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Editorial

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Cover illustration

Staff members from Risø and PSI during the assembly of the RITA-II triple axis spectrometer at SINQ. The instrument is part of the PSI-Risø cooperation and replaces the former DrüchaL spectrometer.

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The SGN/SSDN President's Page

Dear members,

when I was asked to write my first president's page for the Swiss Neutron News, I took this as a chance to make a little pause and look back at the last six months. First of all I would like to thank our past president Klaus Yvon for his contributions to the society and the neutron scattering community in general. During the past years he has enormously helped to strengthen our situation, he has been active in numerous boards such as the scientific council of the ILL and of the Swiss Neutron Facility SINQ, and he has always been an enthusiastic supporter of neutron scattering. The last project that he started as the president of our society has been the initiation of a project for a report on the ‚Status and Future of Neutron Research in Switzerland'. He has outlined this project in his presidential page in the last issue of the Swiss Neutron News. The convenors that are responsible for the different scientific disciplines (structural and magnetic excitations; crystallography; magnetic structures; biology; soft matter, glasses and liquids; materials sciences) have in fact written their reports, and we now have to take the next step and edit the individual contributions into a concise report. This final document should assess the current status of the research with neutrons in Switzerland, estimate our future needs and provide recommendations for our scientific authorities regarding important issues such as the renewal of the ILL contract, the optimal strategy for the support of the project of an ‚European Spallation Source' (ESS) and the necessary investment into SINQ. It is in fact foreseen to dedicate the annual meeting of our society to this report. During this meeting the SGN/SSDN ‚strategy paper' on the future of neutron scattering in Switzerland will be presented together with selected scientific talks that highlight the status and future trends in the different key areas. Details on the meeting can be found in this news letter, and I hope that you will all participate actively.

There were other important developments that have clearly strenghtened the neutron scattering community in Switzerland. The Swiss Neutron Facility SINQ at the Paul Scherrer Institute in Switzerland has applied for membership in the EU Large Scale Facilities Programme. This application has been strongly supported by various organizations such as the European Neutron Scattering Association (ENSA) or the Scientific Council of SINQ. This proposal has indeed been granted, and SINQ will receive Euro 1'166'667,- for a period of 28 months, which corresponds to Euro 500'000 per year. I am sure that we all will profit from this support, and that it represents another important

milestone in the development of SINQ as a world class neutron scattering facility. Moreover, it also shows the recognition that SINQ has already achieved among the international neutron scattering community.

Another interesting development has been the scientific collaboration between the Denish National Research Laboratory in Risø and the PSI in the domains of biophysics, soft condensed matter and high-TC superconductivity initiated this spring. In response to the shut down of the Risø neutron scattering facilities, Risø will now transfer some of its world class neutron scattering instruments (two RITA triple axis spectrometers and the SANS instrument) to SINQ. It is clear that this not only significantly improves the SINQ facilities, but will undoubtedly lead to highly benefitial synergy effects in various research areas.

I believe that all these events demonstrate that the neutron scattering research in Switzerland is progressing steadily, and I am most grateful to all of you who have contributed in one way or the other to these successful developments. However, it is also clear that this should not make us lay back and forget about the most important pending decisions and initiatives that will determine the future of neutron scattering in Switzerland as well as internationally.

Peter Schurtenberger

PSI-Risø collaboration well underway

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1. Har De en smørrebrødsseddel?

This question will echo in the SINQ guide hall, after all, Danes need their daily ration of their national dish, the smørrebrød. Every viewer of the Muppet Show is well aware that smørrebrød stands simply for sandwich and one can find it in a myriad of versions in Scandinavia. PSI onsite restaurant OASE will have to come up with a smørrebrødsseddel (seddel=menu card) if we expect our new Danish colleagues to reach their customary high standards since they will soon show up regularly at the SINQ facility. And this is how the saga started:

In September 2000 the unexpected and final end of reactor operations at the Risø National Laboratory, Denmark was announced. A large, international research community has been intensively using the research reactor‘s instruments for neutron scattering experiments for decades. The Danish colleagues thus investigated the possibility to install their own instruments at other European neutron scattering centres in order to carry on their successful studies in the fields of high-temperature superconductivity, quantum-magnetism, bio- and polymer physics. Finally they chose SINQ, first because of its inherent potential for further developments, second because several beam ports are currently unoccupied and third, PSI in house research program matches well the ongoing research activities at Risø. Already in November 2000 a Risø - PSI taskforce agreed on a six year term cooperation and defined the respective contributions in a letter of intent, which in turn was brought to its final form and signed by the two directors in early 2001. This was the beginning of bipartisan collaboration – maybe the economic term of merger (at least in the neutron scattering area) might be appropriate, from which both sides will undoubtedly profit tremendously. The main points in the collaboration are:

- Installation of three Risø-neutron scattering instruments at SINQ (the first instrument, a cold triple axis spectrometer RITA-II has been installed in early May and is currently being commissioned)
- Transfer of auxiliary equipment such as lowest temperature cryostats, superconducting magnets, etc.) to SINQ;
- Joint research in the above mentioned fields.

All PSI neutron scatterers are looking forward to the future collaboration with their Danish colleagues: Velkommen til PSI og SINQ-hallen!

2. Good-bye to DrüchaL, say hello to RITA-II

In the course of the PSI-Risø collaboration it was decided to replace the cold triple axis spectrometer DrüchaL situated at SINQ neutron guide RNR-13 by the newly developed spectrometer RITA-II (see figure 1).

After final mechanical and electrical tests with RITA-II at Risø National Laboratory the instrument was shipped at the end of April 2001 to the PSI. Prior to the arrival of RITA-II, DrüchaL - which ran successfully since 1998 - was removed from the monochromator shielding, taken apart and mothballed. It will be back in service once funding for the new SINQ thermal triple axis spectrometer TNT will be approved.

Fig. 1: *End of April 2001: Experts from Risø National Laboratory and PSI make sure that the new cold neutron triple axis spectrometer RITA-II (Denmark) is installed on time in the SINQ guide hall. Note the large analyser shielding which houses the analyser and the 2-D detector (rectangular box, visible at centre).*

RITA-II (RITA stands for Re-Invented Triple Axis) has several novel technical features:

- A two-dimensional wire detector replaces the usual single detector.

- The analyser consists of nine blades, each of them can be separately moved. This allows for simultaneous scans (energy, Q, etc).
- The detector and the analyser are mounted inside a joint shielded chamber that can be flooded with argon, thus reducing background contributions.
- The vertical dimension of the detector allows for true background measurements out of the scattered beam.

