Dear colleagues,

the last two decades has seen a tremendous development in the science and applications of thin films, multilayers and laterally patterned heterostructures, with important contribution of reflectometry and grazing incidence diffuse scattering of (polarized) neutrons and (non-resonant, resonant magnetic and nuclear resonant) x-rays. With the advent of new neutron and x-ray sources data acquisition time has much shortened. Many groups around the world have now access to excellent experimental facilities as demonstrated in several presentations in this workshop.

The excellence in the theory and evaluation of diffuse neutron and x-ray scattering is, however, less widespread. There are no generally accepted and internationally tested data fitting programs and simulations with proper account for beam and instrument properties count as exceptions in this field.

Due to the common optical framework of neutron and x-ray optics the two fields may greatly benefit from new results. Moreover, common practise is to investigate systems by various thin film techniques and surface scattering methods. Therefore a scheme for simultaneous data evaluation and fitting routines of spectra is of high interest. Presentations during the workshop will introduce current available programs and discuss theoretical approaches behind.

The present workshop consists of plenary and oral talks and a brief poster session placed around the main fields of interest covering in particular

- Novel Trends in Off-specular Scattering
- Grazing Incidence X-ray and Neutron Scattering
- Off-specular Polarised Neutron Scattering
- Data Evaluation and Treatment
- Software and Alogorithms
- Instrument Developments

The workshop is jointly organized by the Jülich Centre for Neutron Science of Forschungszentrum Jülich GmbH and the KFKI Research Institute for Particle and Nuclear Physics (RMKI) of the Hungarian Academy of Sciences in Budapest.

We are very happy about the large number of registrations to the workshop and wish all participants within the due tome of the workshop a pleasant stay and lively and engaged discussions.

Laszlo Bottyan
(KFKI, RMKI)

Thomas Brückel
(FZ Jülich, IFF-4)

Alexander Ioffe
(FZ-Jülich, JCNS)

JCNS Workshop Off-Spec 2009

"Modelling and Data Analysis for Grazing Incidence and Off-Specular Scattering"

27-29 September 2009, Feldafing, InWent Bildungszentrum

Sunday, Sept. 27. 2009

18:00 Welcome and Barbecue

Monday, Sept. 28. 2009

08:30 Alexander Ioffe — Forschungszentrum Jülich GmbH
Welcome

Theory and Modelling

08:45 Adrian Rennie — Uppsala University
Scattering from Interfaces and what is beneath the Surface

09:20 Boris Toperverg — Ruhr-University-Bochum
Theory of elastic and inelastic off-specular polarized neutron scattering from magnetic films and multilayers

09:55 László Deák — KFKI Research Institute for Particle and Nuclear Physics
Theory and algorithms of diffuse polarized neutron and synchrotron Mössbauer reflectometry of multilayers

10:30 *Coffee break*

11:00 Frederic Ott — LLB
Full dynamical calculation of the scattering on laterally ordered magnetic structures

11:30 Victor de Haan — TU Delft
Theory and data analysis in spin echo neutron refelctometry

12:00 Peter Müller Buschbaum — TU München
Modeling grazing incidence small angle x-ray and neutron scattering data

12:30 *Lunch*

Experiments I

13:30 Max Wolff — Uppsala University
Diffuse scattering, small angle scattering and neutron reflectometry:
Recent experiments that demand for new directions in data analysis

14:00 László Bottyán — KFKI Research Institute for Particle and Nuclear Physics
Evolution of Antiferromagnetic Domains in Multilayers - SMR and PNR studies

14:30 Dénes Lajos Nagy — KFKI Research Institute for Particle and Nuclear Physics
Monte-Carlo simulation of domain ripening in strongly-coupled antiferromagnetic multilayers: the first-neighbour-interaction pixel model.

15:00 *Coffee break*

15:30 Andrew Wildes ILL
Reflectometry in large magnetic fields - some measurements on superlattices containing Fe and Co

15:50 Yury Khaydukov JINR
Neutron waveguide regime to study proximity effects at superconductor/ ferromagnet interface

16:10 Denis Korolkov JCNS
The analysis of self-organized nanostructures with Grazing Incidence Small Angle Scattering

16:30 Michael Paulus TU-Dortmund
On the static structure factor of capillary waves at large wave vector transfers

16:50 Jaroslaw Majewski Los Alamos National Laboratory
Off-Specular Neutron Scattering From Supported Single Lipid Bilayers.

17:10 Discussion of first day

17:30 **Poster session**

Earl Babcock JCNS
Wide angle polarization analysis for the MARIA reflectometer

Victor Bodnarchuk Joint Institute for Nuclear Research
Project of the new multifunctional reflectometer GRAINS with horizontal sample plane at the IBR-2M pulsed reactor in Dubna

Candice Halbert ORNL
SNS Liquids Reflectometer

Elisabeth Josten Forschungszentrum Jülich
Magnetic correlations in laterally structured multilayers

Esther Pfuhl Forschungszentrum Jülich
Proximity effects in Er|Tb multilayers

19:00 *Dinner (Klostergasthof Andechs)*

Tuesday, Sept. 29. 2009

Software

09:00 Christopher Metting University of Maryland
Off-specular neutron reflectometry modeling and fitting software

09:30 Adrian Rühm MPI für Metallforschung
The SUPERFIT program for simulating and fitting reflectivity and off-specular scattering data

10:00 Szilárd Sajti Research Institute for Particle and Nuclear Physics
FitSuite: Simulation and simultaneous fitting of experimental spectra including neutron and x-ray reflectivity and diffuse scattering

10:30 *Coffee break*

11:00 Kozhevnikov Sergey Max Planck Institut für Metallforschung
Data representations in off-specular neutron scattering

Experiments II

11:30 M. Kerscher JCNS
Microemulsions near a planar surface - a GISANS approach

12:00 Wolfgang Kreuzpaintner GKSS Forschungszentrum
Time-of-flight Grazing Incidence Small Angle Neutron Scattering on Gd Nanowires

12:30 *Lunch*

13:30 Dieter Lott GKSS research center
Magnetic off-specular neutron scattering at the reflectometer NeRo at GKSS

13:50 Jean-Francois Moulin GKSS/FRM2
TOF GISANS measurements at REFSANS

14:10 John Ankner ORNL
Initial Off-Specular Measurements at the SNS Liquids Reflectometer

Instrumentation

14:30 *Coffee Break*

15:00 Markus Strobl HZB
BioRef – a time-of-flight reflectometer for soft matter applications at HZB

15:20 Robert Dalgliesh ISIS
Initial results and future directions for the new OffSpec, spin-echo reflectometer, on the ISIS Second Target Station.

15:40 Stefan Mattauch JCNS
The new high flux polarised neutron reflectometer MARIA at JCNS

16:00 Discussion of second day

17:00 End of workshop

JCNS Workshop Off-Spec 2009

"Modelling and Data Analysis for Grazing Incidence and Off-Specular Scattering"

27-29 September 2009, Feldafing, InWent Bildungszentrum

Abstracts Sept. 28. 2009

Sept. 28. 2009, 08:45

Scattering from Interfaces and what is beneath the Surface

Adrian R. RENNIE

Materials Physics, Uppsala University

Conceptually specular reflection is very simple and the interpretation of data from complex interfaces is usually based on optical methods. Scattering from an interface is more complex but is now used for investigations of a number of two-dimensional systems that range from solids that can have structural and magnetic roughness to various nanostructures in soft matter. If samples display strong surface scattering or grazing incidence scattering from beneath the surface is significant, it can be difficult to determine what is the intensity of reflection and to decide how data should be modelled or interpreted.

In this presentation I will review data from a variety of samples such as a silicon substrate/air interface, as well as adsorbed layers and samples that have strong scattering from beneath the surface. Methods of data reduction will be presented and the validity of comparison with models discussed. Some simple results for multiple scattering will be shown. Typical data for a real sample is shown in Figure 1. Intercomparison of data measured under different conditions is not always straightforward and some questions about common procedures will be raised. Typical data is shown in Figure 1. Steps in understanding such systems will be presented.

