to enhance contrast by selecting suitable wavelength bands, and for developing time-of-flight imaging methods. ENGIN-X on a decoupled cold liquid methane moderator on TS1 remains an option for Bragg edge experiments that require sharper pulse widths, such as for edge-broadening studies [2]. INES, on the other hand, views an ambient temperature water moderator on TS1 providing epithermal neutrons for resonance analysis, for elemental and isotope mapping of cultural heritage materials [3], and in other fields such as meteorite studies.

The installation of large diffraction detector arrays and radial collimators on IMAT in 2025 will significantly enhance many Bragg edge experiments by providing additional strain and texture data. A new neutron strain scanner, eMAP [4], has recently been approved as part of the ISIS Endeavour Programme, for installation on a decoupled poisoned solid methane moderator at TS2. The instrument will offer Bragg edge analysis with 2X sharper spectral resolution than IMAT and 5X higher flux than ENGIN-X. Bragg edge imaging and diffraction experiments on the same in-strument on IMAT and/or on eMAP will enable effective in-situ measurements of engineering materials, of structure transformation and in-operando studies. Looking further ahead, the devel-opment of an imaging instrument with a significant thermal neutron energy component is being considered to meet the increasing non-destructive testing demand from industry.

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T2: Enhanced Neutron Imaging at the HIPPO Diffraction Instrument

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The HIPPO neutron time-of-flight diffractometer [1] at LANSCE has been upgraded with an event-mode, energy-resolved neutron imaging camera [2], enabling simultaneous diffraction for microstructural characterization and energy-resolved neutron imaging. This multimodal approach reduces beam time requirements and leverages HIPPO's extensive detector coverage and sample environment capabilities for combined diffraction and imaging investigations.

The imaging system features a 20x20 mm field-of-view viewing HIPPO's 10 mm diameter beam spot (14 mm base-to-base), utilizing a 450 µm 6LiF-ZnO:Zn scintillator intensified and coupled to a TimePix3 sensor. Energy discrimination provides Bragg edge contrast for grain mapping and resonance absorption for isotopic density or sensor-less temperature measurements from Doppler broadening [3]. White beam imaging add information e.g. observing decomposition in hydride experiments [4]. Event-mode readout enables high rates, neutron/gamma discrimination, and center-of-gravity positioning algorithms for quantitative imaging of irregular samples.

By integrating diffraction and imaging, HIPPO enables unique multimodal experiments e.g. combining texture analysis from diffraction with spatial grain mapping for characterization of large-grained samples. We report on the calibration and show example applications of the new capabilities such a wire silver specimen from New Mexico, a large-grained steel sample from a reactor pressure vessel, and Bragg-edge imaging on depleted uranium.

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T3: ODIN @ESS – Finalizing the construction and preparing for Commissioning and First Science

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The proposal for the ODIN (Optical and Diffraction Imaging with Neutrons) instrument was submitted in 2012, and the Neuwave workshop has played a significant role in its development. Thanks to a collaborative effort spearheaded by our in-kind partners, PSI and TUM, and driven by the dedicated work of scientists and engineers, ODIN is on track to become one of the first instruments to receive neutrons by the end of 2025. As the ~12 million Euro construction project approaches completion, ESS is preparing for the commissioning and operational phase of the instrument.

In this presentation, we will provide an update on the latest progress and address the challenges encountered in completing the instrument. We will also outline the commissioning plan for ODIN, which includes nine choppers, a T0 chopper, and a ballistic guide system. Additionally, we will discuss the unique challenges and opportunities associated with operating ODIN on a long-pulsed neutron source and the implications of ESS imposing a stringent standard for data acquisition and data storage.

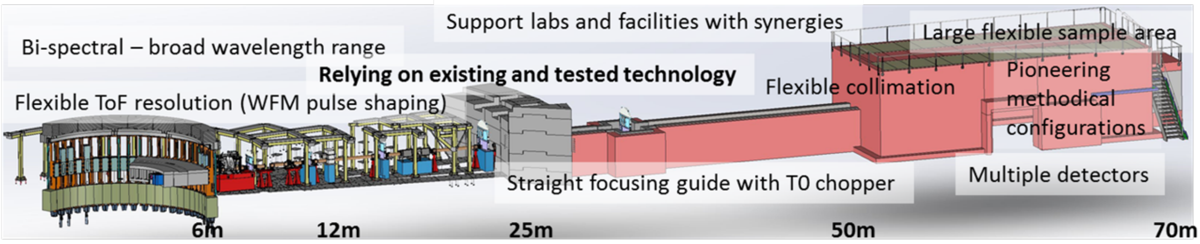

Figure 1. *ODIN layout, several key components are housed inside the common bunker area*

T4: Using pyrolithic graphite crystals as secondary source in neutron imaging

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At WCNR 12, we reported about creating a vertical neutron beam by 90 degree reflection of a horizontal neutron beam to the vertical for the examination of thin liquids.

In this presentation, we want to discuss more aspects of the use of pyrolytic graphite crystals as an effective secondary source. The mosaicity of the crystals destroys the initial collimation of the neutron beam and makes collimated imaging on short distances impossible if the sample is not very close to the detector. However, by increasing the distance between the crystal and the sample, the crystal size acts as effective 'D' in the collimation L/D, with the mosaicity adding only slightly to this unsharpness. Measurements at ATI and ILL will be discussed as well as new ideas for the use of crystals, and additions to existing double crystal monochromators in imaging facilities.

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T5: Multimodal neutron investigation of sodium-ion batteries as a diagnostic tool to track battery operation and failure mechanisms

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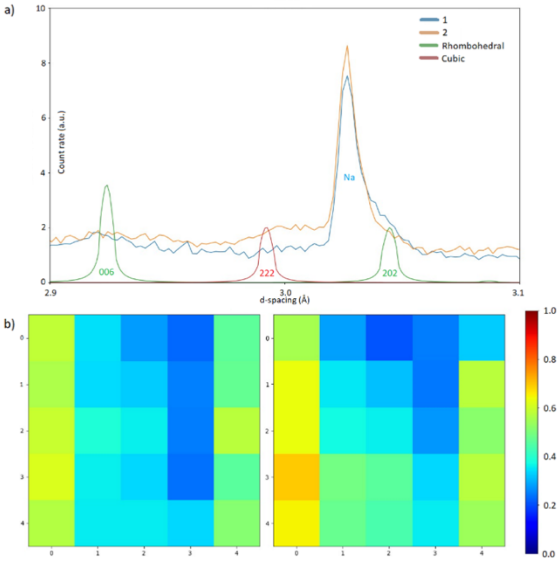

Figure 1. Diffraction pattern (a), and phase mapping of the cell (b). Dark red means total cubic content, dark blue full rhombohedral.

Sodium ion batteries are promising devices that could be a cost-competitive alternative to Li-ion batteries. The expected lower costs, higher safety, and sustainability of such devices would make them one of the best choices for large-scale grid storage, which is essential to store energy produced by renewable sources [1]. This technology is still relatively new, therefore there currently is a lack of operando studies performed on them [2]. To investigate the operando functioning of such a cell, an experiment was performed at SENJU (J-PARC), where a Prussian white Na-ion half-cell was cycled and measured with combined neutron powder diffraction and Bragg-edge imaging. The neutron powder diffraction provided a general overview of the phase transitions occurring during the charge/discharge cycles. Simultaneously, the Bragg-edge imaging provided spatially resolved information which validated the diffraction data, and also served as a way to follow mechanical degradation processes, such as electrode disconnection. Figure 1a shows the diffraction pattern before (pattern 1) and after (pattern 2) a charge step, which shows an increase of cubic phase, observable through higher intensity for the [222] cubic peak. Figure 1b shows a phase mapping, where upon charging, we see an increase in cubic phase, primarily occurring on the left side of the cell. This powerful multimodal approach proves capable of tracking battery operation with high precision.

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T6: Operando visualization of current flow in energy devices using polarized time-of-flight neutron imaging

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In this presentation we show the results of our recent endeavors to map the current flow inside various energy devices, and correlate it with device performance.

We show results from two recent beamtimes performed at JPARC-RADEN in which a commercial LCO battery and a PEM electrolysis cell were imaged in operando using polarized neutron imaging (PNI), to determine the current flow throughout the samples via the magnetic fields induced by the current flow.