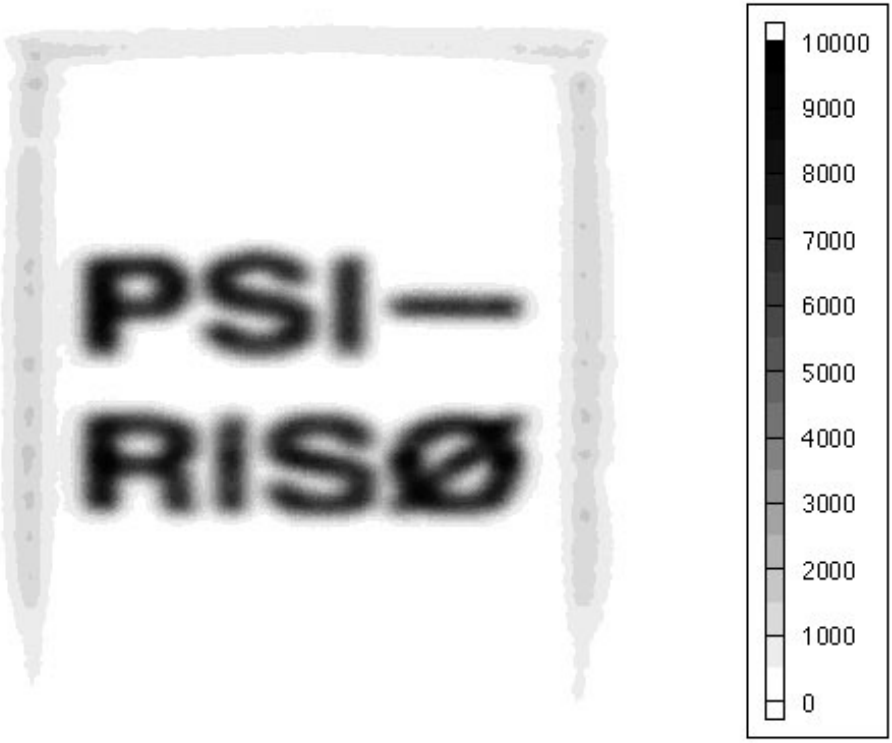

Fig. 2: *Neutrons scattered from an Al2O3 standard sample were incident on a cadmium mask with punched holes arranged to form the logo PSI-RISØ that was mounted in front of the 2-D detector.*

Thanks to the excellent preparation from both sides the installation of RITA-II was well within schedule. After thorough testing of all components the focus was on the calibration of the new detector that quickly delivered the first pictures taken with neutrons. Figure 2 shows an early example where a cadmium mask with punched holes arranged to form the logo PSI-RISØ was used to demonstrate that the 2-D detector is truly operational. User operation of RITA-II will start in June. More information on the instrument can be found under http://rita2.psi.ch.

Formation of a Magnetic Soliton Lattice in Copper Metaborate, CuB_2O_4

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The magnetic ground state of copper metaborate has been investigated by means of elastic neutron scattering. The magnetic structure is incommensurate with respect to the chemical lattice at T=1.8K and undergoes a continuous phase transition to a non-collinear commensurate antiferromagnetic state which is realized at T=10K. Close to the phase transition higher order magnetic satellites are observed. Coexistence of long range and short-range magnetic order has been observed in both magnetic phases. This suggests that the association of the Dzyialoshinskii-Moriya interaction, lattice symmetry and tetragonal anisotropy leads to the formation of a three-dimensional magnetic soliton lattice.

One of the very first quantitative observations of a soliton wave is due to Scott-Russel (Fig. 1), who noticed in 1834 the persistence of a solitary wave in shallow water (published 10 years later in [1]). Five decades later, after the work of Korteweg and de Vries [2], it was recognised that a soliton is a pure non-linear phenomenon which may be viewed as a localised disturbance of a propagating wave as shown in Fig. 2.

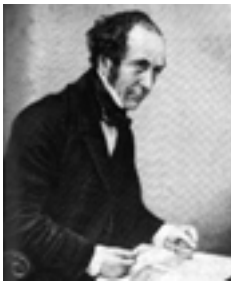

Fig. 1:
John Scott Russell (1808-1882)

Fig. 2:
Sketch of a magnetic soliton wave showing the spin arrangement in a helix.

The recognition that solitons are remarkably stable under the influence of external fields and under mutual collisions is due to the numerical calculations of Zabusky and Kruskal published in 1965 [3]. Nowadays, soliton theory has found applications in various fields of technology and science, such as acoustics, non-linear optics, quantum physics, polymer science and structural phase transitions. The differential equations, which lead to solitonic waves, have special solutions corresponding to localised or topological dislocations of a periodic structure. Well-known examples are the domain walls in ferromagnets. In a magnetically ordered crystal, a soliton is a deformation of a regular spiral resulting in a non-uniform rotation of the magnetic moments along the pitch of the helix. The system can be represented as an array of ordered structures with finite dimensions and separated from each other by domain walls (solitons), as illustrated in Fig. 2. Although the theory of a magnetic soliton lattice is very well developed and yields exact mathematical solutions for the classical energy-density equations in magnetically ordered crystals [4], experimental confirmation of the existence of a static magnetic soliton-lattice is lacking.

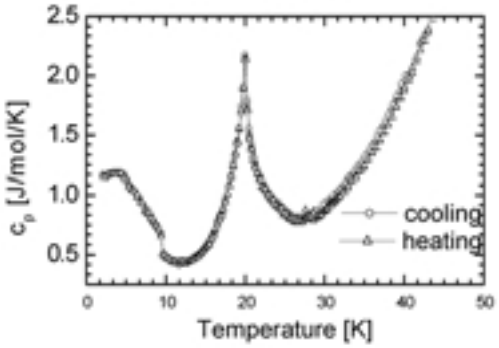

Fig. 3: *Heat capacity measurements of CuB_2O_4.*

Coppermetaborate shows two phase transitions at T_N=21K and at T*=10K as observed with heat capacity measurements shown in Fig. 3. From the magnetization and sus-ceptibility measurements it is concluded that copper metaborate is a weak ferromagnet for $T^* < T < T_N$ [5]. The chemical structure was determined in the paramagnetic phase at T=25K. Due to the relatively large volume and low mosaic of the single crystal, it was necessary to correct the observed neutron intensities for extinction. To allow for a reliable correction, the neutron measurements were carried out at two wavelengths λ =2.4 Å and 1.2 Å, respectively. The refined parameters of the chemical structure were found to be in agreement with the X-ray results of Martinez et al. [6]. CuB_2O_4 crystallizes in space group I -4 2 d (D_{2d}^{12}) with lattice constants a=11.528 Å, c=5.607 Å. The unit cell contains 12 formula units. The Cu^{2+} ions occupy two inequivalent positions at Cu(A) = (site 4b, point symmetry S_4, 0 0 ½) and Cu(B)=(site 8d, point symmetry C_2, x 1/4 1/8, x=0.0815), respectively. Cu(A) is at the center of a square unit formed by four oxygen ions, while Cu(B) is surrounded by six oxygen ions located at the vertices of a distorted octahedron. From high-resolution neutron and synchrotron powder diffraction, we conclude that CuB_2O_4 does not undergo any structural phase transition down to T=1.5K.

Below 10K, the magnetic structure of CuB_2O_4 gets incommensurate due to changes in the spin ordering of the copper atoms. Such incommensurate magnetic structures are characterized by modulations of their spin arrangements over periods, which are long compared to the size of the chemical cell and not commensurate with the underlying lattice [7]. The existence of such magnetic structures in compounds with localized spin densities is either due to competitions between exchange interactions or relativistic effects like spin-orbit coupling. While the former effects can be found accidentally, the latter mechanism depends on lattice symmetry. Relativistic interactions were first considered by Dzyaloshinskii [8] and given a microscopic description by Moriya [9]. The Dzyaloshinskii-Moriya (DM) interaction is usually written as the cross product of interacting spins $H_{DM}=\mathbf{D}\cdot(\mathbf{S}_1 \times \mathbf{S}_2)$ where **D** is the DM-vector. The direction of the DM-vector is determined by the bond symmetry and its scalar by the strength of the spin-orbit coupling [10]. The antisymmetric DM-interaction in antiferromagnets favors a canted arrangement of the magnetic moments, which results in a weak spontaneous magnetization. Spiral structures arise from the presence of a term linear in the gradient of the magnetization (what is referenced by Dzyaloshinskii [8] as "Lifshitz Invariance" [11]) in the thermo-dynamical potential. Dzyaloshinskii has shown that a Lifshitz invariance is naturally obtained from relativistic interactions in chemical structures belonging to the space groups D_2, D_{2d}, C_{3h}, D_3, D_{3h}, S_4, D_4, D_6, T, T_d, O (Schoenflies notation).