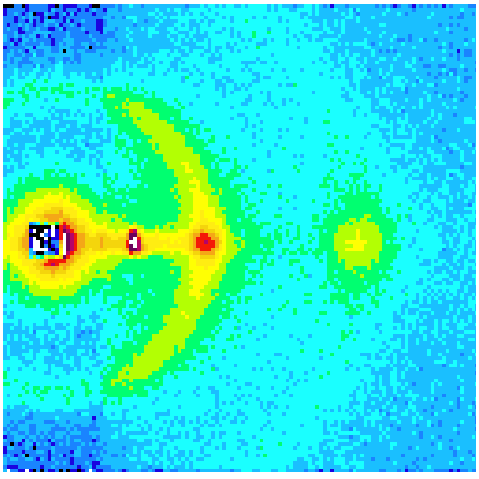

Figure 1. Typical grazing incidence data for a complex interface and subphase (an anionic surfactant solution that shows strong adsorption to Al_2O_3).

Sept. 28. 2009, 09:20

Theory of elastic and inelastic off-specular polarized neutron scattering from magnetic films and multilayers

Boris P. TOPERVERG[1,2]

[1]Ruhr-University-Bochum, Institute of Solid State Physics, Bochum, Germany

[2]Petersburg Nuclear Physics Institute, Theoretical Department, Gatchina, Russia

Simple and rigorous derivation of equations describing elastic and inelastic polarized neutron off-specular scattering (PONOSS) from lateral patterns and excitations in thin magnetic films and multilayers is briefly outlined. Accurate formulation and applicability limits of the Distorted Wave Born Approximation (DWBA) are provided. Special attention is paid to a correct implementation into DWBA of basic principles, e.g. time and space symmetry principles intimately related to various conservation laws. The lateral averaging at grazing incidence is thoroughly examined. General consideration is illustrated with a bulk of numerical calculations highlighting particular effects of DWBA in PONOSS spectra. Benefits of the 3D-vector polarization analysis (VPA) are argued in view of the problem of full reconstruction of the magnetization vector distribution in laterally patterned magnetic (multi)layers.

Results of long term experience collected on quantitative description of PONOSS from, e.g. magnetic domains, functional nano- and micro-patterns [1] is critically reviewed. Further perspectives on applications of PONOSS to, e.g. magnetic domain kinetics and magnon spectroscopy, are discussed. A feasibility criteria and preliminary experimental results on the subjects are reported.

[1] H. Zabel, K. Theis-Bröhl, B.P. Toperverg, "Polarized Neutron Reflectivity and Scattering from Magnetic Nanostructures and Spintronic Materials", in: *Handbook of Magnetism and Advanced Magnetic Materials*, Eds. H. Kronmüller and S. Parkin, **volume 3**, pages 1 – 71 2007 John Wiley & Sons, Ltd.

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Sept. 28. 2009, 09:55

Theory and algorithms of diffuse polarized neutron and synchrotron Mössbauer reflectometry of multilayers

László DEÁK, Szilárd SAJTI, Dénes Lajos NAGY, László BOTTYÁN

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The specularly reflected radiation from a stratified system depends on the lateral averages of the material parameters only; therefore off-specular Polarized Neutron Reflectometry (PNR) and recently off-specular Synchrotron Mössbauer Reflectometry (SMR) have been used to estimate the AF domain-size distribution in magnetic multilayers [1].
In the last two decades nuclear resonance scattering (NRS) of synchrotron radiation (SR) became an established nuclear hyperfine method [2]. NRS of SR is conventionally recorded as a beating time response of the nuclear ensemble following a short resonant synchrotron pulse. Grazing-incidence NRS of SR (often called SMR) [3] is a method that combines the sensitivity of Mössbauer spectroscopy to hyperfine interactions with the depth information yielded by reflectometry.
The theory of the off-specular neutron reflectometry based on the Distorted-Wave Born Approximation [4] (DWBA) has been published earlier [5, 6]. The idea to apply the DWBA technique to describe off-specular SMR experiments is therefore plausible. However, the temporal character of SMR complicates this approach and leads to slow algorithms. The theoretical description of diffuse SMR was recently published by our group [7].
Characteristics of diffuse PNR and SMR will be discussed and compared. Procedures will be presented to account for the finite coherence volume of the incident radiation. Actual numerical algorithm of diffuse SMR and PNR will be outlined including approximations which result in fast calculations suitable for fit algoritms. As an example, the theory will be applied to domains in AF-coupled magnetic multilayers and the actual form of the domain cross-correlation function will be given.

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[2] E. Gerdau and H. de Waard, Hyperfine Interact. **123-125** (2000) reviews and references therein
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[4] S.L. Sinha, E.B. Sirota, S. Garoff, H.B. Stanley, Phys. Rev B **38** 2297 (1988)
[5] B.T. Toperverg, Physica B **297** 160 (2001); B.T. Toperverg, O. Nikonov, V. Lauter-Pasyuk, H.J. Lauter, Physica B **297** 169 (2001)
[6] A. Rühm, B.T. Toperverg, H. Dosch, Phys. Rev. B. **60** 16073 (1999)
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Sept. 28. 2009, 11:00

Full dynamical calculation of the scattering on laterally ordered magnetic structures

Fredric OTT

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Presently, off-specular data are modelled using the DWBA approximation. This approximation has proved to be very efficient and accurate in a number of cases.
However, in the case of very well ordered structures such as gratings, lithographic structures, self-ordered systems, the diffuse scattering can be large and the DWBA may not be the most natural approach to model these systems. I will present an extension of the Parrat matrix formalism in the case of laterally ordered structures. This formalism is derived from algorithms routinely used in electromagnetic waves scattering and allows to perform an exact dynamical calculation. I show how it can be extended to magnetic neutron scattering by using a supermatrix approach. A prototype code in Matlab is available on the Web (http://www-llb.cea.fr/prism/programs/programs.html).

Sept. 28. 2009, 11:30

Theory and data analysis in Spin Echo Neutron Reflectometry.

Victor DE HAAN[1], Ad VAN WELL[2], Jeroen PLOMP[2]

[1]BonPhysics BV, Puttershoek, The Netherlands

[2]Delft University of Technology, Reactor Institute Delft, Delft, The Netherlands

Recent developments of the Spin Echo technique are applied at several sources in the world. A dedicated instrument has been built at ISIS 2nd target station. This technique enables the direct measurement of the sample surface correlation function. The coherence approach to reflectivity is applied to the (distorted wave) Born approximation and Phase Object approximation and is used to describe the measurements as functions of the spin-echo length. With this theory the sample surface correlation function can be calculated in both the specular and off-specular directions. Monochromatic X-ray and TOF-neutron and SE measurements on gratings will be compared to theoretical predictions as an example.

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Sept. 28. 2009, 12:00

Modeling grazing incidence small angle x-ray and neutron scattering data

Peter MÜLLER-BUSCHBAUM[1], Stephan V. ROTH[2], Ezzeldin METWALLI[1], Jean-F. MOULIN[1,3], Robert CUBITT[4]

[1] TU München, Physikdepartment E13, Garching, Germany

[2] HASYLAB at DESY, Hamburg, Germany

[3] Inst. F. Werkstoffforschung, GKSS-Forschungszentrum, Geesthacht, Germany

[4] Institut Laue-Langevin, Grenoble France

Grazing incidence small-angle X-ray scattering (GISAXS) and grazing incidence small-angle neutron scattering (GISANS) emerged to versatile and frequently used analysis techniques in the field of micro- and nano-structured thin films and surfaces [1]. Both are used for the characterization of micro- and nano-scale density correlations and shape analysis of objects at surfaces or at buried interfaces for various classes of materials. As a result, GISAXS provides an excellent complement to more conventional nano-scale structural probes such as atomic force microscopy (AFM) and transmission electron microscopy (TEM).

After a short introduction, general principles of GISAXS and GISANS are explained and illustrated with simulations of two dimensional scattering patterns [2]: The scattering geometry, scattering from rough and patterned surfaces and the interplay of object form factor and interference function. Aspects of the interference function and object form factor are deepened by explaining aspects of object shape, object polydispersity and object size. Moreover, layered systems and possible simplifications are discussed.

