ESS Science Symposium 2012

Physical simulations of processes in engineering materials with in-situ neutron diffraction/imaging

15-16 November, 2012, Prague, Czech Republic

REPORT

http://ofm.fzu.cz/ess-prague

1. The scope of the Symposium

The ESS Science Symposium **„**Physical simulations of processes in engineering materials with in-situ neutron diffraction/imaging**“** was organised with the goal discuss with the specialists in the field the potential of the idea to carry out at ESS Spallation source a special kind of engineering diffraction research - **Physical simulation of materials fabrication, processing and/or testing under extreme loading conditions and complex loading histories.** It involves the exact reproduction of the thermal and mechanical processes in the laboratory that the material is subjected to in the actual fabrication, processing or end use. The concept was formally introduced into engineering metallurgy field by a company Dynamic System Inc. to explain the use of their equipment (special thermomechanical rigs Gleeble equipped with ultrafast heating and cooling, complex loadings, high temperature and vacuum chambers). The physical simulation concept can, however, be employed in many other fields and industries beyond the material engineering.

Physical simulator Gleeble brings a small piece of the material into the required material state by sequences of thermal and mechanical loads resembling as closely as possible the conditions the material is exposed to in the large scale fabrication process. Time evolution of macroscopic parameters as force, strain, temperature is recorded during the treatment. When the simulation is accurate (in the sense that of lab treated material exhibits desired microstructure and properties), the results can be readily transferred from the laboratory to the large scale production process. **Main goal of Physical Simulations in material engineering field is thus to develop new processing technology in laboratory scale and transfer it afterwards to the full scale industrial process.** The method is currently widely used by materials engineers to efficiently optimize the large scale material production routes used in the industry. It is essential to understand the difference between thermomechanical testing and physical simulation. While all physical simulations involve physical testing, the key difference is that physical simulation attempts to replicate real-world processes on a laboratory scale in a way that the resultant data can be used to solve real-world problems.

It is essential that the material follows during the physical simulation the same thermal and mechanical history that it would do in the full scale fabrication process. If this is the case, it can be reasonably assumed that microstructure and properties of the material evolve during the physical simulation as it would do in the large scale process. Since this is never guaranteed, researchers performing physical simulations always try **to follow the evolution of microstructure and properties of the material by conventional ex-situ metallurgical methods** (ex-situ metallography, SEM, TEM, hardness test etc.).

At the same time, mechanical engineers who help to design new better performing engineering materials simulate the materials processing by **numerical models which are capable of predicting the evolution of microstructure and properties of materials** with exactly same ultimate goal - to optimize the large scale production routes.

Evolution of microstructure - property in processed engineering materials thus play key role in both physical and numerical simulations of material processing. **It is the major benefit of neutron and high energy X-ray diffraction methods for material engineering field, that these methods can be employed to track down the evolution of material state (microstructure, internal stress, texture) in-situ during the physical simulation without disturbing the process.**

Although several X-ray/neutron diffractometers dedicated for engineering studies at large scale facilities (e.g. ENGIN-X, SMARTS, VULCAN, TAKUMI) have already been used for variety of "in-situ engineering studies" (time resolved characterization of deformation, phase transformation, residual stress, texture, and microstructure changes during material synthesis, processing, and service), these fell short of representing true Physical Simulations introduced above due to the limits posed by the installed environment - e.g. low deformation speed (forging simulations), low heating rates (welding simulations), low cooling rates (phase transformation during cooling), simple loading modes (rolling, forming) etc..

The above mentioned "In-situ engineering experiments" have been recently steadily gaining in importance and frequency at large scale neutron and high energy X-ray facilities. At the same time Physical Simulation experiments for industry seem to suffer from the lack of in-situ obtained information on evolution of microstructure and internal stresses during thermomechanical processing (currently used ex-situ metallography and electron microscopy is time consuming and frequently not does not provide actual information on the material state which existed in particular stages of the thermomechanical process). **If there is a dedicated material engineering beamline where Physical simulations with neutrons can be carried out, it would be a major step forward that would facilitate the optimization of large scale industrial production routes and better engineering materials could be possibly produced.**

Based on these facts, we have identified „Physical simulations of processes in engineering materials with in-situ neutron diffraction/imaging“ as a potential area for future neutron engineering research on material engineering beamline at ESS and decided to organize ESS Science Symposium on this topic as a brainstorming activity.

2. Preparation of the Symposium

In order to fulfill the goal of the symposium introduced above it was necessary to bring to the symposium representatives of the 3 relatively distinct R&D communities :

1) **engineers and material scientists involved in engineering material research using Gleeble simulators** (researchers carrying out physical simulations for industry) ,

2) **members of neutron diffraction community involved in engineering studies** (neutron instrument scientists, and instrument developers),

3) **material scientists who are actively involved in in-situ neutron and/or X-ray diffraction studies of advanced engineering materials** (typically academic researchers who recognized the power of X-ray and neutron diffraction/imaging to perform world class research in materials engineering field).

The symposium website, personal contacts and support of ESS helped us to assure interests of key representatives of the communities 2 and 3 (Appendix I) but they were not sufficient to attract sufficient interest from members of the community 1. In order to solve this problem, as well as to better understand the actual needs and prospects for physical simulations with neutron diffraction, we have attended meetings of the community 1 – e.g. Workshop on Gleeble Welding Process Simulation held on February 27-28 in Graz Austria or Gleeble European user group meeting held in Delft in Netherlands on April 24-25, 2012 and presented there our ideas to metallurgists and material engineers. Representatives of the community 1 were invited to attend the ESS Science Symposium in Prague. **The ESS Science symposium** itself was then held on Thursday-Friday, November 15-16, 2012 in hotel Amarilis located in central Prague, Czech Republic with two satellite events - **CEED Expert Meeting** prior and **SPEED workshop** after the symposium.

3. CEED Expert Meeting prior the Symposium

The Expert meeting was held on Wednesday, November 14 in Rez near Prague (Appendix III). The main reason for organization of the CEED Expert meeting prior the symposium was to discuss separately the concept of the CEED diffractometer designed by the Czech team with the instrument scientists working at neutron engineering diffractometers at major large scale neutron sources. **Ke An** (VULCAN, SNS), **Stefanus Harjo** (TAKUMI, J-PARC), **Bjorn Clausen** (SMARTS, LANL), **Shu Yan Zhang** (ENGINE-X, ISIS), **Jiří Kulda** (ILL) who came to Prague to attend the ESS Science symposium attended this meeting. **Axel Steuwer** on behalf of ESS, Prof. **Yo Tomota** from Japan and 6 members of the Prague team joined this meeting.

After the morning special scientific talks by S. Harjo and B. Clausen, the attendees visited neutron diffractometers installed at the Řež research reactor LVR-15. The essential part of the meeting was the **3 hour roundtable discussion which followed the talk by Jan Šaroun on the Current concept of the design of the diffractometer CEED for ESS**. Details concerning issues discussed during the roundtable discussion and conclusions of the Expert meeting are covered by a special internal report.

4. Content of the Symposium

Two day program of the ESS symposium (Appendix II) consisted of 5 blocks of lectures in which invited participants presented 10-20 minutes long presentations.

1. ESS Update
Review on the progress of ESS construction.

2. Neutron and X-ray diffraction studies of engineering materials
Facilities, methods, experiments, results.

3. Metallurgy, testing and modelling of thermomechanically loaded engineering materials
Industrial demands, fabrication, processing, physical simulation, testing, microstructures, modelling.

4. In-situ neutron (X-ray) diffraction/imaging studies of engineering materials
Approaches, methods, case studies.

5. Current status of planning of engineering diffractometers for ESS
Presentation on ESS engineering diffractometer and roundtable discussion.