PNI is a technique capable of imaging the magnetic field along the neutron flight path, and utilizing this it is possible to measure changes in the magnetic field inside the samples as it operates. We discuss how to properly measure these fields, and how a correlation between the magnetic changes and an underlying current distribution can be found across different types of energy devices.

Utilizing wavelength-resolved time-of-flight(ToF) imaging, we demonstrate the separation of the magnetic signal from any dynamic attenuation effects caused by structural changes inside the energy device, allowing proper interpretation of the polarization image. Furthermore, ToF analysis allows for a high accuracy assessment of the strength of the magnetic signal, enabling a complex analysis of the underlying mechanisms via modelling comparisons.

Figure. 1 presents the initial polarization data for the battery experiment. A strong regional magnetic response changes location and shape between charge and discharge cycles. Through ToF analysis the underlying mechanisms for such a signal can be found.

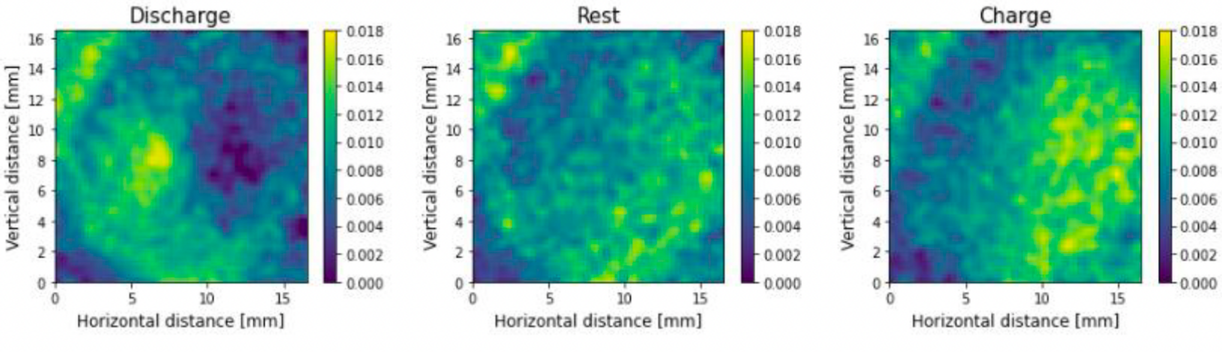

Figure 1 Polarized neutron imaging of 16.5mm commercial LCO coin cell battery summed over 5 cycles for discharge, rest and charge state, blurred with $\boldsymbol{\sigma}$ *_= 1 for visual aid.*

T7: Polarised neutron imaging at ILL

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Polarised neutron imaging is a well-established powerful technique for investigating magnetic properties of samples [1-3]. By making use of the intrinsic magnetic moment of the neutrons, a magnetic field in and around a sample can be visualised as alterations on the transmitted neutron beam. This method is based on the spatially resolved measurement of cumulative precession angles of a collimated, polarised, monochromatic neutron beam going through a magnetic field. The very high neutron flux at NeXT@ILL is employed to achieve high resolution and a good signal-to-noise ratio with reduced acquisition time. This allows for investigation of phase transitions in bulky materials and provides sensitivity to current density changes in renewable power sources and energy storage systems like fuel cells, batteries and capacitators. In this contribution, we present a tomography done with polarised neutrons on an additive manufacturing sample which has previously been transformed mechanically, inducing a plastic deformation [4,5]. The aim of the study is the quantification of the proportion of austenitic to martensitic steel derived from the different magnetic behaviour of the two metallic phases.

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T8: Characterization of beryllium for neutron reflector applications at HIPPO

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Beryllium is used as a reflector material at neutrons sources in order to enhance the production of low-energy neutrons available for neutron scattering studies. Such a reflector will be installed at the European Spallation Source. In order to design the combined target/moderator/reflector system, typically Monte-Carlo calculations are carried out. Standard thermal scattering libraries available for these types of calculations assume a perfect polycrystalline material [1,2]. However, the reality is that inhomogeneities in the real material could lead to deviations from the polycrystalline state. For this reason, we performed combined neutron diffraction and transmission measurements on four samples of beryllium at HIPPO at the Los Alamos National Laboratory. In this work we present an overview of the measurements carried out and analysis using tools developed with the NCrystal software [3,4]. The results of the measurements can be used to benchmark new thermal scattering libraries for Monte-Carlo calculations [5,6].

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T9: Overview of Laue Three-dimensional Neutron Diffraction Tomography and its Applications

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Laue three-dimensional neutron diffraction tomography has emerged as a powerful and highly experimentally efficient technique for the in-depth analysis of polycrystalline and oligocrystalline materials, thanks to its ability to utilize a white neutron beam for simultaneous probing of multiple crystallographic orientations in a single scan. The methodology has seen significant progress over recent years, particularly with the deployment and commissioning of the FALCON double detector system, to serve as an add-on equipment, at the POLDI engineering diffraction beamline, at the Paul Scherrer Institute. This strategic move has enhanced the experimental capabilities and broadened the scope of Laue 3DNDT applications. Key applications of Laue 3DNDT include comprehensive grain mapping and indexing, morphology reconstruction, detailed orientation distribution analysis, as well as the detection of twinning. Additionally, the method has been useful in strain mapping and has proven invaluable in probing complex martensitic transformations. By offering detailed insights into the microstructural properties of materials, Laue 3DNDT supports the development and optimization of advanced functional materials across various fields.

This presentation will delve into the technical aspects of Laue 3DNDT, showcase its experimental achievements, and highlight its pivotal role in advancing material science research. Through case studies and practical examples, we will illustrate how this technique has revolutionized the analysis of material properties and paved the way for new innovations in the field.

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T10: Next Steps for a Bragg Edge Round Robin

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In the past few years, the idea of Bragg edge round robin activities has been presented. The aim is to benchmark the known and new capabilities on different types of neutron imaging instru-ments, and to assess levels of accuracy, precision, and detection limits of Bragg edge transmission imaging mainly for, but not limited to, strain mapping. A preliminary campaign of characterization of sample candidates for a Bragg edge round robin has been performed and lessons learned from the campaign have been reported at previous NEUWAVE meetings. Now it is imperative and timely that the Bragg edge round robin activities are defined with regard to project objectives, sample candidates, and the measurement protocol.

A set of standard samples is being proposed. This includes ring & plug samples, a AlSiC metal matrix composite, and more recently, U-flexures samples data of which will be presented. The latter sample set has the advantage of being able to produce spare set with near-identical prop-erties and, since it is one of the standard samples from EASI-STRESS[1] project, having been char-acterized with other methods, e.g., neutron diffraction and synchrotron X-ray diffraction. Strain maps produced by Bragg edge imaging on IMAT@ISIS on the new samples are presented in Fig-ure 1. At this opportunity, we will propose a list of requirement for samples, discuss a possible measurement protocol, and more importantly gather input from the community on how the round robin activities should be approached. By the end of the workshop, it is hoped that a consensus can be achieved and that a draft document can be produced which will outline when and how the round robin activities can be launched.

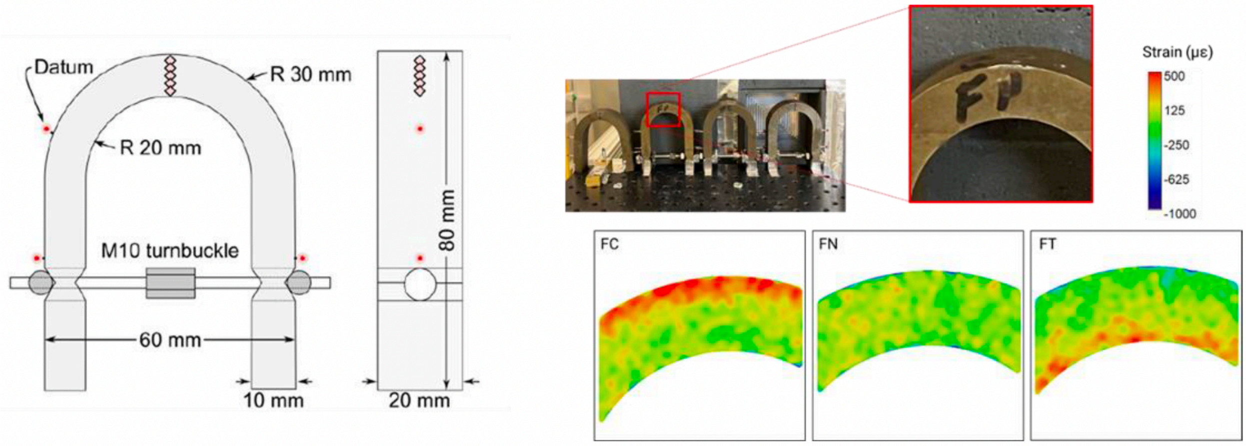

Figure 1 Strain map of U-flexure specimens measured on IMAT at ISIS. These are ferritic steel, U-shaped sample, where tensile (FT) and compressive (FC) force is introduced to the feet via a turn-buckle. Non-loaded (FN) sample is also provided for reference.