The presence of an additional crystal anisotropy distorts the simple helicoidal spin arrangement. Therefore, the angle evolution of the magnetic moments is described by the solution of the sine-Gordon equation for a soliton lattice [10,12]. It should be recognized that a soliton corresponds to localized or topological dislocations of a periodic structure, which arise when non-linear forces are present [13]. In a magnetically ordered crystal, a soliton is a deformation of a regular spiral resulting in a non-uniform rotation of the magnetic moments along the pitch of the helix.

In that case, Dzyialoshinskii has shown that a second order phase transition from the incommensurate to a commensurate structure occurs either at a given temperature T^* or equivalently in the presence of a large magnetic field. The formation of an incommensurate chemical lattice has been often observed in condensed matter physics [14]. The presence of solitons in a three-dimensional magnetic lattice is unusual, but recently observed in the spin-Peierls compounds TTF-CuBDT [15] and $CuGeO_3$ [15]. To our knowledge, a field-induced incommensurate-commensurate phase transition has been observed only for the Dzyaloshinskii-Moriya helimagnet $Ba_2CuGe_2O_7$ [16].

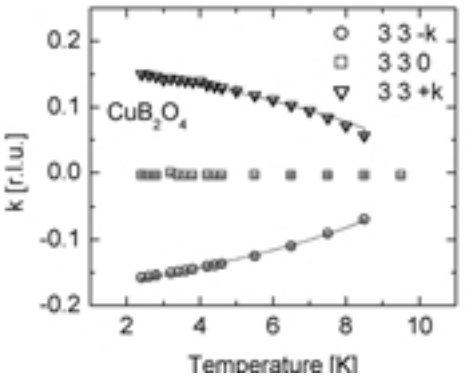

Fig. 4: *Positions of the incommensurate magnetic satellites of the 330 reflection in CuB2O4 as a function of temperature.*

We showed in [17] that the association of the spin-orbit interaction, lattice symmetry and tetragonal anisotropy leads to the formation of a magnetic soliton lattice in CuB_2O_4. The single crystal used for the elastic neutron scattering experiments were performed on TASP at SINQ, D10 at ILL, supported by first measurements on TriCS at SINQ. The crystal was prepared at the Institute of Physics Krasnoyars-kusing using ^{11}B isotope. In the temperature range 10K < T < 21K the magnetic structure is commensurate. Upon lowering the temperature below T*=10K, a commensurate to incommensurate magnetic phase transition of the copper sublattice occurs (c.f. Fig. 4). In addition, strong diffuse scattering is observed at the magnetic Bragg positions indicating that within the time window accessible by neutrons spin fluctuations coexist with static moments (Fig. 4 in ref. [17]).

Systematic scans in reciprocal space allowed magnetic reflections to be found at commensurate Bragg positions for T=12K. At this temperature, the observation of forbidden reflections such as (1,1,0) or (0,0,2) show that the magnetic structure is antiferromagnetic. The magnetic structure is accordingly described by the propagation vector **k**=0, so that the magnetic and chemical cells coincide.

As the lattice symmetry operation I is also a magnetic translation when **k**=0, the relevant irreducible representations of the magnetic structure are those of the point group –4 2 m. This point group contains eight elements and has five irreducible representations. Four of them are one-dimensional (Γ_1, Γ_2, Γ_3,Γ_4) and one, labeled Γ_5, is two-dimensional. The reduction of the induction representation gives

$\Gamma_{4b}=\Gamma_3+\Gamma_4+2\Gamma_5$ and $\Gamma_{8d}=\Gamma_1+2\Gamma_2+\Gamma_3+2\Gamma_4+3\Gamma_5$ respectively.

The magnetic modes Γ_3 and Γ_4 of the 4b site correspond to a collinear ferromagnetic and antiferromagnetic ordering along the z-axis, respectively. The modes associated with the Γ_5 representation describe a non-collinear magnetic structure with the magnetic moments rotated by 90° from each other. Similar magnetic modes for site 8d can be deduced again with help of group theory. As both Cu sub-lattices order simultaneously, the magnetic ordering should correspond to the same irreducible representation (Γ_3, Γ_4 or Γ_5).

From a least-square refinement of a diffraction set consisting of 25 pure magnetic peaks (R_F=4%), we find that the magnetic structure of CuB_2O_4 can be described as a non-collinear arrangement of both the Cu(A) and Cu(B)-spins along the diagonals of the tetragonal plane. The Cu(A) magnetic moments have a small component μ_z=0.25μ_B parallel to the c-axis which corresponds to an angle of 14° out-of the tetragonal ab-plane. Symmetry analysis of the chemical structure of CuB_2O_4 indicates that the DM-interaction is allowed between the Cu(A) nearest neighbor spins [9]. The DM-vector is perpendicular to the tetragonal ab-plane of the crystal and, accordingly, the DM-interaction favors the non-collinear spin arrangement, which is actually observed. This indicates that the DM-interaction plays a significant role in forming the magnetic ground state in CuB_2O_4. From a simple scaling with the data taken in the paramagnetic phase, we obtain the value of the magnetic moment 1 μ_B for the Cu(A) spins at T=12K. Within the precision of the present measurements, the Cu(B) spins are confined close to the ab-plane and have a small magnetic moment 0.25 μ_B, as shown in [17]. As Cu(A) and Cu(B) magnetic moments do not compensate for each other, a spontaneous ferromagnetic moment equal to 0.1μ_B per formula unit exists at T=12K.

As shown in Fig. 4, the propagation vector **k** is temperature-dependent below T=10K and two magnetic satellites appear at symmetrical positions with respect to the commensurate reciprocal lattice-points. This shows that the magnetic structure of CuB_2O_4 becomes incommensurate along the tetragonal axis. The period of the spin modulation continuously increases from **k**=0 below T^*=10K to **k**=(0,0,0.15) at T=1.8K. At this temperature, the modulation of the spin structure has a period of c/0.15 ≈ 40 Å along the crystallographic c-axis. The evolution of the satellite position with temperature, **k**(T), is found to follow a power law and smoothly goes to zero with increasing temperature. The period of the helix growths to infinity at T^*=10K. In addition, considerable diffuse scattering superimposes on the resolution-limited Bragg peaks for neutron scattering vectors **Q** along the [0,0,1] crystallographic direction. The intensity of the diffuse scattering increases with increasing temperature and exhibits a critical divergence close to T*. This is in accordance with the observation of magnetic susceptibility and specific heat peaks at this temperature [17]. The line-shape of the diffuse scattering is well reproduced by the Fourier transform of the spin correlation function proposed by Ornstein and Zernicke [18]. This function, which is a Lorentzian, is valid only in the temperature range where magnetic fluctuations are large. The average correlation length ξ obtained from the line-width κ decreases upon passing into the incommensurate magnetic phase and reflects that the correlation length increases with decreasing temperatures up to ξ≈70Å at T=1.8K. Diffuse scattering is unexpectedly observed at the lowest temperature reached in this experiment. Namely, for three-dimensionally ordered magnets, critical fluctuations are usually sizable only in a small temperature range below the magnetic phase-transition. On the contrary, for spiral structures caused by relativistic interactions, a continuous intensity distribution is expected in a large temperature range, due to perturbations in the simple helix structure. Diffuse scattering is observed at the

lowest temperature reached in this experiment and diverges when T approaches T*. This demonstrates the validity of the soliton concept for CuB_2O_4. In that context, the soliton width is given by the value of the parameter ξ [19].