[1] P. Müller-Buschbaum: *Structure determination in the thin film geometry using grazing incidence small angle scattering*; in "Polymer Surfaces and Interfaces: Characterization, Modification and Applications", edt. M. Stamm, p.17-46 Springer Berlin, ISBN-13: 978-3-540-73864-0 (2008)

[2] P. Müller-Buschbaum: *A basic introduction to grazing incidence small angle X-ray scattering*; in Special issue of Lecture Notes in Physics on "Applications of Synchrotron Light to Noncrystalline Diffraction in Materials and Life Sciences", Vol. 776, edt. Ezquerra, T.A.; Garcia-Gutierrez, M.; Nogales, A.; Gomez, M.; p.61-90 Springer Berlin, ISBN-13: 978-3-540-95967-0 (2009)

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Sept. 28. 2009, 13:30

Diffuse scattering, small angle scattering and neutron reflectometry: Recent experiments that demand for new directions in data analysis

Max WOLFF

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In this presentation I will discuss small angle scattering and neutron reflectivity, including diffuse scattering, data taken for a micellar system of different types of Pluronics. Pluronics are three block polymers know to agglomerate at elevated concentrations or temperatures. Above a certain volume fraction of micelles the systems crystallize. Regarding this they offer an ideal model system to study the interplay between neutron reflectometry and small angle scattering if data are taken under gracing incident beam geometry. The liquids are investigated as bulk samples in contact to solid substrates with varying surface energies. Particular interest will be drawn to the following points that are of utmost importance in future data modelling:

First, for a bulk liquid in contact to a solid substrate measured above the critical angle of total reflection the GISANS signal will always be hidden under the dominating bulk scattering. However, in a series of experiments it was shown that even on a micrometer length scale changing surface energy can enforce different structures and recrystalization rates [1, 2]. An open question is how the signal of the outmost layers can be extracted.

Second, when measuring reflectivity the resolution in the plane of the interface is typically relaxed [3]. This results in the collection of strong small angle scattering signals that dominate the collected data.

Third, the diffuse scattering along the Bragg rod measured in neutron reflectivity is often found to be strongly asymmetric. As the asymmetry may change form low to high incident angles for the same sample by changing extensive quantities the reason for this must contain physical information on the sample close to the interface. An example of such a measurement will be presented and possible explanations will be given.

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[3] M. Wolff, A. Magerl, H. Zabel, Euro. Phys. J. E **16**, 141 (2005).

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Sept. 28. 2009, 14:00

Evolution of Antiferromagnetic Domains in Multilayers - SMR and PNR studies

László BOTTYÁN, Márton MAJOR, Edit SZILÁGYI, Ferenc TANCZIKÓ, Dénes L. NAGY

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Antiferromagnetically (AF) coupled multilayers (ML) show a variety of domain transformation phenomena. As a consequence of the small stray field and the freedom of the regions in selecting sense of rotation [1], in a strongly AF-coupled ML, on unsaturation, patch domains are formed with AF order through the ML stack [2]. A spontaneous irreversible increase of the average domain size, a *domain ripening* was observed at RT in a ^{57}Fe(2.6nm)/Cr(1.3 nm)/MgO(001) ML by synchrotron Mössbauer reflectometry (SMR) and polarised neutron reflectometry (PNR), which takes place in a narrow range of the external magnetic fields. Domain ripening is blocked at $T = 15$ K due to the increased coercivity. Yet, the native domain pattern ripens in remanence on rising the temperature to RT. A sudden explosion of the domain size, a *domain coarsening* was detected [3] on passing the bulk-spin-flop transition [4]. A *domain memory effect* was observed in the same Fe/Cr ML, namely, one can only erase the 'ripened' or 'coarsened' domain structure, when, (depending on the temperature) 25 to 130 % higher external field was applied (for a few minutes) than the experimental saturation field [5]. A first-neighbour-interaction pixel model fairly well describes the details of the field- and temperature-induced ripening in AF MLs, including the supersaturation enigma [6].

Besides the similarities of the methods, the temporal character of and the higher absorption in SMR imposes specific differences between diffuse SMR and PNR [6]. Therefore as to what extent the shape variation of the diffuse scatter reflects the shape and width of the domain correlation function in PNR and SMR was a subject of a detailed theoretical study [7].

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[2] M. Rührig, R. Schäfer, A. Hubert, R. Mosler, J. A. Wolf, S. Demokritov and P. Grünberg, Phys. Stat. Sol. A **125**, 635 (1991)
[3] D. L. Nagy, L. Bottyán, B. Croonenborghs, L. Deák, B. Degroote, J. Dekoster, H. J. Lauter, V. Lauter-Pasyuk, O. Leupold, M. Major, J. Meersschaut, O. Nikonov, A. Petrenko, R. Rüffer, H. Spiering and E. Szilágyi, PRL 88, 157202 (2002)
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[5] M. Major, L. Bottyán, J. Meersschaut, D. L. Nagy, A. V. Petrenko, F. Tanczikó, Physica B 397, 53 (2007)
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[7] L. Deák, L. Bottyán, D.L. Nagy, H. Spiering, Yu. N. Khaidukov and Y. Yoda PRB 76, 224420 (2007) and L. Deák, this conference.

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Sept. 28. 2009, 14:30

Monte-Carlo simulation of domain ripening in strongly-coupled antiferromagnetic multilayers: the first-neighbour-interaction pixel model

Dénes Lajos NAGY, László BOTTYÁN, László DEÁK, Etelka HARTH, Márton MAJOR, Dávid VISONTAI

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Antiferromagnetically (AF) coupled multilayers (ML) show a great variety of domain formation and transformation phenomena. In case of strong coupling, typical patch domains of AF order through the ML stack are formed [1] in decreasing external magnetic field *H* when the ML leaves the saturation region. A spontaneous and irreversible increase of the average domain size, i.e., *domain ripening* in an AF-coupled Fe/Cr ML was predicted [2,3] and experimentally evidenced [4] by off-specular synchrotron Mössbauer reflectometry (SMR) and off-specular polarised neutron reflectometry (PNR) on further decreasing the field to zero, a process driven by the domain-wall (DW) energy density and limited by DW pinning, i.e., the coercivity of the ferromagnetic (FM) layers [3,4]. We will present a simple model of the DWs and of the DW movement in AF-coupled MLs as well as a Monte Carlo simulation based on this model and on a cellular automaton algorithm.

Lattice points of the cellular automaton consist of about 10^8 strongly coupled spins of the ML stack; the whole simulation including about 10^4 lattice points. The cellular automaton rule is to minimise the total energy of the lattice in monotonically changing external magnetic field. The Hamiltonian contains a nearest-neighbour domain-wall energy term as well as a dissipative penalty term, the latter describing the hysteresis loss that belongs to the change of sense of rotation of the layer magnetisations of a lattice point. Further terms of the Hamiltonian, i.e., the Zeeman energy and the bilinear layer-layer interaction of random lateral distribution are replaced by an appropriate logical condition since both terms are independent of the sense of rotation. The model fairly well reproduces all details of domain ripening as deduced from the observed diffuse SMR and PNR maps only by adjusting the ratio of the domain-wall coupling constant to the coercive field of the ferromagnetic layers.

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Sept. 28. 2009, 15:30

Reflectometry in large magnetic fields - some measurements on superlattices containing Fe and Co

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An obvious method for measuring pure nuclear scattering from a magnetic sample is to force the magnetization to be collinear with the scattering vector. In the case of reflectometry, this would require a field direction that is normal to the sample surface. The field direction will also define the axis for the neutron magnetic moments. Any sample magnetization that remains in the plane will result in neutron spin flip scattering, with a concomitant change in the Zeeman potential energy of the neutron. The resulting spin flip specular reflectivity does not satisfy the condition that the incident and final angles are equivalent, hence spin dependent reflectivity is separated in space on a detector. This effect was first observed and explained by Felcher et al. [1].

We have recently attempted the same method to characterize the nuclear structure of superlattices containing iron and cobalt. The measurements on one of the samples showed two surprising effects that required further explanation. The first concerned strong Yoneda scattering that was observed at angles below the critical edge. This can be understood from calculations of the transmission coefficients for the sample, which for this sample showed a series of strong resonances below the critical edge. The second concerned polarization analysis experiments of the scattering, which showed polarization-dependent scattering in the unexpected channels. This observation can be qualitatively understood from considering polarization axes for the beam relative to the instrument, but does not appear to be explainable by the currently published theories.

[1] G.P.Felcher, S.Adenwalla, V.O.De Haan and A.A.Vanwell, Nature, **377**, 409 (1995)

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Sept. 28. 2009, 15:50

Neutron waveguide regime to study proximity effects at superconductor/ferromagnet interface

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The Polarized Neutron Reflectometry (PNR) is the powerful method for studying of the magnetism of layered nanostructures. Using information from different channels – spin-flip, diffuse scattering, GISANS etc., it is possible to restore spatial distribution of magnetization vector with the resolution 1 nm and less. Thus sensitivity of PNR as a magnetometric method makes value $10^{-5} \div 10^{-4}$ emu, which allows to study magnetism of samples with area 1 cm^2 and thickness of magnetic layer 10-100 nm.