After a brief update on the ESS construction by A. Steuwer and M. Strobl, instrument scientists from engineering diffractometers at LANSCE, ISIS, SNS, PSI and J-PARC gave excellent overview of the current state of art of the instrumentation used to perform in-situ engineering studies using neutron diffractometers and identified major challenges for such research at ESS. In the next block of lectures, Brian Alen from the DSI company described the state of art Gleeble simulators and D. Fabregue and G. Korpala introduced Physical Simulation methods and demonstrated the need for in-situ information on phase transition, stresses and microstructures in it. Majority of further speakers focused variety of in-situ neutron and X-ray diffraction studies on advanced engineering materials. Antonio Jose Ramirez Londono, from LNLS, Brasil shared his experiences with installation of the Gleeble simulator on the synchrotron at LNLS in Brazil. In the last block of lectures, the two merging CEED and SPEED concepts of the engineering diffractometer planned for ESS were briefly presented. The PPT slides the invited speakers used for their presentations well collected after the symposium.

5. SPEED workshop after the Symposium

Since the project for building engineering instrument for ESS proceeds in collaboration of Czech and German teams and practically all their members participated in the ESS Science Symposium on November 15-16 2012, it was decided to organize a special meeting of the two teams the day after the symposium on Saturday, November 17, which would be open to the other specialists who could stay one day more in Prague. Since the idea was originally proposed by the German team working on the design and development of the **Structured Pulse Engineering Diffractometer (SPEED)** the meeting was called simply **SPEED workshop.**

The program of the workshop (Appendix IV) started with discussion on the activities related with the planning for Engineering beamline at ESS coordinated by M. Strobl and A. Steuwer. S.-Y. Zwang from ENGIN-X (ISIS) and Ke An from VULCAN (SNS) reported on new activities at these prime neutron instruments. Following that, R. Kampmann introduced recent advance in the Design and expected potential of the **Structured Pulse Engineering Diffractometer (SPEED)** for ESS. H.-G. Brokmeier presented a very interesting talk concerning the advantages of neutron diffraction for texture studies and emphasized the industrial needs and interests in texture studies. P. Sittner briefly introduced ideas of the Prague team for environment to be installed at the engineering beamline at ESS that were mainly discussed in the afternoon discussion.

6. Conclusions from the event

The ESS Science symposium in Prague brought together for the first time members of community of engineers and material scientists who perform Physical simulations on Gleeble simulators with researchers involved in neutron and/or X-ray diffraction engineering studies of advanced engineering materials.

The symposium delivered a very good overview on the current status of the instrumentation used at engineering neutron diffractometers worldwide (diffractometer components and environment). The pointed out issues include:

1. Although the beam time request for strain scanning and texture studies remains high, demand for in-situ experiments has been steadily growing and it is expected to increase further. This contrasts with the prospect for strain scanning and texture studies which is expected to remain flat.
2. Advantages of the possibility of continuous data recording during in-situ studies with high intensity beam were emphasized (already common at high energy X-ray sources)
3. Main advantage of neutrons in the fierce competition with synchrotron X-rays in the material engineering field remains to be the possibility to have large gauge size for engineering materials with large grain sizes and ability to perform 3D scans through large bulk volumes.
4. The advantages of yet rarely used 2D detectors for in-situ experiments on engineering materials were emphasized
5. Benefits of the possibility to carry out some sort of imaging experiment on the same piece of sample was emphasized.
6. Benefits of the possibility to obtain at least partial information on texture evolution during in situ experiments was emphasized.
7. Benefits of maximized detector coverage of the engineering instruments were pointed out.
8. It was agreed that the currently used environment at engineering diffractometers does not allow to perform in-situ studies of true engineering processes due to the limits as sample size, heating/cooling rates, complex state of stress, long term experiments etc.
9. The range of environments used at modern engineering diffractometers (furnaces, cryostats, deformations rigs, scanning tables, robots, hexapod platforms, magnets, environmental chambers) is extremely wide and it is projected to grow significantly towards user defined environments motivated by industrial needs.
10. It was noted by some instrument scientists that, although it is important to cover wide area of material engineering problems, particularly if there is only one engineering beamline at the facility, there is a danger that, due to the shortage of financial and personnel resources, at some point, it will not be possible to perform all the work well. It was noted that there is a lesson from synchrotron beamlines, where they soon realized that, although they could do really great science, the results were not coming, since the instrument and environment were not user friendly.

It became obvious from the presentations of material engineers, that **the idea of the installation of Gleeble simulator on neutron beam at ESS is merely a projection of the current booming area of in-situ neutron and/or X-ray engineering studies** (most of the speakers presented results of such in-situ investigations) **to the industrially compatible scale and wide range of extreme conditions and loading histories.** Though the idea itself was generally welcome, many technical issues were raised. The pointed out issues include:

1. There exist relatively large and **well organized industrial/academic Physical Simulation community worldwide** represented by material engineers who are skillful in operating Gleeble simulators to simulate different kind of industrial processing i.e. welding, forging, melting, solidification etc.
2. Providing such physical simulation community with a world unique facility at ESS, where physical simulation studies could be combined with neutron engineering diffraction, would assure breakthrough in the material engineering field and bring industrial attention. Installing

Gleeble simulator at ESS would level up the current state of art in-situ engineering research at the large scale neutron sources to industrial scale.

3. Although high energy synchrotron X-ray diffraction is more appropriate for time resolved physical simulation, **neutron diffraction is more suitable for application to real industrial problems** due to the possibility to work with large component, to use larger gauge volumes and to study materials with larger grain sizes. Complementary X-ray and neutron diffraction investigations during physical simulations is obviously an ideal solution.
4. Since neutron diffraction methods used in strain scanning and texture measurements on one side and in-situ studies on the other side require slightly different neutron instruments, there will be two options – i) either to have one hybrid instrument and rebuild it frequently which is extremely time consuming or ii) to consider building of two slightly different engineering instruments in the long run. First instrument could be then optimized for angular resolution (strain scanning) while the second one for time resolution (physical simulation). If such two twin instruments are closely located, they will be able to share the expensive and space demanding environments and support labs. Given the envisioned increase of the beamtime demand, **the second option of two engineering instruments located aside is definitely a better solution for ESS.** Though the second option would be more expensive, it is definitely not twice expensive, due to large extent of the sharing.
5. There is **an urgent need for long term in-situ diffraction studies which would reveal evolution of material state** (internal stress, microstructure, texture) **during long term material testing** (creep, fatigue, corrosion etc.) In contrast to the current state of art consisting in performing such experiments in the lab and bringing either set of variously treated samples or bringing one sample periodically removed from the tester to the X-ray/neutron diffractometer, where it is loaded again, there is an alternative option to perform the long term experiment in a support lab (docking station for environment) next to the neutron beamline and periodically bring the tester together with the sample (multiple samples) to the neutron diffractometer for a short time measurement e.g. once a month.
6. It was mentioned that an increasing **demand for doing in-situ neutron diffraction experiments during thermo mechanical testing under magnetic or electrostatic fields** is very likely in near future.