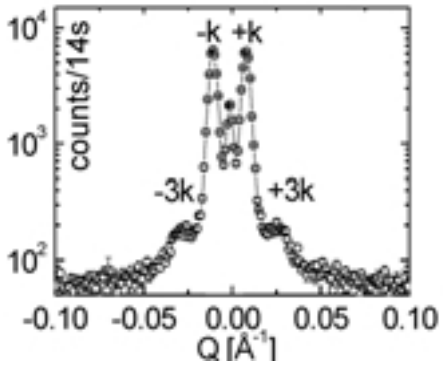

Fig. 5: *Higher order satellites along the (11k) direction approaching the phase transition at 10 K from the incommensurate phase. Measurement has been performed on TASP/SINQ.*

The helix structure can be distorted by the crystalline anisotropy, which induces inhomogeneities in the magnetization density. The solution of the sine-Gordon equation results then in a magnetic soliton lattice [19]. In that case, higher order satellites appear close the principal magnetic satellites. The amplitudes of these higher-order magnetic satellites increase with temperature and are largest close to the incommensurate-commensurate phase transition [20]. Fig.5 shows a neutron scan along the (1,1,k) direction at T=9K which reveals that when the temperature approaches T* higher order satellites are produced.

In conclusion, we have shown that by neutron diffraction that the magnetic structure of CuB_2O_4 is incommensurate at low temperature. The propagation vector of the magnetic structure smoothly decreases to zero and follows the power-law given by theory [20] with increasing temperature. A non-collinear magnetic state commensurate with the underlying chemical lattice is eventually formed at T*=10K. Higher-order magnetic satellites and coexistence of short-range and long-range order are observed. All these observations are in agreement with the theoretical calculations for a three-dimensional magnetic soliton lattice [4,20]. Further diffraction measurements at 400mK are expected to give more information on the ordering of the Cu(B) sub-lattice.

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Recent Progress in Neutron Imaging

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1. Introduction

The investigation of macroscopic material samples by neutrons has a long tradition since powerful neutron sources became available [1]. Neutron radiography stations have been installed at many places world-wide [2]. Commonly, dedicated beam lines at research reactors were used for neutron transmission measurements based on film exposure, similar to x-ray inspections. The majority of facilities are using thermal neutrons, just a few also cold neutrons.

Important fields of application have been the check of explosives, investigations of spent nuclear fuel, of bulky metallic assemblies, of adhesive connections, and of processes like two-phase flow.

These topics are still of interest, but instrumental progress has been made e.g. on new detection principles and by further methodical improvements. The main progress in this field is the direct (inherent) presentation of radiography results in digital formats. Most of the advanced detector systems are able to provide digital imaging data, which can be used in the post-processing applying all options of electronic image data analysis.

Furthermore, the methods mentioned above, which will be described in more detail later, are much more sensitive than traditionally used films. Therefore, it becomes feasible to investigate time-depending processes in more detail. Similarly, the installation of beam lines with higher intensity for radiography purposes (at FRM-II and ILL Grenoble) will give challenging conditions for real-time measurements.

Based on the digital information in the two-dimensional transmission data, neutron tomography becomes possible by several projections of an object from perspectives within 180 degrees and the subsequent reconstruction of the entire sample volume.

Finally, the quantitative non-invasive investigation of material contents (e.g. H, B-10, U-235,...) can easily be performed on the basis of the digital information. In some cases, it is necessary to have a feedback by computer simulations to describe (or correct) special effects like multiple neutron scattering or spectral shifts in bulky samples.

This paper describes the status of methods and applications in neutron imaging including their future perspectives. It intends to demonstrate also some overlap between neutron radiography and neutron scattering.

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2. The radiography set-up

The simplified sketch of the set-up of a radiography facility in Fig. 1 describes the most important components, which are necessary to produce transmission images such as shown in Fig. 2 for a hard-disk drive. Beside the properties of the detector system (as described later), the performance of the facility with respect to the resolution in time and space is mainly given by the beam characteristics. Images without any spatial distortion (blurring) can be produced with an ideally parallel beam. "Value" neutrons in the sense of a parallel beam must be selected by a suited collimator system, because the neutron field coming directly from the sources (reactors, spallation sources) have a large extension and divergence. In addition, the gamma-background from the neutron generation process must be minimised by suited filters.

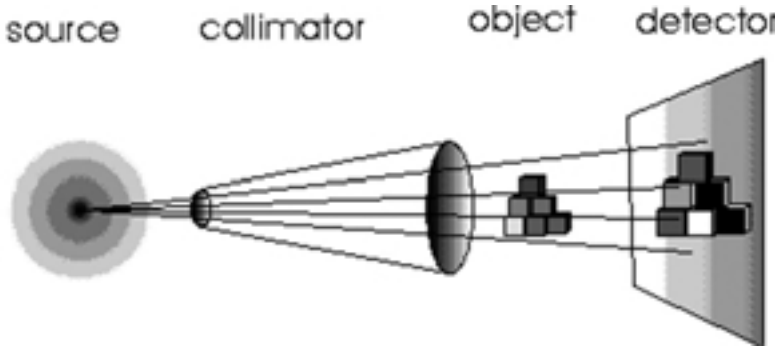

Fig. 1:Simplified set-up of radiography facilities, illustrating the most important components

In the final result, it is a deal between neutron intensity and the collimation quality. A characteristic quantity for a radiography station as a measure for the spatial resolution performance of the instrument is the L/D ratio (L = collimator length, D = aperture diameter). The radiography facility NEUTRA at SINQ (PSI) was designed and installed for a very high L/D (550) in order to have no real limitation in the spatial resolution by the beam geometry. The compromise in beam intensity which is necessary for such conditions can be tolerated because the advanced neutron radiography detectors have a 10 to 100 times higher sensitivity compared to film devices.

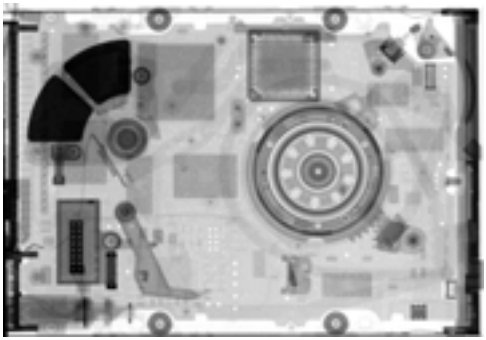

Fig. 2: *Neutron transmission image of a hard disk drive, showing details about the mechanical and electronic parts in high resolution (pixel size 0.05 mm). Non-destructive investigations of such encapsulated devices can be performed within few seconds.*

Accepting less image sharpness, other radiography facilities have much higher neutron flux intensities enabling higher frame rates for time resolved investigations. In Europe, this holds for the installation for dynamic radiography imaging at KFKI Budapest [3] and a project at the "Lohengrin" beam line PN1 at the ILL Grenoble [4].

Other important components of the radiography station NEUTRA can be seen in Fig. 3, i.e. the shutter systems, the beam dump, shielding and sample desks for different investigations.