However for many problems it is necessary to have a thinner layer with thickness of 1 nm and less. Proximity effects in hybrid systems superconductor/ferromagnetic is one of such examples. There are several predicted scenarios of influence of superconductivity on magnetism of a thin nanometer layer [1].

For enhancement of magnetic scattering (i.e. spin flip and diffuse scattering) it is suggested to use waveguide regime of neutron standing waves [2]. Using of this regime allows to increase intensity of magnetic scattering on 1-2 orders.

In this work the basic theoretical expressions, model calculations on optimization of parameters of structures as well as experimental data, showing possibility of the method are presented.

This work was partially supported by the Russian Foundation for Basic Research (grant № 09-02-00566) and Hungarian Academy of Sciences. One of the authors (Yu. Kh.) gratefully acknowledges the financial support by The Foundation for Assistance to Small Innovative Enterprises of Russian Federation (grant № 8455 UMNIK-08-3)

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Sept. 28. 2009, 16:10

The analysis of self-organized nanostructures with Grazing Incidence Small Angle Scattering

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The ability of block-copolymers to self-organize into a rich variety of nanoscale periodic patterns offers the potential to fabricate high-density arrays of nanostructures for spintronics and electronics applications. The quality of self-assembled block-copolymers usually is controlled with surface sensitive technique such as atomic force microscopy (AFM). In order to get depth-resolved information one can use X-ray or neutron scattering methods. In latter case it is necessary to apply theoretical analysis to the obtained data.

By using deuterated polystyrene-polybutadiene diblock copolymers with different molecular weight ratio of the blocks, we could produce nanostructures with a periodicity smaller than 50 nm on a large surface area. The surface analysis of obtained self-organized nanostructures was done by atomic force microscopy. For the depth resolved investigation of the lateral structures shape, ordering and periodicity, grazing incidence small angle neutron scattering (GISANS) was used. Obtained GISANS patterns were analyzed with distorted wave born approximation (DWBA) and shown good agreement with properties obtained from AFM images.

Sept. 28. 2009, 16:30

On the static structure factor of capillary waves at large wave vector transfers

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Currently there is considerable interest in small wavelength fluctuations of liquid surfaces. For small length scales the calculation of the interfacial Hamiltonian yields a length scale dependent surface tension $\gamma(q)$ [1]. Grazing incidence diffraction was used by several researchers to deduce γ (q) down to molecular length scales [2,3]. For data analysis an expression of the static structure factor of capillary waves by Sinha at al. [4] was frequently used which is valid in the limit of small scattering angles. Based on this expression an increase of scattering intensity at large wave vector transfers parallel to the sample surface was interpreted by a decrease of surface tension.
In our approach to calculate the static structure factor the full-wave-motion-induced static correlations are embedded in the calculation. This leads to an increase in scattering intensity especially at large wave vector parallel to the sample's surface. This increase might compensate the observed increase of scattering intensity which was assigned previously to γ (q).

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Sept. 28. 2009, 16:50

Off-Specular Neutron Scattering From Supported Single Lipid Bilayer

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Analysis of the off-specular neutron scattering from a polymer-supported single lipid bilayer provides in-plane height-height correlations of the system. As temperature is decreased from 37 to 25 °C, the thermoresponsive polymer swells. Consequently, the polymer-supported lipid membrane deviates from its previously planar structure. Modifications of the membrane's geometry are highlighted by pronounced changes in the off-specular scattering. Analysis of the off-specular scattering by means of the Distorted-Wave Born Approximation shows that the in-plane height-height correlation length of the membrane changes from 42.5 to 7.2 μm with the decrease in temperature. These results are consistent with the theory of weakly compressed thin elastic membranes.

Sept. 28. 2009, 17:30

Poster session

SEOP based in-situ NSF polarizer for large angle polarization analysis on MARIA at JCNS at FRM II

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Polarization analysis of polarized neutron scattering is a powerful tool for analysis of complex magnetic structures and the study of magnetic excitations. Instrumentation that can address these issues will have access to experiments at the forefront of modern materials science and soft matter research. Consequently polarization analysis will be an integral component for much of the instrumentation and thus science at the JCNS. Polarization analysis for MARIA will require coverage over a large area detector, broad wavelength and/or divergence range. These demands make methods other than neutron spin filters (NSF) inapplicable or technically unfeasible.

Spin-exchange optical pumping, SEOP, is the method of choice to polarize the ^{3}He NSFs at the JCNS because the varied instrument demands. Work and initial testing is underway on in-situ SEOP systems to polarize the ^{3}He gas constantly to steady levels of polarization for the SANS and reflectometry applications. These systems will feature a reversible analyzing power via adiabatic fast passage polarization inversion of the ^{3}He, thus eliminating the need for a neutron flipper in the analyzed beam. Both aspects of this project will rely on the hybrid SEOP technique [1] and frequency narrowed laser technology [2]. Construction of an analyzer suitable to continuously polarize the 3He NSF cell of an area sufficient to cover the full MARIA 2D detector is nearing testing stages.

The current status of the program, design specifications, and results of very recent tests will be presented.

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Sept. 28. 2009, 17:30

Poster session

Project of the new multifunctional reflectometer GRAINS with horizontal sample plane at the IBR-2M pulsed reactor in Dubna

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The new multifunctional reflectometer GRAINS is under construction at the modernized high flux IBR-2 pulsed reactor (IBR-2M) of the FLNP JINR (Dubna, Russia). The principal feature of this reflectometer, the horizontal sample plane (or vertical scattering plane), enables the study of liquid-containing interfaces. The reflectometer will operate in the time-of-flight regime with constant sample illumination during measurements. The important advantage is the constant angular resolution with unvaried background. The additional modes of the GRAINS reflectometer comprise (1) off-specular scattering and GISANS, which are measured simultaneously in the TOF regime at a 2D position-sensitive detector; (2) angular encoding in the horizontal plane, which is provided by a Larmor precession region limited by current sheets in front of the sample; (3) 3D polarimetry in reflection, which is provided by a Larmor precession region around the sample position. The design of the reflectometer is optimized to take better advantage of an exceptionally broad wavelength band of the new cold moderator at the IBR-2M. The set-up will open up principally new possibilities for investigations in the field of interface nano-science at the IBR-2M reactor.

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Sept. 28. 2009, 17:30

Poster session

SNS Liquids Reflectometer

Candice HALBERT

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Sept. 28. 2009, 17:30

Poster session

Magnetic correlations in laterally structured mulitlayers

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Laterally patterned magnetic structures are the basic elements of spintronic devices. With ongoing miniaturization the influence of neighboring cells becomes more and more important. We study the influence of the period of laterally striped magnetic multilayers on the magnetic properties and the magnetic domain formation.

Fe/Cr multilayers with antiferromagnetic-coupling have been grown epitaxially on GaAs (100) single crystals by molecular beam epitaxy (MBE). The magnetic superstructure is easily observable in polarized neutron reflectometry. The lateral structuring is performed by UV-based nanoimprint lithography and reactive ion etching. Structural characterization is done by atomic force microscopy and scanning electron microscopy. Polarized neutron reflectometry and off-specular scattering reveal the magnetic order and domain structure.

For the unstructured multilayers, the remanence shows a dependence on the number of layers. In the case of an odd number of Fe layers the net magnetization of the multilayer at remanence is the magnetization of a single layer. For a small number of layers, this is sufficient to align the magnetization of all layers along or opposite to the applied magnetic field. With increasing number the situation changes. In a multilayer with 19 AF-coupled Fe layers, we have found the entire magnetic signal in the spin-flip channels, which means that all Fe layers are magnetized perpendicular to the field.

In addition a structured sample with odd number of layers shows an influence of the remanence on the orientation of the structure to the external field. When the stripes are perpendicular to the field, most of the scattering signal was measured in the non-spin-flip channel i.e. the magnetization of the Fe layers is aligned parallel or antiparrallel to the applied magnetic field. The opposite was observed for the unstructured reference sample. For a parallel alignment, a structured multilayer acts the same way as the references specimen.