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W1: Enhanced epithermal neutron imaging applied to Heritage and Planetary sciences

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Recent advancements in an energy-selective neutron imaging method at the ISIS Neutron and Muon Source enable to perform Neutron Resonance Transmission Imaging (NRTI) within the framework of a completely non-destructive multi-techniques protocol for characterising samples in the field of Heritage and Planetary sciences.

NRTI is a non-destructive nuclear technique based on resonant neutron absorption, which merges sensitivity to elemental and isotopic composition with detailed morphological 2D data by exploiting the epithermal neutron flux available at the INES instrument of ISIS. NRTI is particularly promising for Cultural Heritage applications, especially when used alongside other techniques to provide comprehensive information about archaeological artefacts' composition and crystalline structure. A Heritage Science study is presented to demonstrate the effectiveness of NRTI in the investigations of heterogeneous artefacts, specifically focusing on excavation finds that provide the earliest evidence of ancient brass production in Milan, Italy, during Roman times [1].

Another explored field application of this imaging technique is the elemental mapping of meteorites [2]. Meteorites are a heterogeneous class of samples typically classified through average destructive quantification and petrological observation, and generally, the dominant physical characterisation techniques are limited to the surface. On the other side, neutron techniques allow the study of the bulk part of the sample without causing significant damage. In this context, the application of Neutron Resonance Transmission Imaging (NRTI) for meteorite characterisation is proposed as part of a non-destructive protocol under development. Results and comparison with other imaging and spectroscopic methods will be discussed.

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W2: White Beam and Monochromatic Neutron Imaging and the reconstruction of the casting process of ancient bronzes: an overview of results and interpretation

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The history of technology of ancient civilizations is mainly the history of their metallurgical ca-pabilities. In fact, metal tools, weapons and art objects were produced using the most advanced knowledge developed by the different civilization, since metalworking requires a wide amount of technical skill and empirical knowledge of complex thermal and mechanical phenomena. Ancient metal artefacts are often studied by extracting sections and applying analytical methods devel-oped within contemporary industrial metallurgy. Several of these methods are destructive or based on basic assumptions on sample composition and thermo-mechanical history that are not available for historical artefacts. What is necessary is, actually, a sort of reverse engineering to derive manufacturing procedures.

The most effective and, in practice, the only methods able to provide such analysis in a non-invasive way are those based on neutron methods as White Beam Neutron Tomography (WB-NT), Time of Flight Neutron Diffraction (ToF-ND) and Bragg Edge Neutron Transmission (BENT) analy-sis.

We present here an overview of the results of the analysis performed on historical bronze artefacts belonging to different civilizations and time periods obtained through WB-NT and BENT, showing how it is possible to map the main compositional, morphological and microstructural character-istics of different technological procedures. From the position of the casting moulds, recon-structed through the distribution of porosity or the presence of single crystal spots, to the identi-fication and reconstruction of welding, repair and cast-on interventions. It will be highlighted how these two imaging techniques can precisely characterize the artefacts, not only from a morpho-logical but also a microstructural point of view [1].

Thanks to the collaboration with prestigious Italian and international museum and conservation institutes, which have made it possible to study bronze masterpieces from the Bronze Age to the Renaissance, the versatility and utmost importance of WB-NT and BENT will be highlighted in deepening the diagnostic study of these artefacts, allowing a cognitive advancement not only of the materials, but also of their manufacturing history.

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W3: Event-type neutron imaging detector development at RADEN

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Energy-resolved neutron imaging using intense, pulsed neutrons at instruments such as RADEN [1] at the J-PARC Materials and Life Science Experimental Facility put severe requirements on the performance of the imaging detector used. In particular, the imaging detector should provide spatial resolution less than 1 mm, time resolution of 1 μs or less, high neutron flux capability, and strong gamma background rejection. At RADEN, we are developing and using event-type imaging detectors based on micropattern gas detectors (Micropixel-based Neutron Imaging Detector (μNID) [2]) and Li-glass scintillators (Lithium-6 Time Analyzer (LiTA) [3]) with fast, all-digital readouts. These detectors can easily provide the necessary time resolution for accurate neutron energy determination via time-of-flight, as well as event-by-event background rejection. However, the main challenge for these event-type detectors lies in obtaining optimal spatial resolution and count rate performance. The μNID detector currently provides spatial resolutions and count rates of 100 μm and 4 Mcps (^{3}He converter) / 300 μm and 10 Mcps (^{10}B converter), respectively, while the LiTA detector provides spatial resolutions and count rates of 3 mm and 15 Mcps (pixel mode) / 0.7 mm and 6 Mcps (centroiding mode), respectively.

In this presentation, we will discuss the status of our detector work at RADEN, including planned upgrades to the detectors and network infrastructure and improvements to the data processing and analysis procedures. We will also report on the performance of the μNID with new readout elements designed for improved spatial resolution and increased count-rate capability.

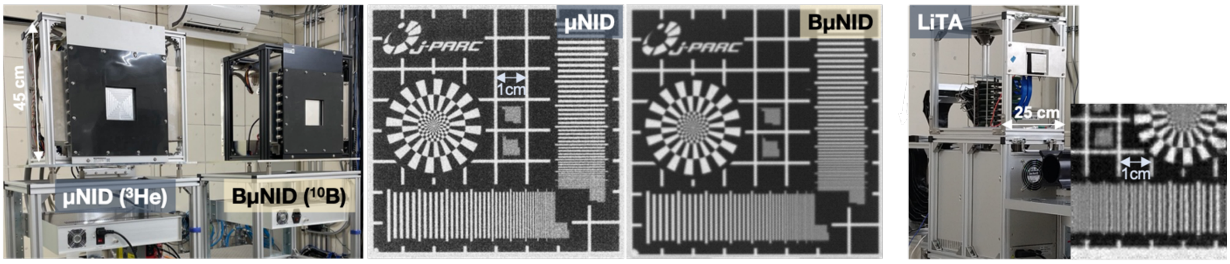

Figure 1. Photographs of detectors and neutron images obtained with a Gd test pattern for the μNID/BμNID (left) and LiTA (right) event-type detectors at RADEN.

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W4: Advancements in Imaging Detectors Based on Event Mode Data Acquisition

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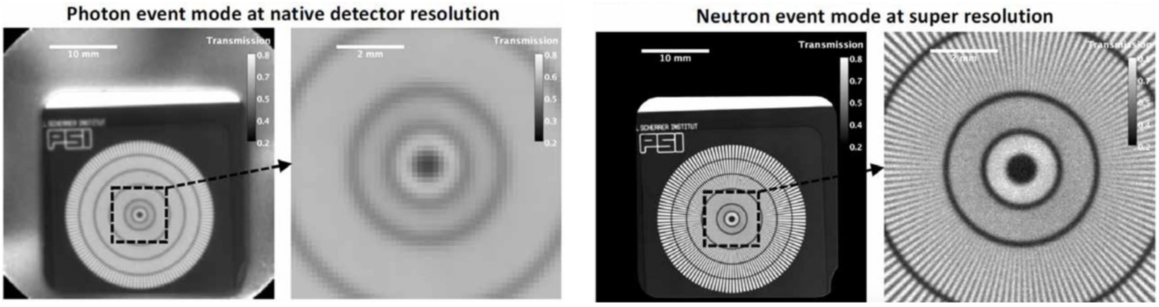
Recently developed event-driven detectors capable of resolving spots of light induced by particle interactions in scintillators opened up new perspectives for detector systems with a concept that fuses the benefits of integrating camera type with counting type detectors 1. A major drawback for many existing detectors is the tradeoff between temporal and spatial resolution. As such, frame-based camera type detectors with sub millimeter spatial resolution often provide comparatively low temporal resolution in the millisecond range with typically high readout noise, e.g. CMOS or CCD cameras. On the other hand, counting type detectors with sub microsecond temporal resolution and low readout noise, such as PMT or SMT type detectors, often come with pixel sizes in the mm range or larger.