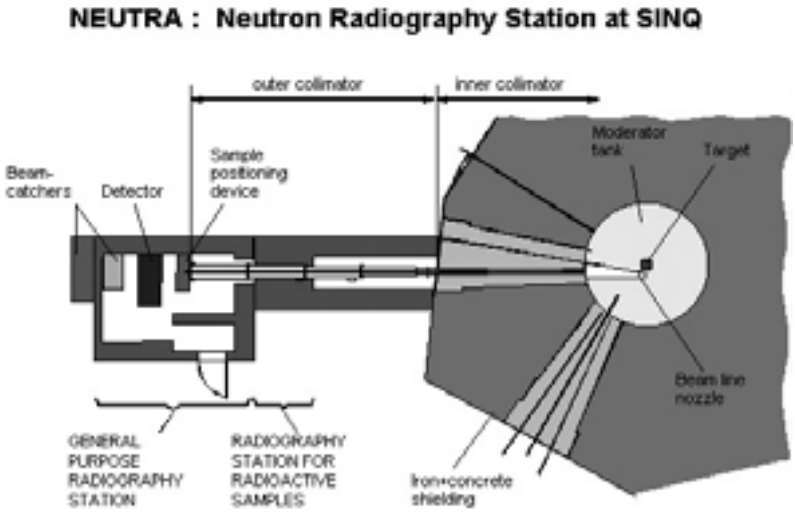

Fig. 3: *Top view on the installations at the thermal beam line 32 of SINQ as the neutron radiography facility NEUTRA*

3. Neutron radiography detectors

In the ideal case, the detector behind the radiography sample should be a highly resolving two-dimensional neutron detector with high efficiency, large dynamic range and low inherent noise. The dimensions are correlated to the beam size which is in the order of 10 to 40 cm. The limitations in the spatial resolution are given either by the nuclear detection reaction or by the read-out principle of the detector system. Time resolution is mainly limited by the intensity performance of the radiography station, but also by the read-out characteristics of the detector. An overview about the application ranges (under the present conditions at NEUTRA) is given by Fig. 4 for six radiography detectors.

Imaging plates can replace the film method for most of the applications because of the follwing performance advantages: high dynamic range, linearity, high sensitivity and results in digital format. Furthermore, no chemical process is involved. Imaging plates can be used again after erasing by light. Because of the high spatial resolution (more than 50 mm), the amount of data is quite large (in the order of 100 MBytes per image).

At some dedicated beam lines, imaging plate devices are also in use for scattering experiments (Laue-diffractometer)

Camera based systems are either cooled slow-scan CCDs or intensified systems using MCPs for image enhancing. The primary detector is a neutron sensitive scintillator in both cases, using the capture in Li-6 or Gd and ZnS for light output. It is important to use a mirror inside a light-tight box to avoid the direct exposure of the CCD-chip. A good shielding around the camera will reduce disturbing events by gamma exposure of the CCD (“white spots”).

Track-etch foils

This method is mainly based on the neutron capture in B-10 and the generation of very small tracks by the emitted a-particles in a nitrocellulose film. By etching out the tracks with a NaOH solution, they become visible. Whereas the contrast in macroscopic images of these tracks is limited, the method provides the highest possible resolution. The main advantage of the method is its insensitivity for gamma radiation, therefore it is applied favourably for heavily activated samples.

x-ray film

In connection with a neutron-to-gamma converter (Gd, Dy, In) it has been the standard method for decades. Therefore, most of the quality assurance procedures are developed and approved for film processing. Nowadays it is an important task to replace the film method with digital methods without loss of information.

amorphous silicon flat panels

This promising approach is based on the light collection from a scintillator by a semiconductor panel, which is directly exposed in the beam. Because single crystal silicon arrays cannot be produced in the needed dimensions, poly-crystalline material is used with the advantage to be more radiation resistant. Presently, there are only few companies delivering with these devices, which are mainly foreseen for medical imaging in hospitals. First and preliminary tests with neutrons have been made at NEUTRA recently providing promising results [3]. After some modifications, such devices might be best suited for high-resolution tomography of large objects or single crystal diffractometry too.

direct exposure CCD

In order to increase the spatial resolution for the investigation of very small samples, a new approach is the use of (relatively) cheap CCD arrays in connection with a suited scintillator layer on it. The device must be replaced periodically because of the limited life-time of the array in the direct beam. Pixel sizes of a few micro-meters should be achievable.

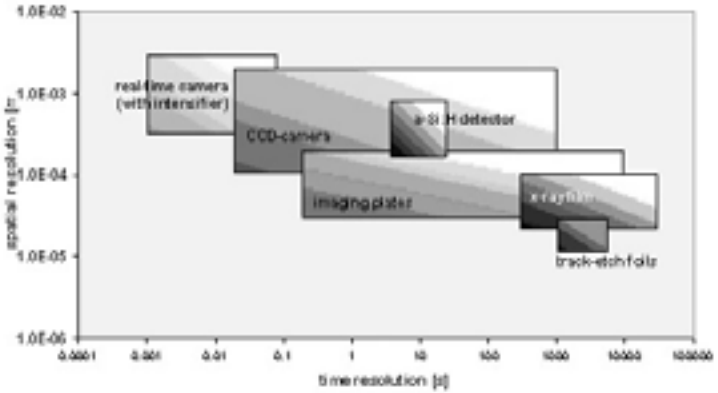

Fig. 4: *Range of applications of radiography detection systems with respect to spatial and time resolution (under the present NEUTRA/SINQ conditions); whereas the spatial resolution is mainly given by the detector itself inherently, the raise in beam intensity would provide a "shift left".*

4. New methods and approaches

Beside the commonly used neutron energy range (thermal and cold in the meV region), other methods can be developed for *higher energy neutrons* by utilisation of the resonance structure of special materials (In and Au in the eV region). In this way, strong neutron absorbers as Cd, Gd, U-235 can be made "transparent", which becomes important when fuel with "burnable poisons" (Gd, Er) must be investigated non-destructively.

The use of *fast neutrons* (from fission or fusion reactions) becomes important if thick layers of material have to be transmitted. Although such a beam line is not available at SINQ, an access to fast neutrons will be given at the FRM-II reactor in Munich. Dedicated detectors and collimators will be developed in order to increase the spatial resolution, which is nowadays limited for several reasons (beam divergence, scattering inside the sample, detector thickness).

Enhancement of the image contrast can be achieved by either interference or energy selection of the incoming neutrons for several materials with large steps of cross-sections in the low neutron energy range. In the first case (*phase contrast radiography*), double crystal arrangements (Si) are used or alternatively very narrow beam apertures. These techniques [4] need exposure times in the order of several hours.

The second approach is using a velocity selector where an image is taken below and above the Bragg edge of the observed material. By image comparison, the contrast can strongly be enhanced if the sample was properlyfixed at the same position.

In the recent years, *neutron tomography(NT)* came into operation routinely similarly (and complementary) to X-ray CT. Next steps will be the increase of the performance in respect to the data acquisition (from hours to minutes) and of the spatial resolution. In this way, NT remains a demanding method regarding the needed computation power. An example of tomography measurements of a waste assembly is given in Fig. 5.

Fig. 5: *Result of the tomographic reconstruction of a poly-ethylene bottle filled with some waste particles, illustrating the high spatial resolution and the ability for separation of plastics and of different materials in this arrangement.*

In neutron tomography, it is important to have images with a wide dynamic range (at least 16 Bit) to be able to distinguish materials having very different attenuation behaviour (the hydrogen in the plastic layer of the bottle is "shadowing" the content inside relatively strongly).

This work was done at the NEUTRA beam line at PSI.

A simplified tomography set-up is under development for NEUTRA (so-called *laminography*) where only one plane inside the sample will be extracted per run. This method is based on the simultaneous rotation of the object together with the imaging plate in parallel position. First promising results [5] were obtained without getting best possible positioning of both components and the potential for the increase in spatial resolution will be used in the next tests.

Time resolved investigations are often limited by the beam intensity and the detector repetition rate. By dedicated CCD-cameras using an MCP intensifier in front of the light sensitive plane enabling a high frame rate , it is possible to detect e.g. processes of moisture movement (see Fig. 7) easily. There is a great demand for such kind of investigations from scientific and industrial partners. Very important is the study of periodical processes where the most interesting events can be selected by the interaction of a trigger signal within the cycle and the frame window given by the camera clock.