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Sept. 28. 2009, 17:30

Poster session

Proximity effects in Er|Tb multilayers

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We will present the data of off-specular diffuse scattering of different Er|Tb superlattices. Previous measurements have shown that in the sample with the thinnest Tb layer [Er_{21}/Tb_5] there is a complex magnetic structure with co-existing ferromagnetic and incommensurate domains, which is coherent for 6 bilayers [1]. In the other samples with larger Tb layers only the ferromagnetic coupling is long range. The new data of polarized off-specular neutron scattering reveals new insight into the anti-ferromagnetic coupling of the ferromagnetic Tb layers. The different samples show a strong thermal hysteresis of the anti-ferromagnetic coupling, which is obviously related to the Er in-plane order. In the [Er_{21}/Tb_5] sample the reflections resulting from this coupling appear during the cooling cycle at 25 K and disappear at 73 K during heating. Compared to this the [Er_{21}/Tb_{10}] sample does not show these reflections until 10 K during cooling and they disappear at 81.5 K.

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JCNS Workshop Off-Spec 2009

"Modelling and Data Analysis for Grazing Incidence and Off-Specular Scattering"

27-29 September 2009, Feldafing, InWent Bildungszentrum

Abstracts Sept. 29. 2009

Sept. 29. 2009, 09:00

Off-specular neutron reflectometry modeling and fitting software

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Neutron Reflectometry is a characterization technique which allows for sensitive measurements of both compositional and magnetic structure. Specular reflectivity is routinely used to determine the scattering length density profile of thin films in the film thickness direction. Work is currently being done to expand its application to the off-specular regime for the characterization of two-dimensional ordered structures in the plane of the film. The combination of this in-plane structural information with the routinely obtained depth profile can produce a detailed description of both magnetic character and composition of ordered films. While significant modeling capabilities have been developed in this area[1,2], off-specular neutron reflectometry as a widely used measurement technique has yet to be fully realized. An end-to-end, open source fitting software would increase the utilization of this useful technique by giving users an addition tool with which to evaluate and interpret data.

The University of Maryland along with NIST Center for Neutron Research (NCNR) and the NSF funded DANSE project are currently developing a software component for fitting multilayer samples, making off-specular neutron reflectometry accessible to a broader scientific community. Simultaneously, scattering simulations of models for a variety of feature structures and patterns in both the Born Approximation and the Distorted Wave Born Approximation are being produced.

The software is being developed in Python and emphasizes well structured object-oriented coding to allow for integration with global optimizers currently under development elsewhere in DANSE. These optimizers will offer parallel distribution for quick fitting of computationally intensive models. Three dimensional samples can be difficult to represent and so a variety of sample building tools are being developed including analytical shape descriptions and polygon representations from 3D modeling software like K-3D[3]. The software will also allow for easy integration of new, more accurate models. The goal of this project is to provide a tool for users to build models, calculated the off-specular scattering, and optimize the models to fit real data sets.

In this presentation, we give an overview of the software's current features and capabilities with an emphasis on its future direction.

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Sept. 29. 2009, 09:30

The SUPERFIT program for simulating and fitting reflectivity and off-specular scattering data

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The SUPERFIT program is based on an article of A. Rühm, B. P. Toperverg, and H. Dosch [1] in which a supermatrix formalism was introduced for the calculation of the spin-dependent neutron reflectivity of layered systems with non-collinear spin-structures. In a second article [2] this formalism was extended to spin-dependent off-specular scattering of magnetic multilayers with rough interfaces, using the distorted wave Born approximation (DWBA). The supermatrix method constitutes a magnetic extension of the Parratt formalism that allows the vectorial analysis of the magnetization in layered sytems. The magnetic DWBA allows the vectorial analysis of spatial inhomogeneities of the magnetic structure of the sample.

The SUPERFIT (*super*matrix *fit*) program is an ANSI C code primarily written for the LINUX operating system. At the moment the program provides the following features: Simulation and fit of both unpolarized and spin-resolved specular neutron data, simulation of unpolarized and spin-resolved off-specular neutron data, simultaneous fitting of unpolarized neutron and X-ray data. By slightly modifying the source code, one can introduce arbitrary constraints and relations between different fit parameters. The program produces graphical outputs and some data files for further processing of the obtained results.

The code uses the very effective MINUIT fitting routine of CERN written in FORTRAN (F. James http://consult.cern.ch/writeup/minuit/). The advantage of the MINUIT package is that the statistical errors of the data points are handled correctly even in the case of small count numbers where the general maximum-likelihood method must be used instead of the least squares method. Furthermore the MINUIT package can handle very large number of fit parameters, and errors and correlations of the obtained fit parameters are calculated correctly.

The SUPERFIT packet can be freely used under the terms of the GNU General Public License and can be download from the home page of the Max-Planck-Institut für Metallforschung, Stuttgart, Germany: http://www.mf.mpg.de/en/abteilungen/dosch/software/software_en.shtml

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Sept. 29. 2009, 10:00

FitSuite: Simulation and Simultaneous Fitting of Experimental Spectra including Neutron and X-ray Reflectivity and Diffuse Scattering

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Experiments often provide raw data of measurements performed on the same sample by different methods, and/or using different experimental conditions, like temperature, pressure, magnetic field, and the like. Data often partly depend on the same set of experimental and sample parameters therefore a *simultaneous evaluation* of all experimental data is prerequisite. However, data evaluation programs are dominantly organized around a single method therefore a simultaneous access to the data for a common fitting algorithm is not typical. Lacking suitable programs, some parameters are determined from one measurement, assumed error-free and kept constant when evaluating other experiments, an obviously incorrect approach. Besides, for different methods different programs are used, which makes it very difficult to tune parameters of such theories and their errors and correlations to each other and to extend or modify the theories to describe different experimental data.
Therefore we developed FitSuite for Windows *and* Linux, a thoroughly documented program with a detailed project home page [1], which is by now suitable for evaluating data of over ten spectroscopic methods, handles the various theories and sample structures consistently in a common structure. Besides, an actual procedure is provided to include new schemes and theories perhaps in the framework of a non-profit international project.

Currently FitSuite is capable of simultaneously fitting several data sets of experiments of the following kinds:

- Specular x-ray reflectometry
- Specular and off-specular (diffuse) polarized neutron reflectometry
- Specular and Off-specular (diffuse) Synchrotron Mössbauer reflectometry (SMR), (in specular case including time integral, time differential, stroboscopic detectection and a *model for self diffusion* in isotope periodic multilayers)
- Nuclear resonant forward scattering of synchrotron radiation (time differential and stroboscopic)
- Conventional Mössbauer absorption, emission and conversion electron spectroscopy

The talk will describe the program structure, the flexible handling of specimen structures and modifications as well as of parameter correlations and will provide examples of evaluations from recent projects.

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Sept. 29. 2009, 11:00

Data representations in off-specular neutron scattering

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Off-specular neutron scattering on time-of-flight and monochromatic wavelength reflectometers are considered. Data representations in different coordinates are described and discussed. Examples of experimental data on off-specular scattering from neutron waveguides and spatial beam-splitting are demonstrated.

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Sept. 29. 2009, 11:30

Microemulsions near a planar surface - a GISANS approach

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Microemulsions are used in many different fields of industrial application. Prominent examples are cleaning processes and oil production, where the microemulsions are not used in a single bulk phase but in the presence of a variety of surfaces.

The aim of this work was to examine the structure of a bicontinuous microemulsion when presented to a planar, hydrophilic surface. The method of choice was Grazing Incidence Small Angle Neutron Scattering (GISANS) where the penetration depth of the evanescent wave was modified with the overall scattering length density of the sample.

For the evaluation of the two-dimensional scattering patterns, we used an empirical fit functions to calculate the amplitudes of the different scattering contributions. The same process was applied to patterns which were calculated from Monte-Carlo Simulations done by M. Belushkin. While in the beginning our understanding was mainly dominated by the Laplace-Transformation, calculations in the simulated patterns have shown, that for a more accurate analysis, the "Distorted Wave Born Approximation" has to be taken into account.

Only due to the calculations, a quantitative agreement between all measurements and the simulations could be achieved.

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Sept. 29. 2009, 12:00

Time-of-flight Grazing Incidence Small Angle neutron Scattering on Gd Nanowires

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A Gd nanowire grating with a periodicity of approximately 225nm prepared on a faceted sapphire substrate was investigated by Time-Of-Flight Grazing Incidence Small Angle Neutron Scattering using REFSANS at the FRM II neutron source [1].