Fundamental to fuse these two types of detectors is the capability of reading individual pixels of imaging sensors with high temporal resolution, such as is the case for the timepix3 sensor. This is achieved via sparse readout, eliminating the need of processing empty image data. Utilizing a light sensitive timepix3 sensor in combination with an image intensifier, the detection of individual neutron interactions led to a significant increase in spatial and temporal resolution beyond the classical limits of regular neutron imaging 1 via reconstruction of the center-of-mass of individual particle interactions (see figure).



Photon event mode at native detector resolution

Neutron event mode at super resolution

Based on this capability, new detectors emerged that allow for time-of-flight imaging using an adjustable field-of-view, ad-hoc binning and re-binning of data based on the requirements of the experiment, including the possibility of particle discrimination via the analysis of the event shape in space and time. It is considered that this novel concept will replace regular cameras in imaging detectors for many applications as it provides superior detection capabilities compared to conventional camera systems, shaping the future of a new generation of detection systems.

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W5: Comparative Study of Scintillator Performance for Event-Mode Neutron Resonance Imaging

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Event-cameras are revolutionizing neutron resonance imaging (NRI), a technique extending the high-precision neutron resonance transmission analysis (NRTA) method to irregular and inhomogeneous samples through imaging. These cameras enable high rates up to 80 MS/s and, through event-by-event data acquisition, facilitate neutron/gamma discrimination and sub-pixel resolution via center-of-gravity algorithms. The temporal resolution, crucial for distinguishing resonance features in NRI, especially at higher energies, is determined by the moderator neutron source time profile, but the detection system response has a large impact as well.

Our setup utilizes the LumaCam, an event-mode camera coupled to a scintillator screen via an image intensifier. However, the scintillator's long decay time (1-100 µs) can span multiple resonances, complicating spectral analysis. Therefore, scintillator choice is increasingly important.

We conducted measurements at the FP-5 beamline at LANSCE, comparing three different scintillator screens for NRI of calibration foils and irregular, complex samples. The results, analyzed using the highly validated SAMMY software, highlight each scintillator's performance and advantages for NRI.

While high scintillator efficiency enables faster measurements and tomographic reconstructions, the current setup requires limiting light collection for large fields-of-view to avoid image intensifier and camera saturation. As larger fields-of-view and thicker, more efficient scintillators become available, these limitations must be addressed to enable quantitative isotopic mapping of large samples through NRI.

W6: Material characterisation through neutron resonance absorption spectroscopy: advances in 2D quantitative isotopic mapping at the ISIS neutron and muon source

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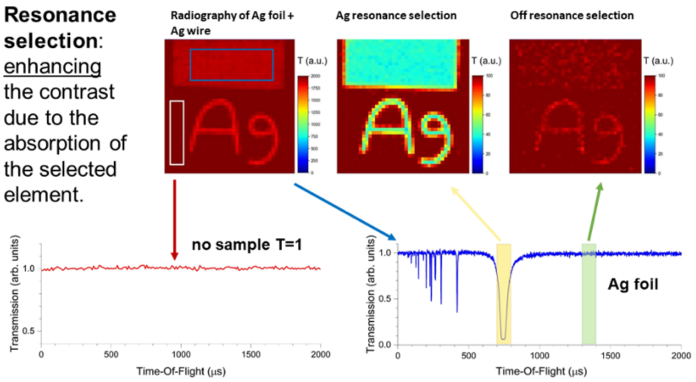
We present novel advances in the implementation of Neutron Resonance Transmission Imaging (NRTI), a non-destructive 2D elemental analysis technique, performed at the Italian Neutron Experimental Station (INES) beamline operating at the ISIS neutron and muon source, UK.

Neutron spallation sources have high epithermal neutron fluxes, which is a profitable energy range for elemental and isotopic material characterisation thanks to the presence of intense resonance structures in the neutron-induced reaction cross-sections. The NRTI technique is based on the absorption in the sample of incident epithermal neutrons whose energy correspond to the one of absorption resonances, resulting in a transmitted neutron beam containing dips univocally related to the elemental composition. With a position sensitive neutron detector, it is therefore possible to obtain 2D radiographies of the object sample, and potentially 3D chemical tomography. However, in contrast with standard neutron radiography, through NRTI it is possible to obtain the distribution of elements and isotopes by selecting a resonance of interest, enhancing the contrast between elements with similar neutron attenuation coefficients, as shown in the figure below.



This striking features of NRTI make it suitable for the characterization of inhomogeneous samples, in particular but not limited to Cultural Heritage studies [1,2]. Potential applications of NRTI will be presented and development towards making the technique quantitative.

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W7: Neutron Thermo Tomography

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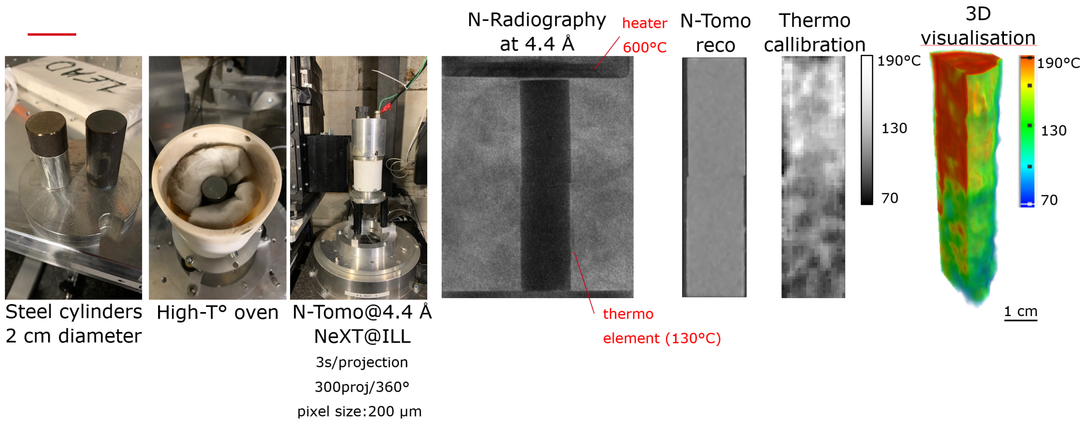
Imaging with monochromatic beams in the thermal to cold neutron energy range exploits wavelength-dependent variations in the transmitted neutron beam. For quantitative data analysis of crystalline materials, it is necessary to take into consideration that the diffracted intensity, as well as the inelastically scattered intensity, depends on the temperature of the investigated material. The Debye-Waller factor is typically used to describe the decrease of the elastically diffracted intensity caused by thermal vibrations of atoms at finite temperatures [1-4].

Here, we would like to present a new technique to investigate in-situ the temperature distribution in steel samples. The method is based on energy-selective neutron imaging in the wavelength region, where the thermal motion of atoms causes significant temperature-dependent changes of the neutron transmission [1,2]. Examples of dynamic studies of temperature distributions in welding experiments [3,4] and 3D mapping of the temperature in bulky samples will be presented.



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POSTER PRESENTATIONS

P1: Scintillators for Time of Flight Event Mode Neutron Imaging

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Event-mode neutron imaging detectors based on scintillators have recently been introduced for imaging [1] and diffraction applications. The structure of these detectors is similar to tra-ditional scintillator-based neutron imaging detectors in that they use a scintillator screen, an image intensifier, an imaging chip, and a set of optics in between these components to focus the light. The most significant difference is that the imaging chip used in the event mode im-aging detectors is fast enough to discriminate individual neutron signals and also resolve the structure of these signals in time. One of the advantages of the event-mode approach is a significantly improved timing resolution. This makes it especially suited for Time of Flight (ToF) applications. However, the ZnS-based scintillator screens most commonly used in tradi-tional neutron imaging detectors have a relatively long decay time. To fully leverage the tim-ing resolution of the event-mode detectors, faster scintillators are desirable. In addition to the improved timing accuracy, the event-mode approach also allows the identification and rejection of noise and, dependent on the scintillator, also the signal from other particles, e.g. gamma rays. This shifts the focus for optimizing signal-to-noise from the traditional view of mostly requiring as much scintillation light per neutron as possible, to a more complex con-sideration of how well the particle reconstruction algorithms can identify neutrons.