5. Applications and clients

Traditionally, neutron radiography investigations were performed on devices and components from nuclear, military and aeronautic departments, which have been directly linked to the centres which run where neutron sources. Nuclear fuel behaviour investigations, fabrication tests of explosives and of turbine blades have been done also on a commercial base. New devices and fabrication techniques are extending the application range for neutron imaging where other methods will fail (honeycomb structures, adhesive connections, lubricant distribution, moisture content analysis, soldering connections between different metals).

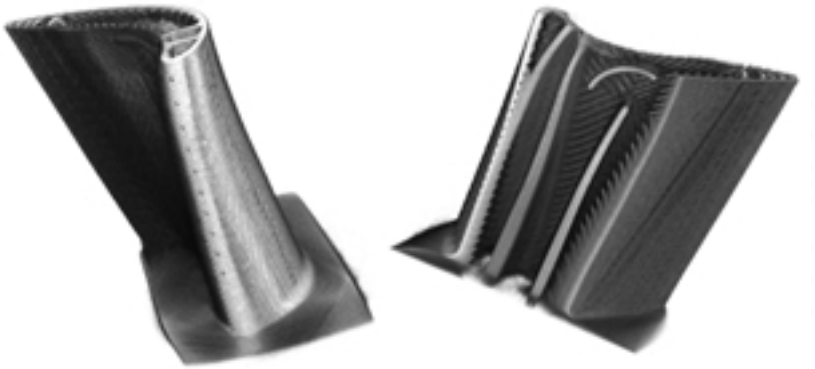

Fig. 6: *Result of a turbine blade investigation by neutron tomography: description of the outer shape - left, cut through for the visualisation of inner structures - right*

The collaboration with different research branches becomes very fruitful when the abilities of neutron imaging techniques are made transparent for non-specialists in these institutes. This holds for building material studies, geology, petrology, soil physics, wood science and other material tests where the distribution of several agents is studied in time and space. Most of such projects are joint investigations supported by external funding including the work of doctoral students [7].

6. Future

The techniques in neutron imaging are strongly depending on the performance of the neutron providing facility and also on the applied detector system. Because neutron imaging is much less beam time consuming compared to neutron scattering experiments, it is easily possible to share best-suited radiography stations for several investigations. Usually, the evaluation of the data needs much more time and manpower compared to experiments – but this can be done off-line.

New facilities in Europe (at FRM-II in Munich, at ILL Grenoble and at the planned ESS) can extend the possibilities of this challenging technique. Whereas the first two mentioned sites will provide higher flux intensities (which makes time depending studies more effective), the ESS [6] as a pulsed source can be used for energy selective investigations over a very wide energy range by time-of-flight neutron imaging.

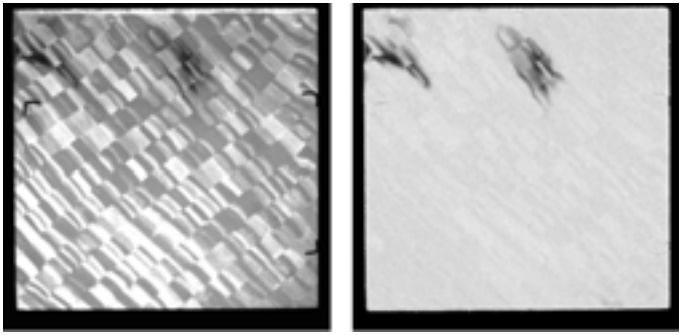

Fig. 7: *Water migration in an artificial soil assembly, observed time dependently with imaging by thermal neutrons; left – raw image, right – after withdrawal*

7. Summary and conclusions

Imaging by neutrons is a straight and powerful method with applications in many different fields of science and technology. The extended production of high-technology components and the studies of complicated processes in nature and technical devices will provide further demanding questions, where some of them can possibly be answered by the help of neutrons.

The more detailed understanding of the interaction of neutrons with the sample material – mainly by scattering of the neutrons – can help to increase the accuracy in quantitative investigations. Some tools as simulation programs are available for this purpose, but the interaction with the neutron scattering community is essential as well.

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[1] H. Kallmann, Research 1, 254-260, 1948

[2] E. Lehmann, Facilities for neutron radiography in Europe: performance, applications and future use, 15th World Conference on Non-destructive testing, Rome, Oct. 2000

[3] M. Balaskó, E. Sváb, Dynamic neutron radiography instrumentation and applications in Central Europe, Nuclear Instr. and Methods in Physics Research A, 377 (1996) 140-143

[4] K. Ibel (ed.), Guide to neutron research facilities at the ILL, "The Yellow Book"

[5] E. Lehman et al., The use of amorphous Silicon flat panels as detector in neutron imaging, paper submitted to the Int. Topical Meeting on NR, Pennstate Uni., 2001

[6] J. Kjems, ESS – A next generation neutron source for Europe, ISSN 1433-559-X

[7] Anwenderworkshop zur Nutzung der Neutronenradiographie, Mai 2001, PSI

News from SINQ Scientific Coordination Office

S. Janssen

There are a few informations we would like to announce concerning the SINQ user program:

1. The PSI is currently rebuilding part of its Web-presentation. Also the SINQ pages have been renewed and moved to a new server. Our new Web-address is:

sinq.web.psi.ch or **www.psi.ch/sinq**

Please update your bookmarks and have a look!

2. For more detailed user statistics we introduced 'areas of research' to classify the SINQ proposals. For that purpose the proposal form has been modified slightly. Please use the new forms that can be downloaded from the SINQ web pages.

3. We are presently updating our address database. So if ever there is a modification of your coordinates please use the address registration form on the SINQ homepage to keep us up-to-date. (http://sinq.web.psi.ch/sinq/registration.html)

4. Also a database with publications resulting from SINQ experiments has been created. At the same web-location as above you will find a registration form where you can send us the necessary information about your SINQ publications. The quality of the database of course is dependent on your input. Additionally we ask our users to send a hardcopy of each such publication by mail to the scientific coordination office.

5. During its last meeting the Scientific Committee has decided that the submission of experimental reports is necessary to obtain beamtime for a continuation proposal. Otherwise the proposal will not be refereed by the committee anymore. So please follow the reminders that are send by the SCO and submit - at the latest - six months after the last beamtime of your experiment a report to us.

EU-FP5 programme: SINQ-proposal successful

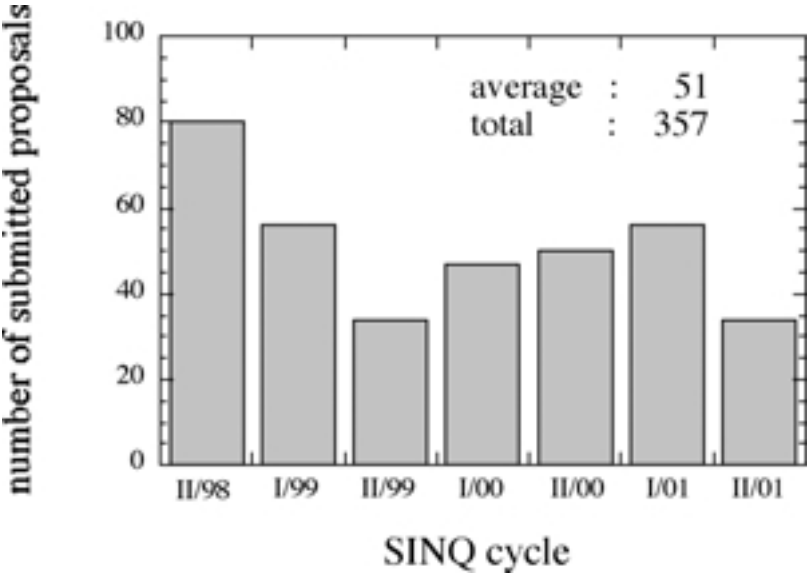
In May 2001 we received the positive reply to our proposal for the EU-programme 'Transnational Access to Research Infrastructures'. The European Commisison granted for 28 months an amount of totally € 1.167.000,- for the support of the SINQ user program.