The technique and its advantage of faster data acquisition by use of a continuous neutron wavelength spectrum over a single wavelength setup in investigating a periodically laterally structured sample by GISANS are presented.

Measurements were performed for various orientations around the sample normal and allowed the information on the critical wavelength and the reflected and transmitted intensities to be obtained. As at a fixed incidence angle the radius of the Ewald sphere is varied with the wavelength, a reconstruction of the (Q_y - Q_z) shape of the grating truncation rods (GTR) in reciprocal space can be performed. Due to the strong penetration depth of neutrons, not only the reflected part of the pattern is explored but also the transmitted one.

The obtained portions of the GTRs could be compared successfully to their expected position and length (covered by the applied wavelength range) using the standard Born Approximation. However, further agreement would imply a more complex analysis.

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Sept. 29. 2009, 13:30

Magnetic offspecular neutron scattering at the reflectometer NeRo at GKSS

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Recently, a 2D analyzer was installed at the polarized neutron reflectometer NeRo located at the GKSS research center. The analyzer covering a range of 90x180mm^2 is placed in front of 2D detector and is designed for the analysis of the polarization of the specular and off-specular scattering. In this paper the performance of the 2D analyzer will be discussed on the basis of first measurements and examples.

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Sept. 29. 2009, 13:50

GISANS and Reflectometry at REFSANS

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Obtaining informations about a sample's structure both in-plane and out-of plane by performing specular and off-specular measurements at the same instrument could help elucidating complex structures and validate or rule out models based on data obtained in one spatial direction only.We here describe the REFSANS reflectometer which is operated at the FRM2 source in Garching (Germany) and which was designed to offer such a polyvalence. By using a polychromatic incident neutron beam and time of flight (TOF) wavelength resolution, REFSANS gives access to the full Q range in a single measurement. The TOF operation mode makes it possible to easily perform detailed analysis of the sample structure, for instance by following the dependence of the position of Bragg and Yoneda peaks as a function of wavelength. Moreover, for a single incidence angle, scattering patterns recorded at different wavelengths span the conditions ranging from full penetration (wavelength shorter than the critical value for total refection) to sensitivity to the very surface of the sample only.

Sept. 29. 2009, 14:10

Initial Off Specular Measurements at the SNS Liquids Reflectometer

John ANKNER

ORNL

Sept. 29. 2009, 15:00

BioRef – a time-of-flight reflectometer for soft matter applications at HZB

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BioRef, a time-of-flight reflectometer complementing the monochromator based V6 reflectometer at Helmholtz Zentrum Berlin (HZB) is currently under construction. Combined with an in-situ infrared spectrometer it will be optimised for soft matter applications at solid-liquid interfaces. A flexible double-chopper set-up together with a wavelength band chopper will enable the selection of well defined wavelength bands at different defined wavelength resolutions in order to optimize measurements with regard to the given application [1]. The selection of different distances between the first choppers allows for choosing constant resolutions of $\Delta\lambda/\lambda$ between 1 % and 5%, while different frequencies of the choppers are intended to alter the used bandwidth. A width of the band of 4 Å up to 12 Å can be selected between a minimum wavelength of app. 3.5 Å and a maximum of 15.5 Å. Lower wavelength resolutions than 5% can be realised when giving up the constant resolution. A state-of-the-art 2D position sensitive 3He detector will be used for the reflectivity measurements in horizontal scattering geometry. The time-of-flight mode is also chosen to realise the investigation of dynamic interface processes under shear and flow conditions. The choice of different wavelength bandwidths enables to focus on defined features in the reflection curve depending on the requirements of the specific measurements utilizing the highest possible efficiency. A q-range spanning 3 orders of magnitude and reflectivity measurements over more than 6 orders of magnitude are envisaged and their feasibility is supported by Monte Carlo simulations [2]. Additionally, the instrument is designed to benefit maximal from the future up-grade project currently planned for the cold source and guide system supplying the instrument. As a consequence a minimum wavelength of approximately 2.5 Å and up to an order of magnitude higher flux densities will be available.

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Sept. 29. 2009, 15:20

Initial results and future directions for the new OffSpec, spin-echo reflectometer, on the ISIS Second Target Station.

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OffSpec has been constructed, over the past 4 years, as a low background reflectometer with Spin-Echo capability and is currently entering its final commissioning phase. In this paper we will present initial results that demonstrate the performance of the new instrument in traditional reflection geometry, polarised reflection with polarisation analysis and finally Spin-Echo Resolved Grazing Incidence Scattering (SERGIS) mode. The preliminary measurements have been extremely encouraging, indicating that the predicted range of in-plane length scales that the instrument could access can be achieved in reasonable counting times. The results will be discussed with regard to data analysis techniques that are currently being developed. Finally the potential for the new instrument will be reviewed and potential improvements and upgrades that have already been noted will be discussed.

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Sept. 29. 2009, 15:40

The new high flux polarised neutron reflectometer MARIA at JCNS

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At the outstation of the Jülich Centre for Neutron Science (JCNS) at FRM II, a new reflectometer MARIA (Magnetism Reflectometer with high Incident Angle) is being built.
It is designed for investigations of thin magnetic layered structures down to the mono layer scale (optimised for layer thicknesses between 3-300 Å) with optional lateral structures of nm to µm size. Consequently the instrument is optimised for small sample sizes up to 1x1cm^2 and has polarisation analysis as standard. Beside the reflectometer mode with vertically focused beam and good resolution in the horizontal scattering plane, MARIA will be able to measure in the GISANS (Grazing Incidence Small Angle Neutron Scattering) mode with additional resolution in the vertical direction. The latter mode allows one to resolve lateral structures down to the nm scale. In this way MARIA is a strongly improved and extended successor of the former HADAS reflectometer at the research reactor DIDO in Jülich.
Unique features of MARIA include (i) vertical focussing with an elliptic guide from 170 mm down to 10 mm at the sample position, (ii) reflectometer and GISANS mode, (iii) polarization analysis over a large 2d position sensitive detector as standard, (iv) adjustable wavelength spread from 10 to 1 % by a combination of velocity selector and chopper, (v) flexible sample table using a Hexapod for magnetic field and low temperature sample environment and (vi) in-situ sample preparation facilities.
According to our simulations with the VITESS suite in combination with specialized programs, we expect a high polarised flux of ~$7 \cdot 10^7$ n/(s*cm^2) at 3mrad collimation. We will therefore be able to attack challenging problems in systems such as ultrathin magnetic layers down to the monolayer regime, laterally patterned thin films, molecular magnets deposited on a substrate, remagnetization kinematics down to 10 µs time windows etc.
In this contribution we will report on the design features, the simulated performance and the scientific case of this unique instrument.

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JCNS Workshop Off-Spec 2009

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JCNS Workshop Off-Spec 2009

Accommodation:

InWEnt - Internationales Bildungszentrum Feldafing

Wielinger Str. 52
82340 Feldafing

Tel.: 08157-938-0
Fax: 08157-938-777

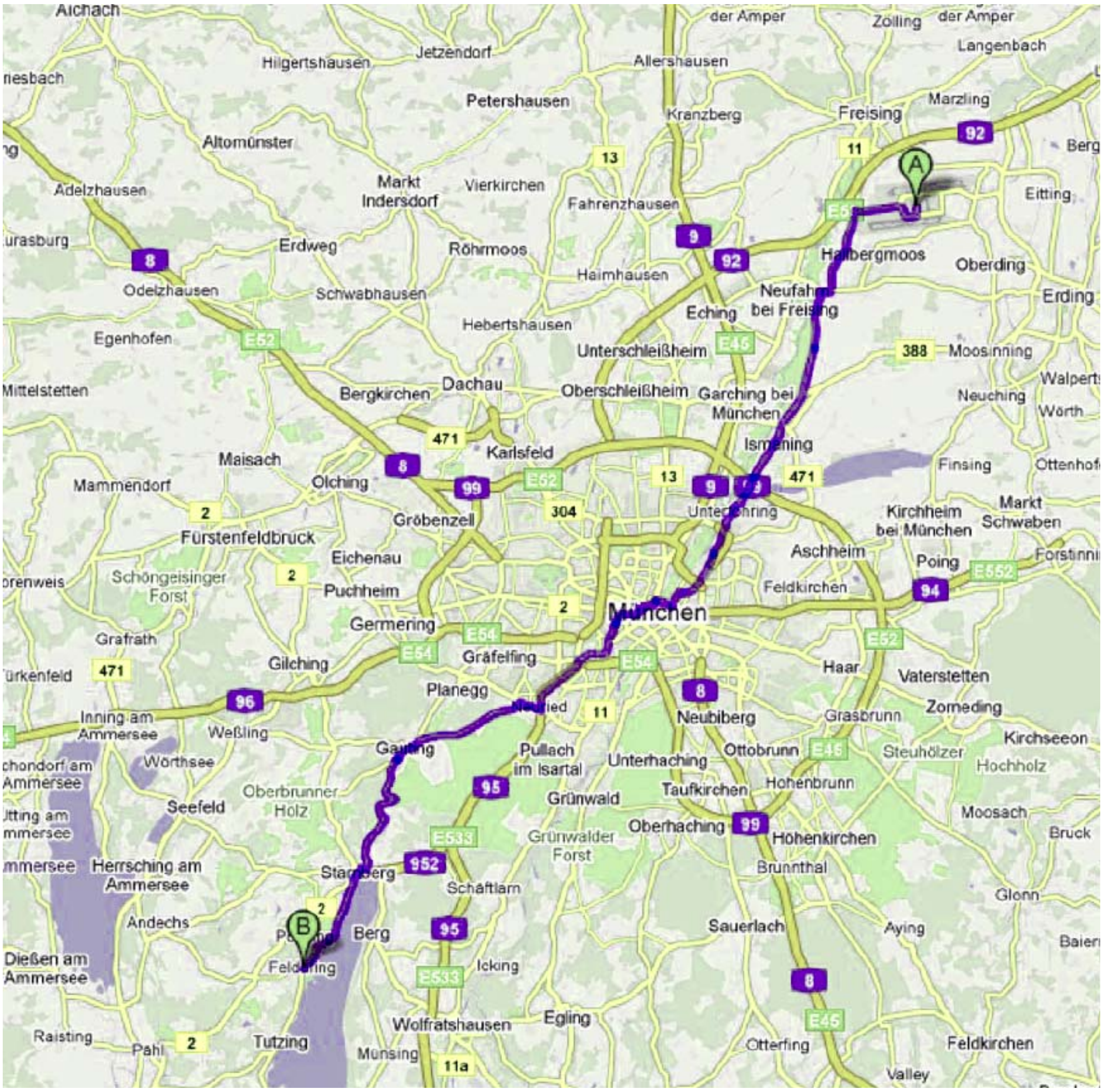
http://www.inwent.org/ueber_inwent/standorte/feldafing/index.php.en

By car:
via München **A95** direction **Garmisch-Partenkirchen** leave at junction Starnberg **(A952)** to **Starnberg**
Then **B2** direction **Weilheim** till **Wieling**, turn left (before Gasthof zur Linde) to **Feldafing**

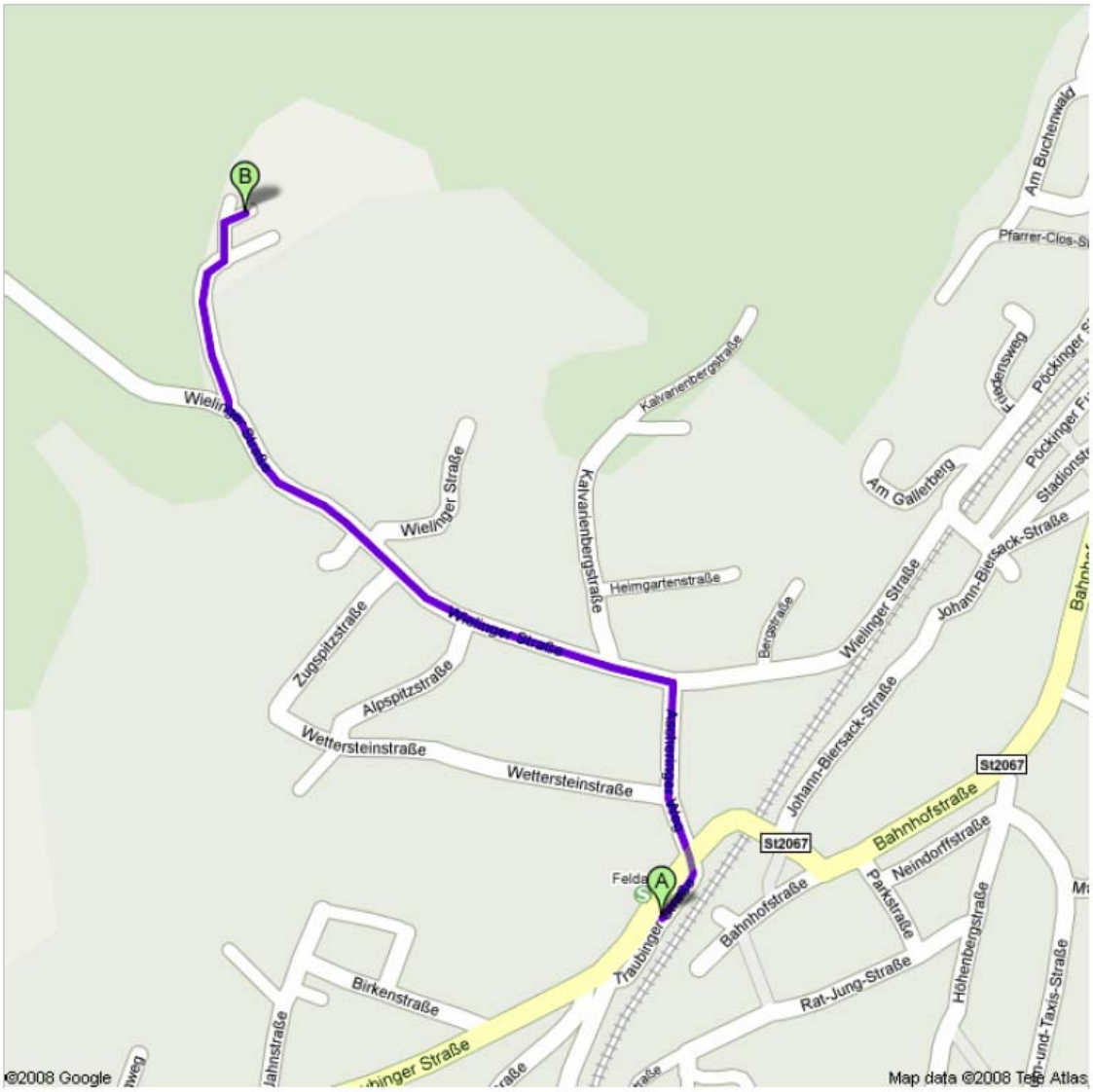
From airport München:
Option 1: Take S-Bahn **S1** to station **München-Laim**. There change to S-Bahn **S6 Tutzing.** Go to station **Feldafing**
Option 2: Take S-Bahn **S8** to station **Isartor.** There change to S-Bahn **S6 Tutzing.** Go to station **Feldafing**

From main station München:
Take S-Bahn **S6 Tutzing** to station Feldafing

From station Feldafing:
Go along Ascheringer Str. / Wielinger Str.. It is about 15 minutes walking distance direction **Wieling.** At the end of the village follow the signs to “InWEnt”.



Aichach
Hilgertshausen
Jetzendorf
Allershausen
der Amper
Zolling
Langenbach
Petershausen
Kranzberg
Freising
Marzling
Altomünster
Markt Indersdorf
Vierkirchen
Fahrenzhausen
Adelzhausen
Eitting
Erdweg
Röhrmoos
Haimhausen
Hallbergmoos
Oberding
Odelzhausen
Schwabhausen
Neufahrn bei Freising
Eching
Erding
Hebertshausen
Egenhofen
Unterschleißheim
Moosinning
Mittelstetten
Bergkirchen
Dachau
Oberschleißheim
Garching bei München
Neuching
Ismaning
Karlsfeld
Maisach
Finsing
Mammendorf
Olching
Gröbenzell
Unterföhring
Kirchheim bei München
Markt Schwaben
Fürstenfeldbruck
Eichenau
Aschheim
Schöngeisinger Forst
Puchheim
Feldkirchen
Poing
Germering
München
Grafrath
Gilching
Gräfelfing
Haar
Vaterstetten
Planegg
Neubiberg
Grasbrunn
Zorneding
Inning am Ammersee
Weßling
Ottobrunn
Steuhölzer
Kirchseeon
Wörthsee
Gauting
Pullach im Isartal
Unterhaching
Hochholz
Oberbrunner Holz
Seefeld
Grünwald
Taufkirchen
Hohenbrunn
Moosach
Oberhaching
Grünwalder Forst
Höhenkirchen
Bruck
Herrsching am Ammersee
Starnberg
Brunnthal
Schäftlarn
Glonn
Andechs
Berg
Sauerlach
Aying
Dießen am Ammersee
Feldafing
Icking
Raisting
Pähl
Tutzing
Wolfratshausen
Egling
Münsing
Otterfing
Feldkirchen
Valley



Footpath from S-Bahn Station Feldafing to InWent Education Centre.
Takes about 10-15 min partly up-hill.