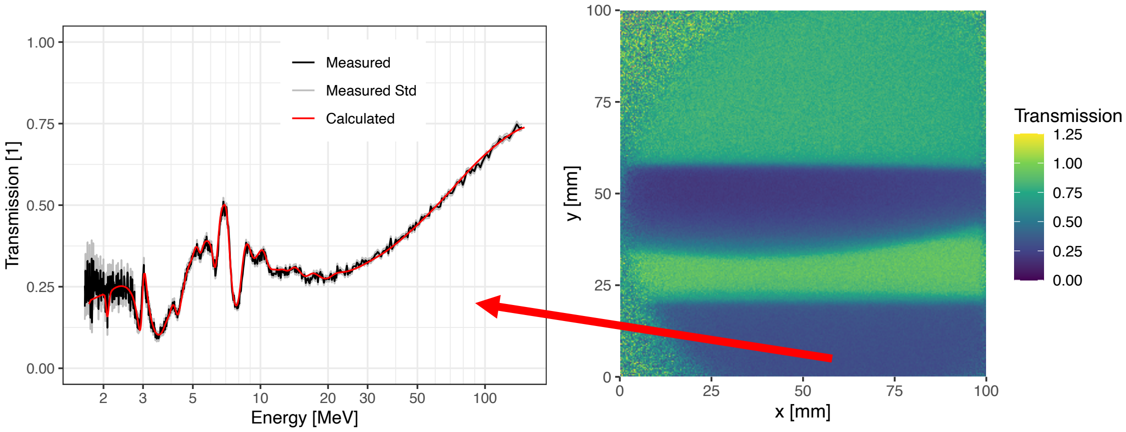

Figure 1: Demonstration image for the usage of event mode imaging for fast neutron ToF measurements. On the right is the acquired radiograph with two samples, on the left the ToF profile for the lower sample region compa-red to values calculated from literature crossection data.

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P2: Understanding and modelling phase-contrast neutron energy resolved imaging

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Propagation-based phase contrast is well established within X-ray imaging as a way to increase contrast on low attenuation materials and decrease noise via phase retrieval. Neutron phase-con-trast imaging has been shown to do the same [1], [2]. However, the phase signal may confuse attenuation measurements where the phase signal overlaps the attenuation signal. In cases where quantitative attenuation is desirable it is important to repress the phase signal or if this is not possible, filter the data. The phase contrast signal is proportional to the square of neutron wave-length, which means this parameter is central to control the phase signal in experiments. It is important to understand the wavelength and its interplay with other experimental parameters in order to optimise experiments to either amplify or dampen the phase effect.

We show results from experiments on metal foil samples (Al and Zr) designed for low attenuation and high phase contrast where we have varied neutron wavelength, sample rotation, and sample-detector distance. The experiments were performed at the ICON and BOA beamlines at the Paul Scherrer Institute [3, 4]. The results show that the wavelength is the only variable, which can re-move the phase signal entirely. The experiments were compared to simulations based on both the wave theory of the neutron and a particle-based ray-tracing simulation conducted in McStas [5]. Both simulations reproduce attenuation and phase contrast features in the data, but the McStas simulation has a better qualitative agreement with the experimental data.

We also demonstrate phase filtering of experimental data where the attenuation- and phase sig-nals are separated. Two phase-filtering approaches were applied and compared: the transport of intensity (TIE) based Paganin filter [1] and McStas simulations of the experiments. The TIE filter worked well at low sample-detector distances, but required a larger than the theoretical value for coherent scattering, which makes this method unsuitable for quantitative phase filtering. The McStas data showed good qualitative agreement between the simulation and experimental data. We present a discussion of the underlying causes and suggest further work on quantitative phase contrast analysis.

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P3: Correlative, Longitudinal Imaging: Time-of-Flight Neutron Radiography and X-ray Tomography

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There are research projects that require two or more imaging techniques---correlative imaging---applied to a sample as it evolves in time---longitudinal imaging. Examples include such diverse projects as hydrogen embrittlement in steel, degradation of lithium ion batteries, and monitoring productive in agricultural products.

This poster will present preliminary correlative, longitudinal imaging results from a newly constructed time-of-flight neutron radiography imaging system and a commercial X-ray tomography instrument. At this writing, the neutron instrument is built, testing, and awaits final operational approval from the radiation safety officials. The neutron instrument's key features include a pulsed neutron source from a DD-neutron generator operating, typically, a 500 Hz with 10 ms pulses and moderation with room temperature polyethylene. The transmission images are detected with a Li6F/ZnS scintillator and a mirror-coupled Princeton Instruments CCD with a gated intensifier. For the 1 Angstrom neutrons, 2-D images can be acquired in a few minutes.

The correlative 3-D X-ray images will be obtained with a Thermo Fisher HeliScan instrument.

The planned correlative study will include agricultural products (avocado, walnut, orange, pepper, corn). The planned longitudinal study will include monitoring hydrogen degassing from electrolytically charged carbon steel test coupons.

P4: Imaging Results at Adelphi Technology, Inc., and LSU

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Introduction to the Adelphi Technology fast (2.5 MeV DD and 14 MeV DT) neutron sources and moderated thermal neutron sources. Presented are recent applications in the areas of fast and ther-mal neutron radiography and tomography, Gamma Neutron Activation Analysis (PGNAA), boron neutron capture cancer therapy (BNCT), and Associated Particle Imaging (API).

Presented are unpublished radiographic imaging resolution and contrast results, using a pulsed Adelphi thermal neutron source (DD110M) and time of flight imaging camera gated intensi-fier/CCD (Princeton Instruments PI-MAX:2048f) at Adelphi Technology.

Also presented are results of thermal neutron radiographic imaging experiments with an Adelphi DD110M neutron generator at LSU using grating optics, applied to imaging plant roots in soil and small angle neutron scattering.

P5: Beam characterization of Time-of-Flight Neutron Imaging instrument IMAT at ISIS after upgrade of the liquid H2 moderator

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IMAT (Imaging and MaTerials science) is a neutron imaging and diffraction instrument located on target station 2 (TS2) of the pulsed neutron spallation source ISIS, UK.1,2 In addition to attenuation based neutron radiography and tomography, the pulsed beam from the spallation source enables energy dispersive (Bragg edge) imaging as well as time-of-flight diffraction. TS2 is currently undergoing an upgrade of its cold (18K) liquid hydrogen moderator which will affect several instruments including IMAT. The moderator renewal involves an increase of the thickness of the moderator vessel and improved alignment with respect to the tungsten target. The instrument performance of the new setup was simulated using McStas. Characterization of the beam includes measurement of the neutron flux, spatial and beam uniformities, and spatial resolutions for different L/D collimation ratios.1,2 The changes of the moderator are not expected to affect pulse widths over the IMAT wavelength range. Bragg edge and Bragg peak line profiles from standard samples before and after the upgrade will also be presented. 1,2 The upgrade is expected to result in a 25% increase in flux for the longer wavelength range enabling faster neutron radiography, tomography and energy-resolving experiments at IMAT.

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P6: Additive manufacturing of custom neutron shielding

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Additive manufacturing using the fused deposition modeling (FDM) allows to easily and inexpen-sively manufacture complex geometries using 3D printers. Typical base materials are thermoplas-tics such as polylactic acid (PLA) or acrylonitrile butadiene styrene (ABS). The significant increase in availability and quality of hobbyist grade 3D printers provides unique opportunities for rapid manufacturing of prototypes in science.

An important technical aspect of neutron science is shielding of samples, instrument components and sample environment. Shielding with neutron absorbing material greatly reduces the risk of radiation induced electronic failures during measurements or activation of components. The ge-ometry of the required shielding often pushes the limits of traditional manufacturing techniques.