APPENDIX I

List of Participants

First name	Last name	Country	Institution	E-mail
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APPENDIX II

PROGRAM of the ESS Science Symposium

	PROGRAM of the ESS Science Symposium, Prague 2012			
	Wednesday November 15	**Thursday** November 15	**Friday** November 16	**Saturday** November 17
9:00		**Opening** Petr Lukáš	**Klaus-Dieter Liss** ANSTO, Australia	SPEED satelite meeting
9:10				
9:20		**Axel Steuwer** ESS		
9:30			**Helena Van Swygenhoven-Moens,** PSI, Switzerland	
9:40		**Oliver Kirstein** ESS		
9:50			**Ivan Lonardelli University of** Cambridge, UK	
10:00		**Markus Strobl** ESS		
10:10			**Alexander Evans** ILL, France	
10:20		*Coffee break*		
10:30			*Coffee break*	
10:40		**Bjorn Clausen** SMARTS, LANSCE, USA		
10:50			**Antonio Jose Ramirez Londono,** LNLS, Brasil	
11:00		**Shu Yan Zhang** ENGIN-X, ISIS, UK		
11:10				
11:20		**Ke An** VULCAN, SNS, USA	**Steven Van Petegem** POLDI, PSI, Switzerland	
11:30				
11:40		**Steven Petermans** PSI, Switzerland	**Yo Tomota** Ibaraki University, Japan	
11:50				
12:00		**Stefanus Harjo** TAKUMI, J-PARC, Japan		
12:30				
13:00		*LUNCH*	*LUNCH*	
13:30				
13:40				
13:50				
14:00		**Damien Fabreque** INSA, Lyon, France	**Jan Šaroun,** NPI, Řež, Czech Republic	
14:10				
14:20			**Jan Pilch** IP ASCR, Czech Republic	
14:30		**Brian Allen** Dynamic Systems Inc., USA		
14:40			**Reinhard Kampmann**	

14:50			HZG, Germany	
15:00 **15:10**		**Grzegorz Korpała** TU Freiberg, Germany	**Peter Staron** HZG, Germany	
15:20 **15:30**		**Thomas Kannengiesser** BAM, Germany	**Roundtable discussion** Axel Steuver, Petr Lukáš	
15:40 **15:50**		***Coffee break***		
16:00 **16:10**		**Alain Jacques** Inst. J. Lamour, Nancy,France	**Symposium closure** Farewell drink & refreshment	
16:20 **16:30**		**Ondrej Muransky** ANSTO, Australia		
16:40 **16:50**		**David Dye** Imperial College London, UK		
17:00 **17:10**		**Debashishe Mukherji** TU Braunschweig, Germany		
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19:00	**Welcome registration**	**SYMPOSIUM DINNER**		

APPENDIX III

Program and list of participants of the CEED Expert meeting

CEED Expert meeting *Saturday, Nov. 14, 2012*		
Stefanus Harjo	Japan	TAKUMI – Design Concept & Present Status
Bjørn Clausen	USA	Obtaining Material Parameters using Neutron Diffraction
		Tour the Řež research reactor LVR-15
		Lunch
Jan Šaroun	Czech Republic	Current concept of the CEED design
All		Roundtable discussion on the CEED concept

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APPENDIX IV

Program and list of participants of the SPEED workshop

Workshop on the Structured Pulse Engineering Diffractometer (SPEED) *Saturday, November 17 in Prague*		
09:00 - 10:00	**1. Welcome and overview of ESS and SPEED**	
09:00 - 09:05	Welcome	A. Schreyer
09:05 - 09:25	Overview engineering investigations at ESS	A. Steuwer
09:25 - 10:00	Design and expected potential of the Structured Pulse Engineering Diffractometer (SPEED) at ESS	R. Kampmann & M. Rouijaa
10:00 - 10:20	coffee	
10:20 – 12.30	**2. Needs, wishes and visions for engineering diffraction at ESS**	
10:20 - 11:00	Visions for engineering investigations at the ESS (invited)	P. Sittner & J. Pilch
11:00 - 11:20	Texture and strain investigations: Status and expected developments (tentative title, invited)	H.-G. Brokmeier
11:20 – 11:40	Celebration of 10 years of ENGIN-X (invited)	S.-Y. Zwang
11:40 – 12:00	Cutting edge engineering investigations at VULCAN (tentative title, invited)	A. Ke
12:00 - 12:30	**Discussion**	
12:30 - 14:00	Lunch	
14:00 - 15:00	**3. Discussion of requirements on SPEED**	

First name	**Last name**	**Country**	**Institution**	**E-mail**
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Lukáš	Kadeřávek	Czech Republic	Fyzikální ústav AV ČR, v.v.i.	kaderavek@fzu.cz
Reinhard	Kampmann	Germany	Helmholtz-Zentrum Geesthacht	reinhard.kampmann@hzg.de
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APPENDIX V

Abstract book

ESS Science Symposium 2012

Physical simulations of processes in engineering materials with in-situ neutron diffraction/imaging

November 15-16, 2012

Prague, Czech Republic

Organized by

Petr Lukáš, Nuclear Physics Institute AS CR /NPI/, Řež, Czech Republic

Petr Šittner, Institute of Physics AS CR /IoP/, Prague, Czech Republic

Table of Contents

PROGRAM of the European Science Symposium Prague 2012

	Wednesday November 15	Thursday November 15	Friday November 16	Saturday November 17
9:00		**Opening** Petr Lukáš	**Klaus-Dieter Liss** ANSTO, Australia	SPEED Satelite Meeting
9:10				
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11:50				
12:00		**Stefanus Harjo** TAKUMI, J-PARC, Japan		
12:10				
12:20 ~		*LUNCH*	*LUNCH*	
14:00		**Damien Fabreque** INSA, Lyon, France	**Jan Šaroun** NPI, Řež, Czech Republic	
14:10				
14:20			**Jan Pilch** IP ASCR, Czech Republic	
14:30		**Brian Allen** Dynamic Systems Inc., USA		
14:40			**Reinhard Kampmann** HZG, Germany	
14:50				
15:00		**Grzegorz Korpała** TU Freiberg, Germany	**Peter Staron** HZG, Germany	
15:10				
15:20		**Thomas Kannengiesser** BAM, Germany	**Roundtable discussion** Axel Steuver, Petr Lukáš	
15:30				
15:40		*Coffee break*		
15:50				
16:00		**Alain Jacques** Inst. J. Lamour, Nancy, France	**Symposium closure** Farewell drink & refreshment	
16:10				
16:20		**Ondrej Muransky** ANSTO, Australia		
16:30				
16:40		**David Dye** Imperial College London, UK		
16:50				
17:00		**Debashishe Mukherji** TU Braunschweig, Germany		
17:10				
~				
19:00	**Welcome registration**	**SYMPOSIUM DINNER**		

Symposium Dinner

The Symposium dinner will be held on the evenning of Thursday 15 November, commencing at 7.00pm, in the „U Zlaté podkovy" restaurant. It takes 30-40 min. walk from AMARILIS through the old city to the restaurant.