Public Transportation Munich Airport to Feldafing

Selection single ride

Station/Stop	Date	Time	Platform	Products	
München Flughafen Terminal	Su, 27.09.09	dep15:51	1	S 1	S-Bahn Direction: München Ost Number of bicycles conveyed limited, 2nd
München-Laim	Su, 27.09.09	arr 16:28	2		class only
München-Laim	Su, 27.09.09	dep16:39	1	S 6	S-Bahn Direction: Tutzing
Feldafing	Su, 27.09.09	arr 17:11			Number of bicycles conveyed limited, 2nd class only

Duration: 1:20; runs Sa, Su, also 2. until 14. Sep 2009

Fares not available

Station/Stop	Date	Time	Platform	Products	
München Flughafen Terminal	Su, 27.09.09	dep16:11	1	S 1	S-Bahn Direction: München Ost Number of bicycles conveyed limited, 2nd
München-Laim	Su, 27.09.09	arr 16:48	2		class only
München-Laim	Su, 27.09.09	dep16:59	1	S 6	S-Bahn Direction: Tutzing
Feldafing	Su, 27.09.09	arr 17:31			Number of bicycles conveyed limited, 2nd class only

Duration: 1:20; runs Sa, Su, also 2. until 14. Sep 2009

Fares not available

Station/Stop	Date	Time	Platform	Products	
München Flughafen Terminal	Su, 27.09.09	dep16:31	1	S 1	S-Bahn Direction: München Ost Number of bicycles conveyed limited, 2nd
München-Laim	Su, 27.09.09	arr 17:08	2		class only
München-Laim	Su, 27.09.09	dep17:19	1	S 6	S-Bahn Direction: Tutzing
Feldafing	Su, 27.09.09	arr 17:51			Number of bicycles conveyed limited, 2nd class only

Duration: 1:20; runs Sa, Su, also 2. until 14. Sep 2009

Fares not available

Station/Stop	Date	Time	Platform	Products	
München Flughafen Terminal	Su, 27.09.09	dep16:42	2	S 8	S-Bahn Direction: Geltendorf Number of bicycles conveyed limited, 2nd
München-Pasing	Su, 27.09.09	arr 17:32	6/7		class only
München-Pasing	Su, 27.09.09	dep17:39	3	RB 30627	Regionalbahn
Tutzing	Su, 27.09.09	arr 17:59	3		Number of bicycles conveyed limited
Tutzing	Su, 27.09.09	dep18:04	1 Nord	S 6	S-Bahn Direction: Kreuzstraße
Feldafing	Su, 27.09.09	arr 18:07			Number of bicycles conveyed limited, 2nd class only

Duration: 1:25; runs daily

Fares not available

Station/Stop	Date	Time	Platform	Products	
München Flughafen Terminal	Su, 27.09.09	dep16:53	1	S 1	S-Bahn Direction: München Ost Number of bicycles conveyed limited, 2nd
München-Laim	Su, 27.09.09	arr 17:28	2		class only
München-Laim	Su, 27.09.09	dep17:39	1	S 6	S-Bahn Direction: Tutzing
Feldafing	Su, 27.09.09	arr 18:11			Number of bicycles conveyed limited, 2nd class only

Duration: 1:18; runs Sa, Su

Station/Stop	Date	Time	Platform	Products	
München Flughafen Terminal	Su, 27.09.09	dep17:11	1	S 1	S-Bahn Direction: München Ost Number of bicycles conveyed limited, 2nd
München-Laim	Su, 27.09.09	arr 17:48	2		class only
München-Laim	Su, 27.09.09	dep17:59	1	S 6	S-Bahn Direction: Tutzing
Feldafing	Su, 27.09.09	arr 18:31			Number of bicycles conveyed limited, 2nd class only

Duration: 1:20; runs Sa, Su, also 2. until 14. Sep 2009

Public Transportation Feldafing to Munich Airport

Selection single ride

Station/Stop	Date	Time	Platform	Products	
Feldafing	Tu, 29.09.09	dep16:28		S 6	S-Bahn Direction: Aying
München-Laim	Tu, 29.09.09	arr 17:01	2		Number of bicycles conveyed limited, 2nd class only
München-Laim	Tu, 29.09.09	dep17:11	1	S 1	S-Bahn Direction: München Flughafen Terminal
München Flughafen Terminal	Tu, 29.09.09	arr 17:46			Number of bicycles conveyed limited, 2nd class only

Duration: 1:16; runs daily

Fares not available

Station/Stop	Date	Time	Platform	Products	
Feldafing	Tu, 29.09.09	dep16:48		S 6	S-Bahn Direction: Kreuzstraße
München-Laim	Tu, 29.09.09	arr 17:21	2		Number of bicycles conveyed limited, 2nd class only
München-Laim	Tu, 29.09.09	dep17:31	1	S 1	S-Bahn Direction: München Flughafen Terminal
München Flughafen Terminal	Tu, 29.09.09	arr 18:06			Number of bicycles conveyed limited, 2nd class only

Duration: 1:16; runs daily

Fares not available

Station/Stop	Date	Time	Platform	Products	
Feldafing	Tu, 29.09.09	dep16:50		S 6	S-Bahn Direction: Tutzing
Tutzing	Tu, 29.09.09	arr 16:56			Number of bicycles conveyed limited, 2nd class only
Tutzing	Tu, 29.09.09	dep17:00	2	RB 5420	Regionalbahn
München-Pasing	Tu, 29.09.09	arr 17:20	2		Number of bicycles conveyed limited
München-Pasing	Tu, 29.09.09	dep17:29	4/5	S 8	S-Bahn Direction: München Flughafen Terminal
München Flughafen Terminal	Tu, 29.09.09	arr 18:17			Number of bicycles conveyed limited, 2nd class only

Duration: 1:27; runs not every day, 15. Sep until 11. Dec 2009 Mo - Fr

Fares not available

Station/Stop	Date	Time	Platform	Products	
Feldafing	Tu, 29.09.09	dep17:08		S 6	S-Bahn Direction: Kreuzstraße
München-Laim	Tu, 29.09.09	arr 17:41	2		Number of bicycles conveyed limited, 2nd class only
München-Laim	Tu, 29.09.09	dep17:51	1	S 1	S-Bahn Direction: München Flughafen Terminal
München Flughafen Terminal	Tu, 29.09.09	arr 18:26			Number of bicycles conveyed limited, 2nd class only

Duration: 1:16; runs daily

Station/Stop	Date	Time	Platform	Products	
Feldafing	Tu, 29.09.09	dep17:28		S 6	S-Bahn Direction: Aying
München-Laim	Tu, 29.09.09	arr 18:01	2		Number of bicycles conveyed limited, 2nd class only
München-Laim	Tu, 29.09.09	dep18:11	1	S 1	S-Bahn Direction: München Flughafen Terminal
München Flughafen Terminal	Tu, 29.09.09	arr 18:46			Number of bicycles conveyed limited, 2nd class only

Duration: 1:18; runs daily

Fares not available

Station/Stop	Date	Time	Platform	Products	
Feldafing	Tu, 29.09.09	dep17:48		S 6	S-Bahn Direction: Höhenkirchen-Siegertsbrunn
München-Laim	Tu, 29.09.09	arr 18:21	2		Number of bicycles conveyed limited, 2nd class only
München-Laim	Tu, 29.09.09	dep18:31	1	S 1	S-Bahn Direction: München Flughafen Terminal
München Flughafen Terminal	Tu, 29.09.09	arr 19:06			Number of bicycles conveyed limited, 2nd class only

Duration: 1:18; runs daily