Therefore, we recently developed a 3D printable shielding material based on PLA in corporation with ColorFabb, allowing to easily manufacture complex shielding geometries. For the shielding material PLA was mixed with boron nitride in hexagonal form, creating an easy to 3D print shield-ing material, which can be manufactured with most commercial FDM 3D printers.

In our contribution we will present the excellent shielding properties of this material determined from calculation and neutron transmission measurements (See Fig. 1 and 2) and share our expe-rience in working with this novel shielding material.

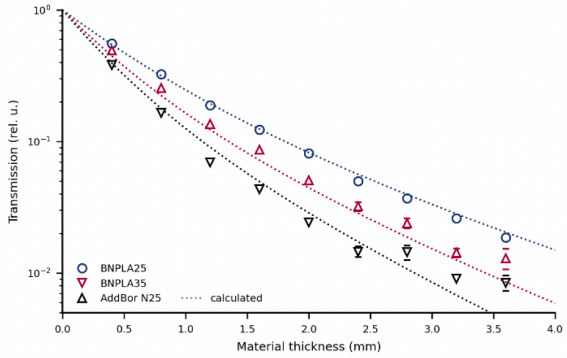

Fig. 1: Neutron transmission over thickness. Comparison between BNPLA25 (25wt% BN), BNPLA35 (35wt% BN) and AddBor N25 (25wt% B_4C). The dotted lines represent the calculated transmission for the different materials. Figure from [1].

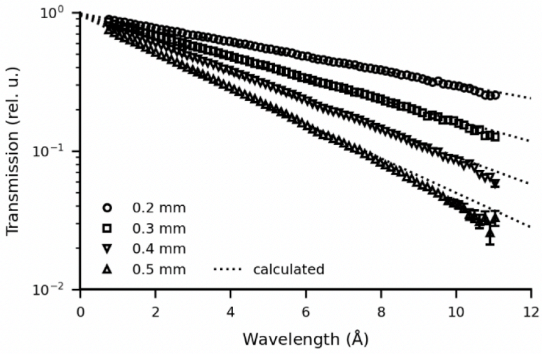

Fig. 2: Wavelength-dependent neutron transmission of BNPLA35 for varying material thicknesses as well as the corresponding calculated transmission (dotted lines). Figure from [1].

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P7: Visualization of current flow inside the porous transport layer (PTL) in PEM electrolyzer cells using neutron imaging methods

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The porous transport layer (PTL) is one of the most critical components to achieve high-performance PEM electrolyzers as it aids the transport of electrons, water, and produced oxygen to and from the catalyst layer. In this presentation, we show our latest understanding of the correlation of current flow and mass transport within the PTL with the electrolyzer efficiency.

Herein we cover the findings of two recent beamtimes performed at J-PARC-RADEN and ILL, NEXT where polarized time-of-flight (TOF) and radiography neutron imaging methods were used to determine the distribution of current flow and produced oxygen in the electrolyzer, respectively.

Polarized neutron imaging is a powerful technique that can measure magnetic field changes resulting from flowing current through the PTL layer. Using this method, we can associate the electrochemical changes happening inside the electrolyzer with the corresponding current distribution on the PTL layer during cell operation. Moreover, by applying wavelength resolved TOF imaging, we can distinguish the current induced magnetic effects from the attenuation changes caused due to structure changes, leading to a more accurate assessment of the polarization image. This can be seen by our initial polarization data for the electrolyzer cell and PTL in Fig. 1 where different regional magnetic responses were observed due to different PTL layers. Also, an in-situ investigation on two different PTLs revealed the advantage of a Pt coated PTL compared to a non-coated counterpart. Furthermore, as current flow directly influence the oxygen formation inside the electrolyzers, we examined different PTLs (varying thickness, porosity, etc…) using radiography neutron imaging to further support current distribution results in the electrolyzers.

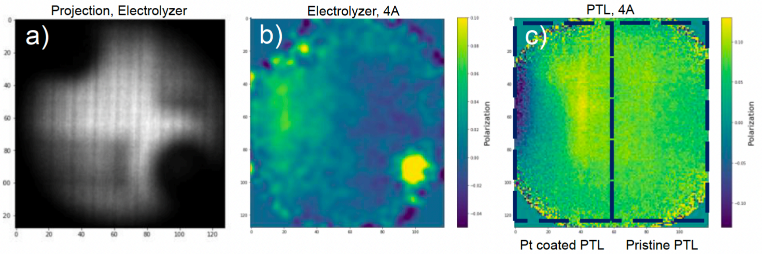

Figure 1 demonstrates a) the projection of the PTL layer inside the electrolyzer cell and b) its relative polarized neutron imaging during cell operation at 4A constant current and 60 C temperature while c) shows the polarized neutron imaging for Pt coated PTL (left) and pristine one (right).

P8: Elastic and in-elastic grain-resolved deformation behaviour in oligocrystalline materials

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Being able to experimentally characterize grain-resolved deformation behaviour in poly- and oligocrystalline samples is essential for tailoring the microstructure of engineering materials for optimal performance as well as for validating the accuracy of theoretical plasticity models.

Three-dimensional neutron and X-ray diffraction tomography methods have proven efficient at providing grain-scale morphology reconstructions of polycrystalline samples [1-5]. X-rays have additionally demonstrated stain-mapping capabilities [6]. Here, we here present a high-throughput strain mapping method based on Laue three-dimensional neutron diffraction (Laue 3DNDT) [7-9], in which the in-situ stress-induced movement of the diffraction spot centres are used to fit the lattice strains of each grain. The wavelength of each diffraction spot is resolved through the fitting analysis. We demonstrate to what degree the experimentally characterized strains can be described by model predictions, utilizing both a simple single-crystal model as well as a Fast Fourier Transform simulation that takes the overall sample morphology into account [10].

In addition to the characterization of lattice strains, we also demonstrate how the rich Laue diffraction data can be used to infer qualities of the in-elastic deformation behaviour of each grain through a quantitative analysis of the evolving diffraction spot shapes

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P9: Neutron radiography liquids under pressurized gases

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Hydrogen gas has been considered as the oil of the future, which will power a wide range of electrified transports. The production sites for green hydrogen, such as off-shore wind farms and photovoltaic stations in deserts, are typically located far from the end-users, necessitating ad-vanced storage and transport technologies for hydrogen. Liquid Organic Hydrogen Carriers (LOHCs) offer a promising solution by absorbing and releasing hydrogen gas through hydrogena-tion-dehydrogenation processes, using heat or catalysts. Compared to other technologies like ammonia conversion and liquid hydrogen, LOHCs (methanol, dibenzyl toluene, and toluene [1]) are not only non-flammable and non-explosive but also feature high energy density and scalabil-ity. They are compatible with existing fuel storage and transport infrastructures, providing signif-icant cost advantages over alternatives.

In our research, we conducted a systematic study [2] to explore how the physical properties of liquids change under exposure to methane, ethane, and hydrogen across a range of pressures (1-120 bar) and temperatures (5-60 °C), which are relevant to industrial applications. We employed high-resolution neutron radiography at the NEUTRA beamline to observe concentration changes in bulk liquids and meniscus deformation. These observations were then used to determine gas diffusivity, solubility, surface tension, contact angle, and swelling through analytical methods.

This study underscores the potential of LOHCs as a viable and efficient means of hydrogen storage and transport, paving the way for a future where hydrogen can be used reliably and safely across various applications. The findings provide valuable insights that could accelerate the transition to a hydrogen-based economy, contributing significantly to global efforts in reducing carbon emis-sions and fostering sustainable energy solutions.

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P10: Stroboscopic Bragg edge imaging applied to Ni2MnGa

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We have used stroboscopic Bragg edge radiography to visualize twin flipping in Ni2MnGa under applied magnetic field and stress. Ni2MnGa is a magnetic shape memory alloy that produces large elongations up to 6% upon application of a magnetic field at ambient temperatures. This property combined with their fast response makes this 'smart material' ideal for actuator applications.

Stroboscopic neutron imaging was performed on the IMAT instrument at the ISIS Facility using Ni2MnGa single crystals at 40 °C. A custom-made actuator produced a cyclic magnetic field of 20 Hz, and it used a restoring spring to counter the effect of the magnetic field on a crystal's twin structure. Using stroboscopic acquisition, temporal behaviour during one 50 ms cycle was studied with a time resolution of 2.5 ms.