We wish to thank everyone who supported us e.g. by submitting 'letters of intent'.

Some statistical data from the SINQ user program:

In the year 2000 seven instruments were scheduled and 1320 instrument days have been available. The total number of experiments was 229 and hence almost the same as in 1999 (222).

The figure below shows the development of the number of submitted proposals since the start of the user program in 1998. The relatively low number in II/01 is mainly caused by the prolongated accelerator shutdown in 2001 that prevented almost any beamtime between the deadlines for I/01 and II/01.



Development of SINQ proposal submission. The average number is 51 per cycle.

Announcements

Annual Meeting SGN/SSDN 2001: 'Status and future of neutron scattering in Switzerland'

The annual meeting of the ‚Swiss Neutron Scattering Society, SGN/SSDN' 2001 together with the general assembly takes place on Friday, Nov. 16 at the Paul Scherrer Institute.

During this meeting the SGN/SSDN ‚strategy paper' on the future of neutron scattering in Switzerland will be presented together with selected scientific talks that highlight the status and future trends in different key areas. The paper is presently under preparation within various science working groups of the SGN/SSDN. One purpose of the paper is to formulate a statement of the ‚Swiss Society for Neutron Scattering' on the ‚European Spallation Source Project, ESS'. Hence it is foreseen to combine the above meeting with an informative event on the current status of the ESS-project.

For further informations, please have a look at the SGN/SSDN website

'http://sgn.web.psi.ch' and follow the link ‚News'.

International Conference on Crystallography IUCr 2002

The president of the International Union of Crystallography, Prof. H. Schenk recently announced that the IUCr meeting 2002 with the general assembly has been moved from Jerusalem to Geneva/CH because of the present political situation in Israel.

The conference will take place from August, 6 – 15 in the 'PALEXPO' Congress Center, Geneva. More information can be obtained from the conference website:

http://www.ch.iucr.org/iucr-top/index.html

Conferences 2001

date	place	conference
01.07.-04.07.	Lyon	Dynamical Processes in Excited States of Solids http://pcml.univ-lyon1.fr/DPC01/welcome.html
06.08.-10.08.	Ann Arbor	SCES 2001, Int. Conference on Strongly Correlated Electron Systems http://research.physics.lsa.umich.edu/sces2001
12.08.-25.08.	Argonne	National School on Neutron and X-ray Scattering http://www.dep.anl.gov/nx/index.html
25.08.-31.08.	Cracow	20th European Crystallographic Meeting
28.08.-01.09.	Grenoble	JEMS‘01 (Joint European Magnetic Symposia) http://www.polycnrs-gre.fr/JEMS01/
04.09.-08.09.	Orsay	Crystallography at High Pressures-HPCr 2001 http://www-llb.cea.fr/hpcr2001
05.09.-07.09.	Berlin	TINX, Time-resolved Investigations by Neutron and X-rays of Structural Changes in Soft and Solid Matter http://www.hmi.de/bereiche/SF/ess/ESFworkshop.html
09.09.-13.09.	Munic	ICNS 2001 http://www.icns2001.de
16.09.-20.09.	Kerkrade	Dynamical Properties of Solids DYPROSO XXVIII http://www.fz-juelich.de/oea/termine.html
18.09.-28.09.	Jülich	5th Laboratory Course on Neutron Scattering d.richter@fz-juelich.de

date		place	conference
21.09.-25.09.	Patras	Euro Conference on 'Electron Correlations and Magnetism' http://www.physics.upatras.gr/euroconference	
22.09.-26.09.	Sao Paolo	Rare Earth's - 2001 http://www.dq.ufscar.br/Labs/LACREMM/RAREEARTH/congress.html	
26.09.-29.09.	Seggau	7th General ESS Meeting http://ess.tu-graz.ac.at	
01.10.-03.10.	Les Diablerets	Swiss Workshop on Materials with Novel Electronic Properties http://www.manep.ch/swm01	
18.10.	Yverdon	Annual Meeting of the Swiss Society for Crystallography	
18.10.-19.10.	Villigen	4th TECHNI Workshop daniel.clemens@psi.ch	
04.11.-09.11.	Hayama	Actinides-2001 http://act2001.tokai.jaeri.go.jp/	
12.11.-16.11.	Seattle	46th Conference on Magnetism and Magnetic Materials http://www.magnetism.org	
13.11.-16.11.	Kerkrade	Jülich Soft Matter Days http://www.fz-juelich.de/oea/termine.html	
16.11.	Villigen	Annual Meeting of the SGN/SDN: Future of Neutron Scattering in Switzerland http://sgn.web.psi.ch	

PSI hosts 2nd Workshop on Sample Environment

Michael Meissner, HMI-BENSC, Berlin, Germany

In 1995 the ENSA started an initiative to collect information on the various instrumentations available at European neutron scattering centers which, in 1997, was extended to data acquisition, neutron optics and sample environment. The latter topic was proposed to be co-ordinated by HMI. Starting with the collection of database material on sample environment equipment used at the ENSA centers, more shared activities like standardization of equipment (Orange cryostats, pressure cells), documentation techniques (catalogues, internet platforms), staff training (exchange with other centers) and regular workshops were planned. The first workshop, entitled "New Techniques and Developments for Sample Environment at Neutron Scattering Research Facilities" was held at the Hahn-Meitner-Institut in Berlin, Germany in April 1999. At this meeting, the creation of a platform for scientists and engineers specialized on sample environment techniques for neutron scattering experiments was successfully started.

This year, from April 5-6, the second workshop was organized by the Paul Scherrer-Institute in Villigen, Switzerland and was financially supported by Neutron Round Table, a Concerted Action of ENSA Initiative. The meeting was attended by 27 participants from 8 countries, combining members of sample environment groups from 8 European facilities (GKSS, FRM, HMI, ILL, ISIS, JINR, PSI, PTB) and from 4 North-American neutron scattering centers (IPNS, NIST, SNS, CRL). In addition, staff and guest scientists from PSI visited some of the 15 talks given by the participants during the course of the two days. In return, the PSI staff provided an experimental tour through the new SLS synchrotron facility and the two SINQ experimental halls, where – at the end – the experts were allowed to put hands on Markus Zollikers sample environment equipment.

The seminar sessions started with the opening remarks by Walter Fischer, Head of Department "Condensed Matter Research with Neutrons" at PSI, who introduced to neutron instrumentation at SINQ and then focused on the recent implementation of the Risø National Laboratory instruments and sample environment equipment. In a majority of 8 talks recent developments and projects with low temperature equipment was presented: Ben van den Brandt (PSI) reported on the in-house developed dilution fridge cryostat, Peter Smeibidl (HMI) on new magnetic cooling systems, Richard Down (ISIS) on ULT instrument performance, Jürgen Peters (FRM), Frederic Thomas (ILL) and Louis Santodonato (SNS) on pulse tube and closed cycle refrigerator based cryogenic systems, Michael Meissner (HMI) and Daniel Dender (NIST) on their experience with superconducting magnets at high fields. Reports on ambient and high temperature equipment (some designed for high resolution temperature control) were given by Ken

Volin (IPNS), Gerhard Kozik (GKSS), Robert Hammond and Mike Watson (CRL). In addition, Chris Goodway presented a poster on the status of high temperature furnaces at ISIS. Finally, Ravil Sadykov from the Institute for High Pressure Physics (RAS Moscow) reported on clamped pressure cells up to 18 kbar, which operate at PSI.