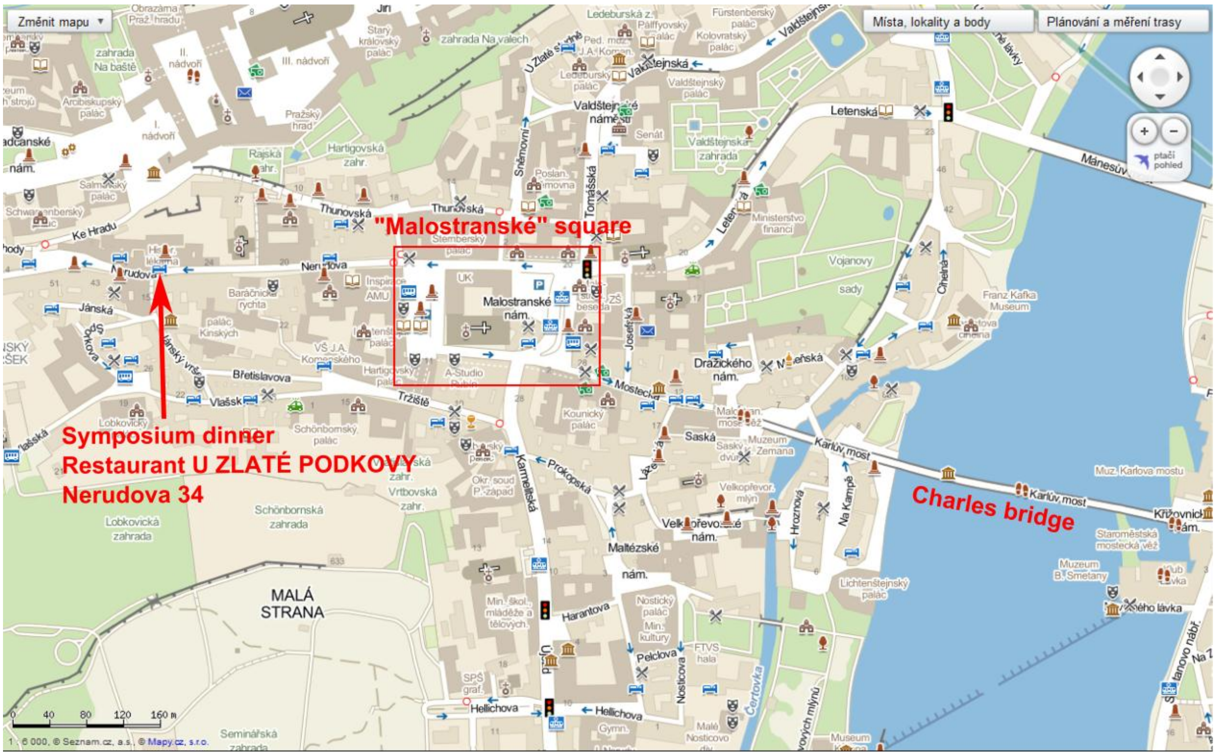
Restaurant U ZLATÉ PODKOVY

Nerudova 34

Praha 1

Česká republika

50°5'18.819"N, 14°23'54.247"E



Program overview & Abstracts

Program of ESS Science Symposium

ESS Update
Review on the progress of ESS construction.

Neutron and X-ray diffraction studies of engineering materials
Facilities, methods, experiments, results.

Metallurgy, testing and modelling of thermomechanically loaded engineering materials
Industrial demands, fabrication, processing, physical simulation, testing, microstructures, modelling.

In-situ neutron (X-ray) diffraction/imaging studies of engineering materials
Approaches, methods, case studies.

Current status of planning of engineering diffractometers for ESS
Presentation on ESS engineering diffractometer and roundtable discussion.

Program of SPEED satelite meeting

Structured Pulse Engineering Diffractometer (SPEED) for ESS
Design and expected potential

Engineering research at VULCAN and ENGIN-X
Overview on cutting edge engineering studies at ISIS and SNS

Visions for Engineering investigations at ESS
Discussion on planning of the ESS engineering diffractometer

The symposium webpage: **http://ofm.fzu.cz/ess-prague/**

Materials Engineering at the ESS

Axel STEUWER*

**ESS AB*

The ESS will be, when completed, the premier neutron source world wide. The 22 instruments envisaged in the reference design will serve a variety of scientific disciplines, including materials science & engineering. IN this presentation we will summarise and review the current status of neutron scattering instrumentation for materials engineering and the options for maximising the performance of a materials engineering beam line at the ESS, from both instrumental aspects such as choppers, but also sample environment and other user facilities.

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Notes:

Neutron Scattering Systems at the European Spallation Source

Oliver KIRSTEIN*

**European Spallation Source ESS AB*

The European Spallation Source ESS will be the next generation neutron scattering facility to be built in Lund, Southern Sweden. Contrary to existing short-pulse spallation sources ESS will utilise a long pulse of 2.86 ms with a repetition rate of 14 Hz, and we anticipate an increase by an order of magnitude in neutron peak brightness. ESS as a 5 MW source will be optimised for cold neutrons and consequently for cold neutron scattering instruments where the unprecedented intensity will allow new kinds of experiments to be carried, out in particular where only small amounts of new materials are available. At the present the ESS in its final stages of the Design Update Phase, which precedes the Construction Phase which will start on 2013. First neutrons on the instruments will be delivered in 2019 and we will givean update of the Neutron Scattering Systems project, that covers work related to the neutron scattering instruments, and ESS in general.

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Notes:

ESS – Instrumentation at the European neutron source of the future

Markus STROBL*

**ESS AB*

The ESS is currently planning a next generation spallation neutron source to be built in Lund, Sweden. The 5MW source with a repetition rate of 14Hz is with a pulse duration of 2.86ms designed to be a long pulse source. The unique source parameters also trigger unique instrumentation solutions in order to take maximum advantage of the powerful source for all kinds of instruments. A straw-man suite of 22 instruments to be built at the ESS is currently under intense investigation. The combination of the high source brilliance and unique instrument solutions is foreseen to push the boundaries of science that is currently feasible through the utilization of the unique probe, which neutrons represent for large number of applications. Envisaged efficiency gains up to more than an order of magnitude will allow for smaller samples, more irregular or sophisticated and hierarchical structures as well as faster kinetics or slower dynamics in systems to move into the focus of neutron scattering.

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Notes:

In-situ Studies of Engineering Materials at SMARTS

Bjorn CLAUSEN*, Thomas SISNEROS, Donald BROWN

**Los Alamos National Laboratory*

SMARTS (Spectrometer for MAterials Research at Temperature and Stress) is the engineering instrument at the Lujan Neutron Scattering Center at Los Alamos National Laboratory. It has been available in the user program since 2000, and has accommodated more than 350 user experiments. The majority of those experiments have been in-situ type experiments aimed at understanding the properties of engineering materials at ambient conditions, or at conditions representative of the applications for the specific material. Several examples of in-situ measurements will be given, including in-situ measurements of phase properties within composite materials, both at room temperature and at high temperature, and in-situ measurements during friction stir welding. Furthermore, a summary of the current and future ancillary equipment facilitating the in-situ type measurements at SMARTS will be given.

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Notes:

Neutrons for Materials Engineering at ISIS

Shu Yan ZHANG*

**ISIS, Science and Technology Facilities Council*

"The Engin-X instrument at ISIS is a world leading neutron diffractometer purpose-built for stress evaluation. Engin-X is used extensively by both engineers and materials scientists to address a wide range of engineering problems: new welding techniques; thermal cycling of materials; fatigue crack initiation and propagation, etc. Engin-X has large sample mounting space, which provides the flexibility for the users to bring their own ancillary devices, such as welding rigs to perform real-time strain measurements during joining. An in situ mountable servo-hydraulic stress rig can apply up to 100 KN tensile or compressive cyclic loads. The rig is equipped with a furnace and a cryogenic chamber that allow the sample to be maintained at temperatures from -200 °C to 1100 °C within normal atmosphere or under inert gas. A range of case studies will be discussed how the technique provides the basis for developing improved insight into materials of great importance to applications and industry."

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Notes:

VULCAN – new scientific opportunities in materials science and engineering

Ke AN*, Alexandru STOICA, Harley SKORPENSKE, Dong MA

**Spallation Neutron Source, Oak Ridge National Laboratory*

VULCAN is designed for deformation, phase transformation, residual stress, and texture studies. Auxiliary equipments, such as loadframe, furnaces, and electrical fields for in situ and time-resolved measurements are integrated in the instrument. As a time-of-flight diffractometer at the Spallation Neutron Source, VULCAN provides rapid volumetric mapping and ins-situ measurement time of minutes for common engineering materials. In extreme cases, VULCAN has the ability to study kinetic behaviors in sub-second times. VULCAN should target new experiments that cannot be readily done with existing instruments. In-situ study of time-dependent or transient behaviors was identified as one of the new scientific opportunities where VULCAN is expected to make an impact. Some results including stress/stain mapping, in-situ loading, phase transition at elevated temperature and exploration of new type of experiments will be reported and other new research opportunities will be presented.