For Ni2MnGa we observed domain contrast (Figure 1) which can be used to analyse twin variant compositions, domain size distributions and twin boundary velocities as a function of magnetic field amplitude and phase, as well as temporal crystal degradation over many actuator cycles.

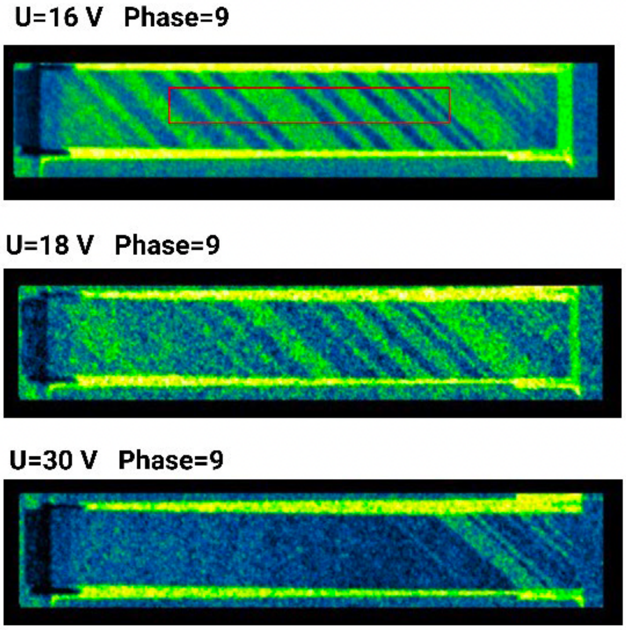

Figure 1: Visualisation of crystallographic domains in Ni2MnGa at different field levels.

P11: Detectors for the ESS beamlines – status of the installation and preparations for cold-commissioning

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After almost a decade of designing, prototyping and intense testing, the neutron detectors for the first 6 beamlines that will become operational at ESS arrived at the Lund site from the local and the partners' laboratories and workshops [1,2]. The detector modules for the LoKI, DREAM, BIFROST, ODIN, NMX and the Test beamline are currently being installed in the support structures and connected to the associated readout electronics or undergoing the last inspection test before installation. The cold-commissioning activities with cosmic rays will be preceded by a pre-commissioning phase which will include connectivity, noise and grounding tests, configuring the detector readout with the proper settings and testing the functionality of the slow-control. This paper presents the current status of the detector installation at ESS and the plans for the commissioning to attain the optimal performance and level of readiness required to move the beamlines toward the operational state.

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P12: ESS Testbeamline: Readiness to Beam-on-Target to characterise milliseconds pulsed neutron source

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European Spallation Source (ESS) will deliver first neutron beam (BOT) in autumn 2025. Test beamline (TBL) will be the first instrument station to verify the success of ESS spallation process. A simple principle of TBL using camera obscura provides flexibility to measurements. This will include characterisations of not only thermal-cold neutrons but also epithermal-fast neutrons as well as gamma radiations. During the early stage (up to 3 months), the beam power will start from very low, i.e., tens of Watts, where the focus in this stage dedicates to commissioning of the accelerator and spallation target. Meanwhile, the beam power will increase up to 200 kW, where the proton beam energy is varied between 400 – 800 MeV. The pulse width of proton beam starts from 5 μs to 2.86 ms. For these parameters, an estimate thermal-cold neutron flux at TBL cave is 10^2-10^5 n/cm^2/s at the TBL cave. Due to such low to medium flux, a preparation of measurement is carefully designed to ensure the readiness for neutron measurement since BOT.

TBL provides time-of-flight detectors have been foreseen to be used for the measurements including: i) neutron gas-electron multiplier (nGEM) utilising neutron capture of double ^{10}B sheets, ii) 4 tubes of He-3 detectors, iii) CMOS camera coupled with an image intensifier, iv) in-house multiblade detector, and v) TimePix3 detector. Several filters can be used to attenuate or select neutron energy. We expect to detect very first neutrons which needs high efficiency detector, e.g., He-3 tubes, for integrated intensity detection of neutrons. A position-sensitive detector like nGEM or camera will be used to observe spatial-resolved neutron beam generated from ESS moderator. Simple single/poly crystal diffraction will be carried out, using the multiblade detector to characterise beam pulse. Figure 1 shows a schematic layout of ESS Test Beamline.

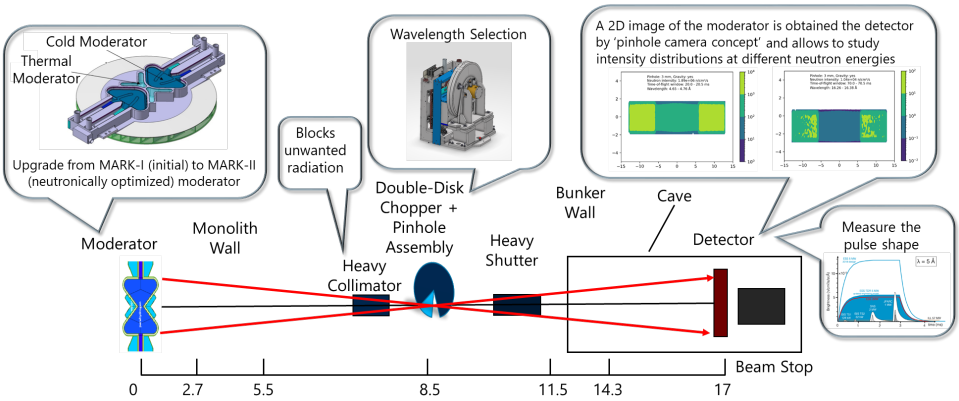

Figure 1. ESS testbeamline (TBL) layout.

P13: Polarized neutron imaging at CARR and observation of trapped flux in superconductors

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Neutrons have 1/2 nuclear spin and neutral electrical charge, enabling deep penetration into matter and interaction with magnetic field, making them an ideal probe for magnetic fields. CARR has recently outfitted its cold neutron imaging facility with a polarized neutron imaging (PNI) option, with a V-cavity polarizing supermirror as polarizer and an *in-situ* spin-exchange optically pumped ^{3}He system as spin analyzer. The facility can switch between white-light and energy-selected mode using a double-crystal PG monochromator. In the shakedown voyage, we have observed the trapped flux in a piece of superconducting Niobium. In order to explain the measured data, we developed a technique for calculating the effect of flux pinning on magnetic field, using existing finite element method (FEM) software with commonly available magnetostatic solvers. The measured results could be well explained with McStas simulations using calculated field distribution as input, demonstrating the possibility of observing pinned flux using PNI, and modelling the results using numerical calculations.

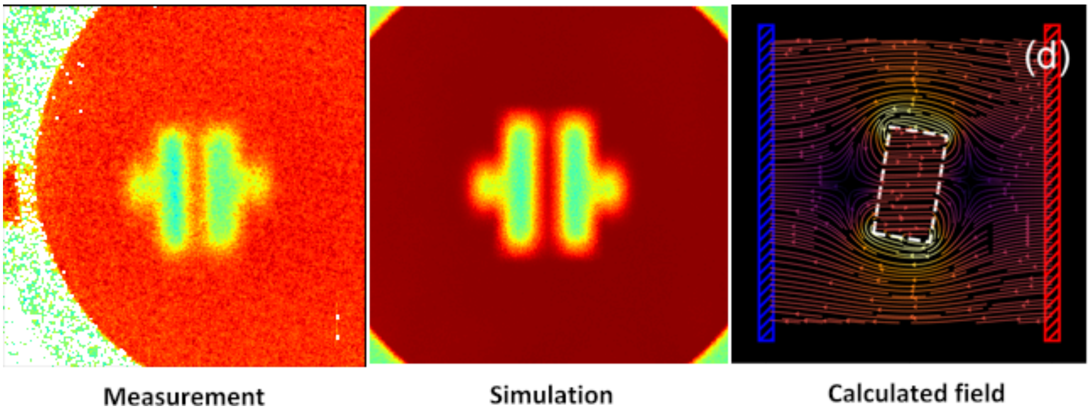

Figure 1: From left to right: measured polarization transmission, simulated polarization transmission, and magnetic field calculated using the FEM method

P14: Data reduction and Analysis at ODIN

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The poster will provide an overview of the planned data reduction and analysis at the ESS imaging instrument ODIN.