As an up-to-date item, remote control of sample environment was presented by Volker Wagner and Frank Kaufmann (PTB) and Markus Zolliker (PSI). More specific, the present status of modern temperature controllers in operation at the various centers became an interesting topic at the final round-table discussion. As a result it was agreed that at present commercial devices cannot fit all the needs of thermometry at the centers (due to the large number of thermometers in use with individual calibrations, for instance). In a short contribution Paul Dagleish (ILL) reported on his survey with the low-cost industrial Eurotherm controller which can be custom-programmed to the needs of temperature control with the ILL-Orange cryostats.

In his closing remarks Michael Meissner pointed out that the success of the workshop is due to the fact that technicians, engineers and scientists come together for international collaboration and exchange of ideas in this specialized field. For instrumentation the meeting has shown that in the new centers (FRM, SNS) future low temperature equipment will be “cryogenic liquid free”, i.e. will operate on electrically driven apparatus, only. For documentation it is important to extend internet applications like user information on specific equipment or visualization of remote data and control – both, the staff and the user community will benefit from direct access to the most recent developments. Last but not least: the workshop at PSI was perfectly organized by Markus Zolliker and Renate Becher, the workshop secretary. The participants have to thank PSI for the scientific and the gastronomic hospitality and the sample environment community is looking forward to meet for the 3rd workshop in 2003.

No pain - no gain ! Participants of the workshop followed attentively the talks on theoretical aspects of sample environment.

Ton Konter (PSI) demystifies the secrets of the dilution refrigerators at SINQ.

Third SINQ User Meeting, PSI, 25/01/2001

S. Janssen, SINQ Scientific Coordination Office

On January 25 the third SINQ user meeting was held at the Paul Scherrer Institute, Villigen. The meeting started with a joint session together with the μSR-user meeting. Mark Adams (Laboratory for Neutron Scattering, PSI&ETHZ) opened the session with a presentation entitled 'Superfluid ^{4}He – a very Novel Material'. Alex Amato (PSI) continued with 'Critical Point(s) and Unconventional Superconductivity in UPt_3'. Finally the session was closed by E.M. Forgan (Univ. of Birmingham) who combined both methods and talked about the use of both probes for the 'Investigation of Static and Moving Flux Lines in Superconductors'.

The afternoon sessions started with some announcements and statistical information from the Scientific Coordination Office before G. Bauer (ASQ, PSI) and A. Furrer (LNS, PSI&ETHZ) informed the audience about the status and foreseen upgrades of SINQ and its instrumentation. In particular, they emphasized the high reliability of SINQ in the year 2000 and the great effort to succeed with the upgrade of several of its instruments.

D. Richter (Forschungzentrum Jülich), who is the chairman of the scientific council of the European Spallation Source (ESS) then gave a presentation about the actual status of the ESS project. In his talk he pointed out some of the perspectives for science in general and neutron scattering in particular which would be opened by the tremendous flux available at ESS.

In two scientific sessions thereupon some of the SINQ users presented their work. The titles of the contributions can be seen from the table below:

speaker	**title of presentation**
E. Clementyev, Villigen	Soft Mode Instability in the Singlet Ground State Ferromagnet PrNi
A. Zheludev, Brookhaven	Interacting Haldane Chains Near the Critical Point
G. Kostorz, Zürich	Alloy Physics and Fun
K. Krämer, Bern	Magnetic Neutron Diffraction of Ce- and Er-Halides
D. Rubio, Villigen	Pseudogap in High-Tc Superconductors Studied by Neutron Crystal Field Spectroscopy
D. Middendorf, Oxford	Dynamics of Hydrated Biopolymers using FOCUS

The gallery below shows some photos that were taken during the meeting.

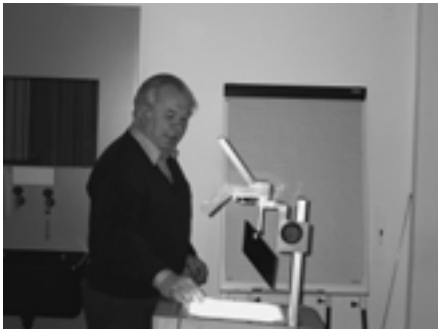
View into the audience

D. Richter, FZ Jülich and ESS

E. Clementyev (left) and B. Dorner

A. Zheludev

D. Richter, A. Furrer, R. Eichler (from left)



G. Bauer

The next SINQ user meeting will be held on 17/01/2002.

SINQ

Swiss Spallation Neutron Source

RESEARCH PROPOSAL

Paul Scherrer Institute (PSI)
SINQ Scientific Coordination Office
WHGA/147, CH-5232 Villigen PSI, Switzerland
Phone: +41 56 310 2087, Fax: +41 56 310 2939
Email: SINQ@psi.ch, Web: sinq.web.psi.ch

Experiment Title:	**Proposal number** (to be completed by SINQ-SCO)

[ ] **Short term proposal (next allocation period)**	[ ] **Long term proposal (2 years)**

Proposer *(to whom correspondence will be addressed)* Name and first name: Address:	Phone: Fax: Email:

Co-proposer(s):
Name: Address: *(if different from above)* Phone/Fax/Email:

Sample description

Substance and formula: Mass: Size:

[ ] Polycrystalline [ ] Single crystal [ ] Multilayer [ ] Liquid [ ] Gas

Sample Container: Space group: Unit cell: a= b= c=

Area of Research

[ ] strongly correlated electron systems [ ] quantum spin systems [ ] superconductivity
[ ] structure [ ] dynamics [ ] magnetism [ ] materials science
[ ] polymer systems [ ] colloidal systems [ ] biological systems [ ] others

Hazard

Is there any danger associated with the sample or sample environment?
[ ] No [ ] Yes [ ] Uncertain If yes or uncertain, please give details of the risks associated:

Experimental details

Instrument	**Days**	**Sample cond.:** Temp., Pressure, Magn. field	**Exp. cond.:** E, ΔE, λ, Δλ, Q, ΔQ

[ ] **New SINQ user** [ ] **New proposal** [ ] **Continuation of……..** [ ] **Resubmission of……..**

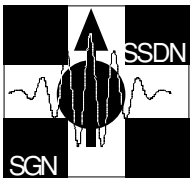
Requested dates:	**Unacceptable dates:**

Experiment Title:

Research funded by:

Scientific background/Aim of experiment: *(Please restrict to the space given within this box!)*

I certify that the above details are complete and correct.
Date: Signature of proposer:



Schweizerische Gesellschaft für Neutronenstreuung
Société Suisse pour la Diffusion des Neutrons
Swiss Neutron Scattering Society

Anmeldeformular / Registration Form

Name / Surname ……

Vorname / First Name……..……..

Akad. Titel / Academic Degree ……

Geschäftsadresse / Business Address ……

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Telefon / Phone ……

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E-mail ……

Privatadresse / Home Address ……...…….

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Zustelladresse / Mailing Address: O Geschäft / Business
O Privat / Home

Datum / Date Unterschrift / Signature

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Please submit to: **Secretariat SGN/SSDN, c/o Laboratory for Neutron Scattering, bldg. WHGA/147, Paul Scherrer Institute, CH-5232 Villigen-PSI**