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Notes:

Neutron imaging for materials research - recent developments

Steven PEETERMANS*, Eberhard LEHMANN

Paul Scherrer Institut

Neutron Tomography delivers 3D spatial information at resolutions down to ~ 10 um. It has become a standard method at PSI used to solve problems in numerous fields: ranging from virtually separating different alloys in the weld zone in materials science, to separating fossils from stone in paleontology. Diffraction studies typically need high energy-resolution, but have low spatial resolution. Moreover, one is faced with the question of where to position the gauge volume in complicated heterogeneous samples. The combination of both techniques has shown great potential e.g. internal stress distribution in turbine blades with internal cooling channels or alloy compositions in ancient hollow bronze statuettes. This talk will cover the basics of neutron imaging as well as present emerging advanced techniques on the basis of selected examples relevant in material research. Potential benefits to neutron diffraction and the determination of internal stress properties is discussed.

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Notes:

Engineering & Related Studies at TAKUMI of J-PARC

Stefanus HARJO*, Kazuya AIZAWA

**J-PARC Center, Japan Atomic Energy Agency*

A dedicated neutron diffractometer (TAKUMI) for investigations of stresses and crystallographic structures in engineering components, has been built at Materials and Life Science Experimental Facility (MLF) of J-PARC. MLF has a pulsed neutron source designed to operate up to 1 MW with 25 Hz repetition rate. TAKUMI is a TOF neutron diffractometer having a pair of 90 degree scattering detector banks, and it can perform multi hkl diffraction for a d range between 0.05 nm to 0.5 nm. An event data recording method is also adopted which make us easily to manipulate data as we like, even during measurement and/or after measurement. In the presentation, current status of TAKUMI, current sample environments and those to be developed, and several examples of researches done at TAKUMI, will be introduced. Examples of residual strain measurements will be introduced as well as various in situ measurements on engineering materials and high pressure sciences.

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Notes:

Metallurgical phenomena during thermo mechanical treatments: challenges in understanding

Damien FABREGUE*

**MATEIS INSA Lyon*

This presentation deals with some actual research topics in metallurgy where some in situ measurements could lead to a better understanding of the metallurgical phenomena taking place. Indeed, thermo mechanical treatments of metals are used for a long time but for some of them, information about the kinetic of the phenomena is still missing. These data are now mandatory to further optimize the microstructure and the resultant mechanical properties. In this study few examples are given. Firstly, the case of Co superalloys is presented. These alloys used for biomedical or aeronautics applications need to be optimize in terms of grains size. Thus, the influence of process parameters (temperature, strain, strain rate,…)on the final microstructure must be evaluated to tailor the mechanical properties. Then Gleeble thermo mechanical simulations give interesting data. However, these data are ex situ ones and thus in situ experiments could lead to a better understanding of the phenomena (for example here, dynamic recrystallization). An other example given is the case of new ODS (oxide dispersed strengthened) steels where precipitation of nanometric oxide leads to enhanced mechanical strength and creep resistance. However, fabrication process of this type of steels is complex and involved multiple steps. The only way to reproduce all these steps is to use thermo mechanical simulation where rapid and/or rapid cooling can be applied as well as stress state. Once again, acquisition of in situ measurement (fraction and size of precipitate,…) would definitely leads to improvement in the process and to a wider use of this type of steel. We will also present other metallurgical process where thermo mechanical simulation coupled to in situ measurements of microstructure features can lead to a real scientific breakthrough.

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Physical Simulation Using Gleeble Systems

Brian ALLEN*

Dynamic Systems Inc.

Physical simulation is defined as the replication in laboratory of the precise physical parameters of an actual process, either currently existing or proposed for the future. Physical simulation encompasses mechanical testing but extends much farther. The goal of mechanical testing is to rigidly define easily achievable test parameters so the maximum number of laboratories can achieve comparable results. Physical simulation also requires very exact test parameters, but in this case those parameters are defined by actual industrial processes, either currently existing or proposed. Since the possible range of actual processes is unlimited, the design goal of a physical simulation machine should be to encompass as wide a range of physical parameters as possible. This presentation will discuss physical simulation with a focus on the capabilities of the Gleeble line of thermal mechanical simulators produced by Dynamic Systems Inc.

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Notes:

Simulation of thermo-mechanical processes with HDS-V40

Grzegorz KORPAłA*, Rudolf KAWALLA

**Institut für Metallformung Technische Universität Bergakademie Freiberg*

The thermo-mechanical simulator HDS-V40 of DSI Company has been in operation since 2005 at the Institute of Metal Forming. This machine was and is used to simulate the industrial processes like hot rolling of flat product, continuous casting, wire rolling or continuous annealing. Relatively large samples can be used with in HDS-V40, making it possible to detect the mechanical properties of materials in an integrated deformation process, most importantly, even in a thermo-mechanical process. Several attempts have been carried out, and the results showed the possibility for this machine to be used further in half industry scale on this matter. The presentation will show some examples the advanced usages of this machine for the simulation of thermo-mechanical process in experiment and industrial scale.

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Notes:

In situ synchrotron diffraction studies of phase transformation in steels

Thomas KANNENGIESSER*

**BAM Federal Institute for Materials Research and Testing*

Combined application of x-ray diffraction and digital image correlation offers the possibility for evaluation of the spatial resolved material behavior during mechanical stimulus. While energy dispersive x-ray diffraction (EDXRD) allows for measurement of diffraction spectra containing information of various diffraction lines of all contributing crystalline phases from the material interior, digital image correlation permits for determination of the macroscopic strains occurring on the materials surface. Transformation induced plasticity, strain hardening and load partitioning effects of transformation induced plasticity (TRIP) steel were observed under tensile deformation. Energy dispersive diffraction allowed for characterizing the austenite to martensite transformation due to elastic and plastic deformation by taking into account multiple crystal lattice planes. The lattice plane strains were measured in loading as well as in perpendicular direction. Additionally, the phase specific stress evolution was determined applying the $\sin^2$?-technique during increasing load steps. Simultaneously, the macroscopic true strains were calculated from three-dimensional deformations measured in-situ by digital image correlation. The results show, that in-situ techniques are an ideal tool for investigating microscopic phase-specific and macroscopic material behavior with the purpose of improving material models to predict complex load situations.

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Notes:

Transient behaviour of metallic alloys during plastic strain: in situ X-ray synchrotron diffraction results

Alain JACQUES*, Laura DIRAND, Thomas SCHENK, Jean Philippe CHATEAU-CORNU, Jean-Philippe TINNES, Olivier FERRY, Jean-Briac LE GRAVEREND, Jonathan CORMIER, Pierre BASTIE

**Institut Jean Lamour (UMR CNRS-UdL N° 7198)*

While modelling the plastic behaviour of poly-phased and/or polycrystalline materials becomes more and more sophisticated, new experimental data are necessary to test the relevance of the constitutive laws which are used. Those data are very difficult to obtain from room temperature post mortem studies, especially when the transient behaviour of a material is investigated: real time investigation is needed. Two examples will be discussed: the mechanical response to stress and temperature jumps of a single crystal superalloy during high temperature creep testing, and slip band propagation in austenitic steels which deform by a combination of dislocation glide and twinning (so called TWIP steels).