P15: Hydrogen embrittlement - the role of wavelength resolved neutron imaging

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Hydrogen embrittlement (HE) significantly impacts metallic materials, especially in engineering alloys under corrosive and mechanical stress. Atomic hydrogen, introduced via electrochemical or gaseous processes, causes lattice deformation and strain localization, leading to material failure. Although mechanisms such as adsorption-induced dislocation emission and hydrogen-enhanced local plasticity have been proposed, understanding and detecting hydrogen's effects in metals remain challenging.

Neutron techniques, with their deep penetration and high sensitivity, offer a promising approach. While neutron diffraction can monitor changes in lattice parameters and dislocation density and correlate them with hydrogen content during in-situ tests, neutron imaging can directly detect hydrogen. Using neutron radiography, it has been demonstrated that a few wt.ppm of H in Zr alloys can be detected, where H precipitates as zirconium hydride and is hence immobilized. Neutron tomography has been used to visualize localized hydrogen in technical iron, though pre-charged samples have shown artificially high hydrogen levels.

However, the potential of these techniques has not been fully exploited due to the lack of suitable sample environments and measurement protocols. This poster will showcase the challenges encountered during recent experimental campaigns and discuss possible ways forward to enable significant progress using wavelength-resolved neutron imaging.

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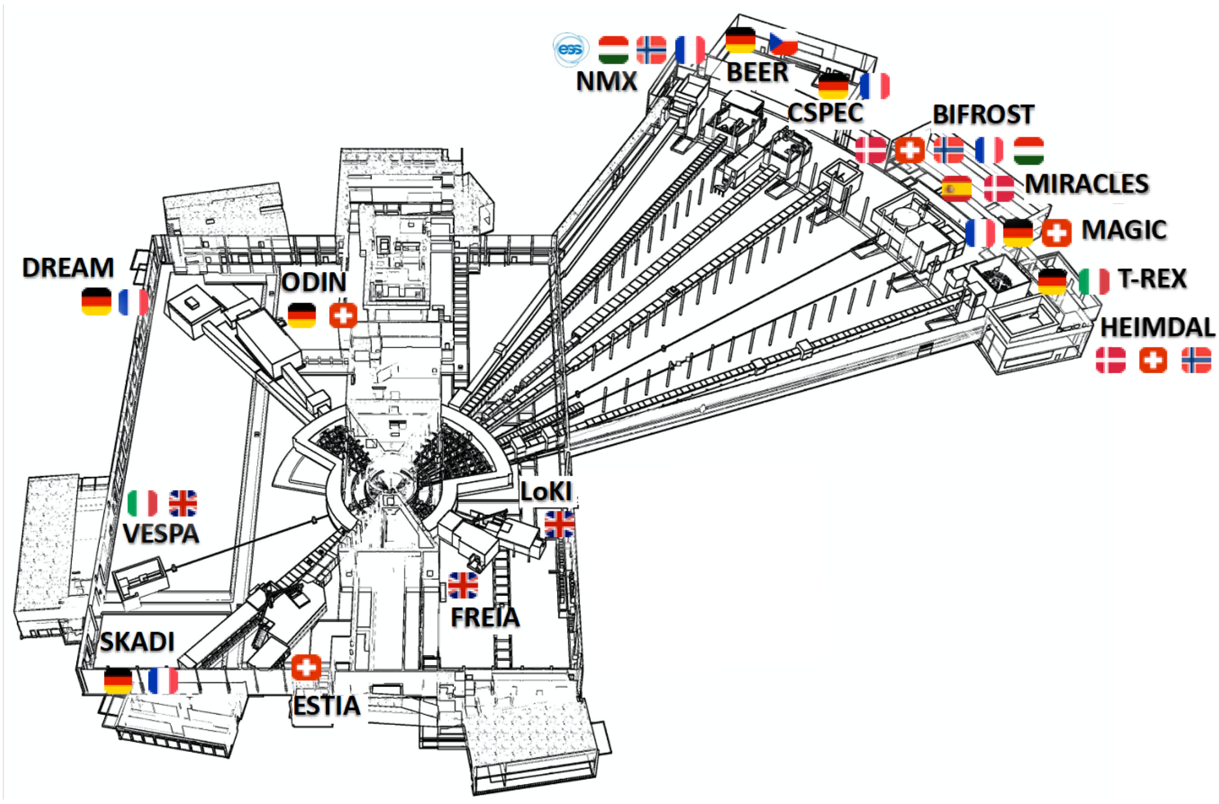
EATING IN LUND


SPOLETORP
Govindas Vegetarian Restaurant
House of Salads
Karl XI gatan
Lund C
The Bishops Arms
The Herbivore
Bangatan
Inferno
Mui Gong
AF Borgen
Ihsiri
Hummus Bar
Fengsson Dumpling House
Izakai
Lunds domkyrka
Grand Hotel Lund
Thuy
The South Indian
Five Flower Noodle Bar
Italia il Ristorante
John Scott's
Mediterranean
Svanegatan
Hotel Concordia
Lundafalafel
M.E.A.T.
CENTRALA STADEN
Osteria Cucco
Trädgården
Högevall
Temporarily closed
Lilla tvärgatan
Grönegatan
Aiko Sushi
Hos Talevski i Stadsparken
Stadsparken
Nöden
Bankgatan
Råbygatan
Södra Esplanaden
Biskopsgatan
Sölvegatan
Google

- House of Salads (Sun: Closed / Mon-Thu: 10.00-19.00)
- Govindas Vegetarian Restaurant (Sun: Closed / Mon-Thu: 11.00-15.00)
- The Bishops Arms [Pub] (Sun-Mon: 16.00-22.00 / Tue-Thu: 16.00-00.00)
- The Herbivore [Vegan] (Sun: Closed / Mon-Thu: 14.00-01.00)
- Hummus Bar [Vegetarian] (Sun: Closed / Mon-Thu: 11.00-19.00)
- Ihsiri [Southeast Asian] (Sun: 12.00-17.00 / Mon-Thu: 11.30-22.30)
- Mui Gong [Chinese] (Sun: Closed / Mon-Thu: 11.30-22.00)
- Inferno [Pub] (Sun: 14.00-23.00 / Mon-Tue: 14.00-00.00 / Wed-Thu: 14.00-01.00)
- Fengsson Dumpling House (Sun: Closed / Mon-Thu: 11.00-19.30)
- Izakai [Japanese] (Sun: Closed / Mon-Thu: 11.00-14.30)
- The South Indian (Sun-Thu: 11.30-21.00)
- Thuy [Vietnamese] (Sun: Closed / Mon-Thu: 11.30-14.30 & 17.00-21.30)
- Five Flower Noodle Bar (Sun: Closed / Mon-Thu: 11.30-20.00)
- Italia il Ristorante (Sun: 12.00-21.30 / Mon-Thu: 11.30-22.00)
- Mediterranean [Greek] (Sun: 13.00-22.00 / Mon-Thu: 14.30-22.00)
- John Scott's [Pub] (Sun: 12.00-18.00 / Mon: 12.00-22.00 / Tue-Thu: 12.00-23.00)
- Mezaya - Cafe&Restaurang [Lebanese buffet] (Sun: Closed / Mon-Sat: 11.00-20.00)
- M.E.A.T. (Sun: Closed / Mon-Thu: 11.30-23.00)
- Lundafalafel [Takeaway only] (Sun: 12.00-22.00 / Mon-Thu: 11.00-22.00)
- Osteria Cucco [Italian] (Sun: 12.00-20.00 / Mon-Thu: 12.00-22.00)
- Trädgården [Swedish] (Sun: Closed / Mon-Thu: 12.00-23.00)
- Aiko Sushi (Sun: 12.00-21.30 / Mon: Closed / Tue-Thu: 11.00-21.30)

THE ESS INSTRUMENT SUITE

- Imaging × 1
- SANS × 2
- Reflectometers × 2
- Spectrometers × 5
- Diffractometers × 5
- Test Beamline × 1



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