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Notes:

Deformation Twinning in Mg Alloys and its Effect on Yielding and Post-Yielding Deformation: In-situ neutron Diffraction & Acoustic Emission

Ondrej MURANSKY*

**ANSTO, Institute of Materials Engineering*

The in situ neutron diffraction and in situ acoustic emission were used in a single in situ experiment in order to study deformation twinning in two Mg alloys with significantly different grain size. The combination of these two techniques enables the distinction between twin nucleation and twin growth. It is shown, that yielding and immediate post-yielding plasticity in compression along the extrusion direction is governed primarily by twin nucleation, whereas the plasticity at higher strains is governed by twin growth and dislocation slip. It is further shown that the collaborative twin nucleation dominates yielding in the fine-grained alloy whereas twin nucleation in the coarse-grained alloy is rather progressive and is happing over a larger strain range. Additionally, it is shown that despite the increasing stress required for twinning with the decreasing grain size, roughly the same overall volume fraction of twins is formed in the fine and coarse parent grains.

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Notes:

Requirements for diffractometer and sample environment design - experience from shape memory, beta titanium and superalloys

David DYE*

*Imperial College

Time-of-flight diffractometer designers have to trade off intensity and resolution, with different recent designs taking different approaches. In contrast, for triple axis machines, this is essentially a user decision. In this presentation, our recent experience from Co-base superalloys, shape memory alloys and superelastic beta titanium alloys will be reviewed in order to illuminate the issues raised by real technological material micromechanics studies. Sample environment cells also affect the types of experiments that can be performed, as well as the fabricability of samples. We have had much experience with the ESRF ETMT (resistance heating), have recently been developing a 5kN loading apparatus for I12 at Diamond, as well as our experience with the servo-hydraulic machines at Vulcan and ENGIN-X. Some frustrations and issues with different arrangements will be shared. On both of these topics, the aim is to illuminate the choices for the construction of future beamlines.

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Notes:

CO-RE-BASED ALLOYS – A HIGH TEMPERATURE ALLOY UNDER DEVELOPMENT

Debashis MUKHERJI*, Joachim RöSLER

Techinsche Universitaet Braunschweig Material Science Institute (IfW)

There is a primary need to develop new alloys with very high melting point for future gas turbines. Presently, Ni-based superalloys are extensively used in the hot section of turbines but they are now reaching limits posed by their melting temperatures. High melting Co-Re-Cr based alloys introduced by the TU Braunschweig in 2007 [1] show promise as a new material class for high temperature application. In the Co-Re alloy development two main concepts of strengthening, namely precipitation hardening with MC carbides and composite hardening by Co2Re3-type sigma phase are explored separately. In-situ measurements at high temperatures by synchrotron and neutron scattering are used to study high temperature phase evolution and transformation. These new tools are providing vital information and guiding the alloy development. Selected results of microstructural characterizations by neutron and X-ray measurements are presented here.

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Notes:

In-situ diffraction under physical thermo-mechanic simulation: beyond classical powder diffraction

Klaus-Dieter LISS*

**Australian Nuclear Science and Technology Organisation*

Modern neutron and high energy synchrotron radiation allow for in-situ and time-resolved bulk observations. Neutron beams average over a large volume to perform quantitative phase, strain and texture analysis. Primary extinction gives a measure of crystal perfection to study the kinetics of defects. A fine synchrotron beam allows to distinguish reflections of individual grains, embedded in a polycrystalline matrix and to show up lattice coherency and correlations between phases or grains. In-situ, time-resolved analysis is obtained while the metal undergoes physical thermo-mechanic simulation. The motion of the reflection spots on the diffraction rings reveals grain evolution, rotation, texture, dynamic recovery and recrystallization. Results on selected metals are given, related to the study of in-situ elasto-plastic deformation. An outlook will be drafted regarding requirements, opportunities and fiction for a load-frame setup at the ESS and integration into a dedicated beamline.

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Notes:

In-situ stress relaxation studies using neutrons

Alexander EVANS*, James ROLPH, Micheal PREUSS, Ania PARADOWSKA, Michael HOFFMAN, Mark HARDY, Philip WITHERS

*Formally ILL

The stability of residual stresses in engineering compoenehts has an impact on manufacturing and engineering applications. In-situ neutron diffraction can provide a unqiue insight to transient relaxation processes. This will be illustriated by two case studies. The first related to manufacturing, understanding stress relief of residual stresses in Ni-superalloy forgings during isothermal heat treatment. The second pertains to the relaxation of laser peening residual stresses under typical operating temperatures. These examples the highlight the future requirements for fast neutron diffraction measurements of mutliple strain directions and dedicated sample environments to accomodate typical engineering components.

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Notes:

Phase transformations studies at the Brazilian facility for parallel thermo-mechanical processing and synchrotron x-ray diffraction

Antonio J. RAMIREZ*, Guilherme FARIA, Leonardo WU, Thais ALONSO, Julian D. ESCOBAR, Maysa TERADA

**Brazilian Nanotechnology National Laboratory*

Physical simulation has been instrumental for the unveiling of materials fundamentals, and the development and optimization of new materials and processes. Using x-ray diffraction techniques, a state of the art station has been opened for users at LNNano-Brazil. This instrumentation is equipped with a custom-made thermo-mechanical simulator integrated with X-ray optics suitable for X-ray diffraction experiments. This simulator allows unprecedented versatility and control of the imposed conditions. The synchrotron source and the advanced detectors grant high quality and time-resolved data, allowing unprecedented dynamic experiments. This instrumentation opens possibilities to address fundamental materials science and processing questions, such as the interrelationships of stress/strain, temperature, elements partitioning, and crystallography on phase transformations. Experiments on the combined temperature-stress effect on several materials phase transformations will be presented.

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Notes:

In-situ Neutron Diffraction Studies at POLDI

Steven VAN PETEGEM*, Vadim DAVYDOV, Helena VAN SWYGENHOVEN

**Paul Scherrer Institut*

Predicting the development of intra- and intergranular stresses during deformation is a challenging task, especially for materials with a complex microstructure such as advanced steels and multiphase engineering components. A detailed knowledge of these so-called 'micro-stresses' is of utmost importance for understanding the link between microstructure and mechanical properties. Time-of-flight (ToF) neutron diffractometers are ideally suited for the determination of such stresses in engineering components. In this presentation we present some of the recent in-situ neutron diffraction studies performed at POLDI (SINQ, Switzerland), a ToF diffractometer based on the multiple pulse overlap principle (U. Stuhr et al. Nucl. Instr. Meth. A 545 (2005) 319-338). The applications range from steels, over superconducting wires to MAX phases. We further highlight some of the advantages and disadvantages of the setup.

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Notes:

Phase transformation in steels studied using in situ neutron scattering

Yo TOMOTA*

Ibaraki University

"Phase transformations upon heating and cooling for steels were examined using in situ neutron diffraction; tempering behavior of martensite followed by reversion to austenite was tracked; then, on cooling ferrite and pearlite transformations were monitored where carbon partitioning was estimated. In case of bainite at a low temperature, two austenites were confirmed by diffraction while the size of bainite lath was detected by small angle scattering. Texture memory at ferrite–austenite cyclic transformation was revealed to occur, which was explained by the double K-S relation rule. The effects of thermo-mechanically controlled process on ferrite and bainite transformations were studied using in situ neutron diffraction. It is found the dislocation-structure is a key point for the following transformation behavior. Low temperature ausforming is found to accelerate the transformation, resulting in very fine nano-bainite microstructure where a strong variant selection takes place."

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Notes:

Complex-environment engineering diffractometer (CEED) for ESS

Jan SAROUN*

Nuclear Physics Institute ASCR, v.v.i.

Design and construction of a time-of-flight (ToF) neutron powder diffractometer for material science and engineering has been proposed as a part of Czech in-kind contribution to the ESS. Presented concept of the instrument aims at in-situ experiments with materials under variety of sample environment (SE) conditions. Apart of a standard suite of neutron SE devices, the instrument should provide space and infrastructure for accommodation of specialized facilities such as high-strength pulsed magnets or a cell for dynamic thermo-mechanical testing and physical simulations of material processing (Gleeble®). We present conceptual design of the complex-environment engineering diffractometer (CEED) proposed for the ESS long pulse source and results of Monte Carlo simulations, which allowed us to assess quantitative characteristics of such an instrument.

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Notes:

Planning for sample environments at ESS engineerining beamline

Jan PILCH*, Pavel STRUNZ, Přemysl BERAN, Jan ŠAROUN, Petr LUKáš, Petr ŠITTNER

**NPI & IoP AS CR*

While neutron strain scanning represented a typical experiment performed at neutron engineering diffractometers worldwide, currently the interest of engineering community seems to be shifting towards in-situ experiments. The vision for ESS to be built till 2020 is to move from ad hoc proposed experiments to an European network of labs where engineering experiments involving material production, processing and testing are readily carried out with the neutron engineering beamline being a unique member within such network where standardized experiments can be performed with the benefit of in-situ neutron diffraction/imaging. The already existing community of labs performing standardized industry oriented Physical simulation experiments on Gleeble simulators is a good example. This approach demands a very sophisticated system for efficient exchange of sample environments. Further features include support labs right at ESS, where long termed testing with occasional neutron diffraction/imaging measurements (e.g. creep or fatigue) are performed. The vision is that potential users will first contact one of the network laboratories, where the experiment will be prepared, performed off line, proposal written and experiment finally carried out at ESS.

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Notes:

PERSPECTIVES FOR MATERIALS INVESTIGATIONS AT THE STRUCTURED PULSE ENGINEERING DIFFRACTOMETER (SPEED)

Reinhard KAMPMANN*, Mustapha ROUIJA, Peter STARON, Heinz-Günter BROKMEIER, Markus STROBL, Martin MüLLER, Andreas SCHREYER

**Helmholtz-Zentrum Geesthacht*

The Helmholtz-Zentrum Geesthacht proposes to build a novel structured pulse engineering diffractometer (SPEED) at the European Spallation Source (ESS) in Lund/Sweden. The instrument will be based on a novel ToF-design distinguished by a modulation chopper positioned at a distance of ~ 25 m from the source and ~ 50 m from the sample. This chopper allows setting the wavelength resolution almost independently of its transmission of about 17%. SPEED thus will make full use of the high flux of the long pulse spallation source for high resolution diffractometry from samples of high symmetry. The presentation is focussed on the perspectives for high resolution diffraction resulting from optional design of the modulation chopper. The development of SPEED is performed as an in-kind contribution to the ESS instrumentation, it is part of the German support to the ESS Pre-Construction Phase and Design Update.

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Notes:

Sample environments for an engineering diffractometer at ESS: from robotic texture analysis to in situ friction stir welding

Peter STARON*, Heinz-Günter BROKMEIER, Martin MüLLER, Andreas SCHREYER

**Helmholtz-Zentrum Geesthacht*

In texture analyses, sample throughput often is a problem when engineers want to look at large sample series resulting from the requirements e.g. of process optimization. This problem can be solved with a novel robotic sample changer, as it is already available at STRESS-SPEC at the FRM II [1]. A six-axes-robot can be used for sample positioning and sample changing. Dilatometers are commercial instruments for the study of phase transformations as a function of temperature, measuring the extension of a sample. It is planned to modify such a commercial dilatometer for use at a neutron beamline. A large machine is required for the in situ study of the friction stir welding process to be able to apply the necessary welding forces. In contrast to an existing synchrotron experiment using high X-ray energies, the development of residual stresses could easily be studied during friction stir welding using neutrons because the wavelength range enables scattering angles around 90°.

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Notes:

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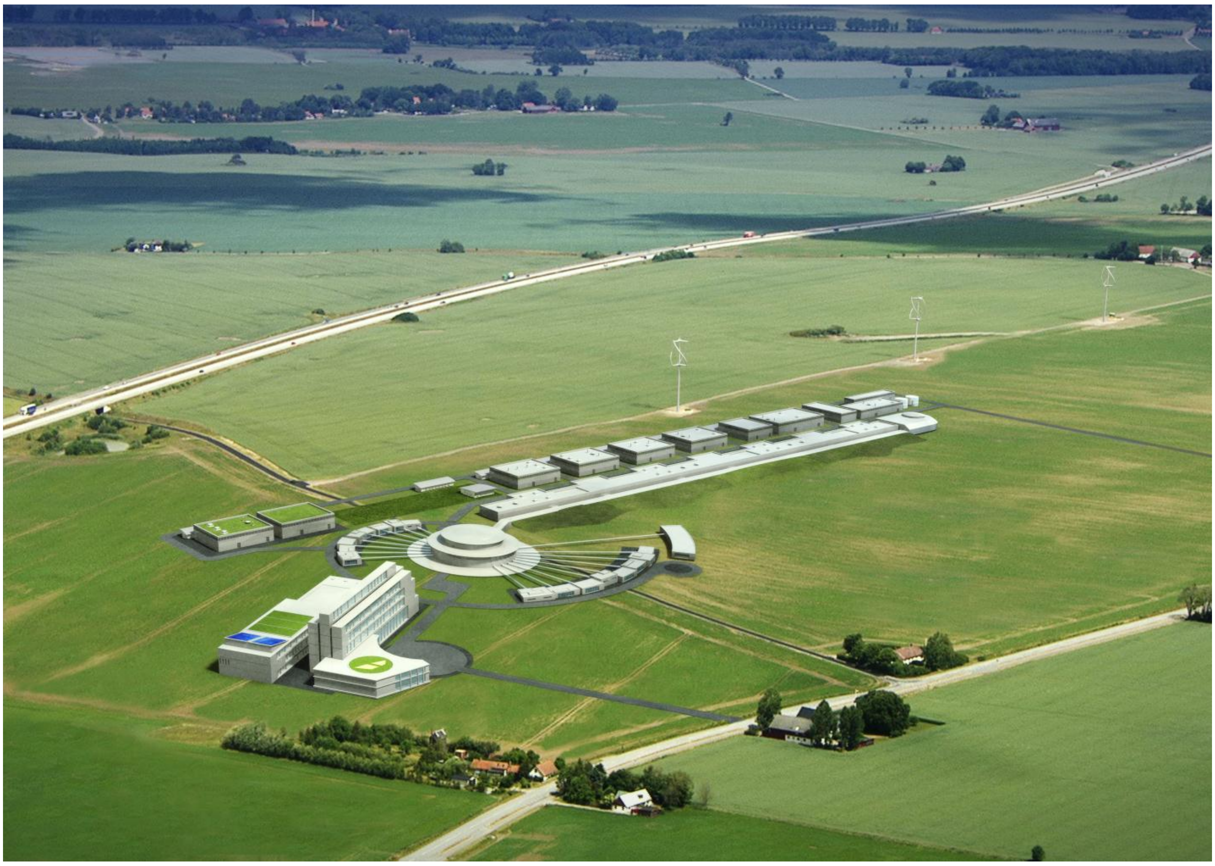
ESS European Spallation Source

The European Spallation Source is a Partnership of 17 European Nations committed to the goal of collectively building and operating the world's leading facility for research using neutrons by the second quarter of the 21st Century

EUROPEAN SPALLATION SOURCE

The European Spallation Source (ESS) aims to be the brightest source of neutrons in the world for scientific research. By the end of this decade it will be generating long pulses of neutrons. These will be used in parallel experiments that will foster major advances from aging and health, materials technology for sustainable and renewable energy, to experiments in quantum physics, biomaterials and nano-science.



The ESS will be located in Lund, Sweden, co-hosted by both Sweden and Denmark and will be funded and operated by a partnership of 17 European countries. The ESS and our partners are currently engaged in a technical design review that will act as the blue-print for the construction of ESS to start in 2013 and to become operational in 2019.

European Spallation Source is a joint European project, like that of many large-scale research facilities such as CERN in Geneva. The European countries that are interested in building and operating ESS are forming a coalition and entering into a formal agreement with one of the countries that has offered to be host. Consequently, ESS is not an EU project.

ESS will become a multi-scientific facility for advanced research and industrial development. More than 300 researchers from 11 countries have taken part in the planning, which has lasted about 15 years.

ESS will open up entirely new opportunities for researchers within a large number of fields of research: chemistry, nano and energy technology, environmental engineering, foodstuff, bioscience, pharmaceuticals, IT, materials and engineering science and archaeology. ESS can be compared to a large microscope, where neutrons are used to probe various materials. High precision instruments will enable detailed analyses under realistic conditions.

More information is available at:

http://eval.esss.lu.se/DocDB/0000/000045/001/FROAN1.pdf

http://www.bigscience4business.com/presentatie/Nederlandse%20plannen%20voor%20ESS.pdf

ELI Beamlines

The most intense laser for user-based research

http://www.eli-beams.eu

ELI Beamlines is the project of the Institute of Physics of the Academy of Sciences of the Czech Republic.

The international Extreme Light Infrastructure, ELI project is part of a European-wide plan to build a new generation of leading research facilities open to scientists worldwide and dedicated to investigation and applications of laser-matter interaction at highest intensity levels. The first ESFRI (European Strategy Forum for Research Infrastructures) roadmap project to be built and operated in new Member States of the European Union, and the first R&D infrastructure project financed by European structural funds ELI is a breakthrough example to boost the European competitiveness.


ELI stands on three pillars

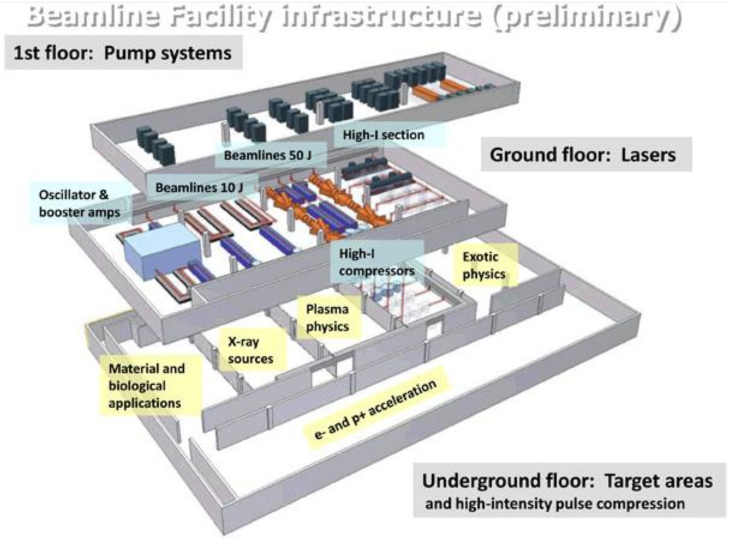
The ELI infrastructure will be composed of three pillars under one European umbrella, the ELI Beamlines in Dolní Břežany in Central Bohemian Region of the Czech Republic, the ELI Attosecond facility in Szeged, Hungary and the ELI Nuclear Physics in Magurele, Romania. Recently, the implementation phase of ELI Beamlines has started. A strong cooperation with prestigious research organizations throughout Europe will allow for preparing completely new research areas for scientific and industrial users from all over the world. The preparation and construction of ELI Beamlines, plus all related costs, requires a total of 272 mil. €. 85% of are co-financed by the EU and 15% of the Czech Republic state budget.

Dolní Břežany – The capital of European science

The construction of three buildings including a three-stories single monolithic laser hall of the footprint 110 x 65 m and installing of laser and experimental systems and supporting technologies should be completed by end of 2015. Early 2016 the "first intense light" should be available for users. ELI Beamlines will provide 250 workplaces and will host about 50 visiting researchers at a time. The cornerstone ceremony was held on 9th October 2012 attended by Prime Minister Petr Nečas.

The Research in ELI Beamlines

ELI is expected to push the frontiers of science and technology in several directions. ELI's electric and magnetic fields will exert forces of unprecedented strength on charged particles such as electrons, protons, ions, allowing thereby tests of basic physical theories in different fields like plasma physics, astrophysics, nuclear physics or high energy physics under previously not accessible conditions and the development of unique sources of high-energy photon and particle beams.



ELI's ultra-brilliant beams of protons, ions and x-rays may revolutionize cancer diagnosis and therapy as well as structural biology, by reduced-cost proton/ion therapy, phase-contrast x-ray imaging and x-ray diffraction imaging of individual biological molecules

Brilliant attosecond x-rays, on the other hand will open the prospect of imaging in 4 dimension with with picometre resolution in space and attosecond resolution in time.

ELI Beamlines project is structured into six research programs (RP).

RP 1: **Lasers generating rep-rate ultrashort pulses and multi-petawatt peak power.** Development of ultra-intense Petawatt laser systems will be using the latest technology, enabling high repetition rates due to diode lasers pumping.

RP 2: **X-ray sources driven by rep-rate ultrashort laser pulses.** Operation for use in applications of complementary X-ray sources, plasma X-ray lasers, X-ray free electron laser, advanced K-alpha sources, betatron radiation.

RP 3: **Particle acceleration using lasers.** Investigation of laser driven electron and proton acceleration schemes. Development of high quality high energy compact laser accelerators and particle beamlines.

RP 4: **Applications in molecular, biomedical and materials sciences.** Studying of early phase of photochemical or radiation induced chemical processes. Interest in coherent X-ray display and holography with atomic-level resolution, X-ray diffraction, sub-picosecond pulsed radiolysis, etc.

RP 5: **Laser plasma and high-energy-density physics.** Non-linear plasma physics and laser interaction with low-density plasma, relativistic plasma, laser interaction with solids, clusters and targets with limited density, generation of hot dense materials and testing advanced fusion schemes.

RP 6: **Exotic physics and theory.** Theoretic and experimental research in the so-called ultra-relativistic mode of interaction between radiation and matter where the electrons as well as the protons move due to the action of the strong laser field with extremely high speeds close to the speed of light.

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ADC has been dedicated to delivering custom equipment to the neutron & synchrotron community for the last 17 years. We have steadily grown our market base while expanding our capabilities by continuously improving our skills and practices. In recent years we have consistently shipped quality equipment leading to significant repeat business all around the world. We owe our success to the implementation of written procedures covering all aspects of our business including designs, modeling, quality control, manufacturing, receiving, assembly, vacuum cleaning, purchasing, and cost accounting. We invested millions of dollars on machine tools, floor space, clean rooms, vacuum part cleaning equipment, measurement systems, inspection tools, RGA, leak checking, and software; detailed information in section B. Our mechanical engineers use Inventor 2012. We have also invested in our people by developing and implementing training policies covering assembly, UHV part cleaning and handling, and inspection. In recent years we have enjoyed excellent employee retention. We have also implemented numerous specifics to improve our customer interaction such as an FTP website for exchanging large files, GoTo Meeting video conferencing, and monthly reports. All of our large projects include a Preliminary Design Review (PDR) and Final Design Review (FDR). We encourage the customer to visit our facility for the PDR so they can see our operations. ADC visits our customer's site for the FDR so additional customer personnel can participate in the review and our engineers can see the application and machine site. We have also implemented internal reviews and weekly project assessments. We encourage our customers to visit us at any time.

Advanced Design Consulting USA, Inc.