Report on the
Workshop on new directions and opportunities for

Small-Angle Neutron Scattering in Condensed Matter Science

Oak Ridge National Laboratory
24-27 July, 2014

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1. Executive summary

During the last several years there has been an increasing use of small-angle neutron scattering (SANS) for what may be characterized as "hard" condensed matter science. The goal of this workshop was to identify important scientific problems in this category, and to make recommendations that will allow Oak Ridge National Laboratory to become the world's premiere neutron scattering facility for condensed matter science studies using SANS.

The key scientific areas identified during the workshop include studies of skyrmions and other low-*q* magnetically ordered states, multiferroics, magnetic inhomogeneities and phase separation, magnetic domain structures and dynamics, functionalized nanoparticles, vortices in unconventional superconductors, and non-equilibrium states of matter.

The developments required for ORNL to assume the leadership role in "hard" condensed matter SANS experiments falls in three categories: Improving available sample environment suitable for SANS, providing state-of-the-art SANS instrumentation, and enhancing support for the condensed matter science SANS community. The main recommendations are listed below, divided into two groups according the timescale (short and long term) in which they may realistically be implemented.

Short term:

- Purchase of new SANS cryomagnet capable of accommodating existing dilution refrigerators.
- Restructure the peer review process for SANS beam time proposals.
- Add a beam line scientist with a "hard" condensed matter background to the GP-SANS instrument team.
- Implement neutron polarization and spin analysis capabilities to the HFIR GP-SANS instrument.
- Increase technical support for cryogenic equipment and magnets and testing capabilities for user-provided auxiliary equipment.
- Extend instrument software to allow integrated control of user equipment.
- Develop a rapid sample changer for SANS measurements in a magnetic field.
- Develop a compact pressure cell for SANS measurements in magnetic fields.

Long term:

- Design and build a compact SANS instrument at HFIR dedicated for the unique requirements of the "hard" condensed matter community.
- Facilitate a combination of ORNL strengths in neutron scattering and high performance computing.
- Convene a network of hard matter experts to develop the scientific case and specifications for SANS instrumentation at the proposed SNS second target station.
- Construct a state-of-the-art SANS instruments for the SNS STS dedicated for "hard" condensed matter studies.

2. Workshop motivation and scope

Small-Angle Neutron Scattering (SANS) is ideally suited for studies of large-scale structures, ranging from one to several hundred of nanometers in size. During the last several years there has been an increase in the use of SANS for what may be characterized as "hard" condensed matter and related studies. Prominent examples of this include skyrmions and other low-q magnetically ordered states, spin glasses, magnetic nanoparticles and vortices in type-II superconductors. The goal of this workshop was to review recent uses of SANS in condensed matter science broadly, and to explore how such efforts may be strengthened.

The objectives of the workshop were two-fold:
(i) To foster collaboration among instrument scientists and users with experience or interest in applying SANS to condensed matter physics and related fields.
(ii) To identify the needs of the user community in order to guide further development at Oak Ridge National Laboratory (ORNL), including new SANS instruments at a second target station (STS) at the Spallation Neutron Source (SNS).

Particular emphasis was placed on identifying capabilities that will make ORNL the worldwide premiere facility for condensed matter science SANS studies, such as low temperatures, high magnetic fields and high pressure. Furthermore, recent innovative experiments have combined SANS with the use of AC magnetic fields, DC and AC electric fields and/or current, time-of-flight analysis and neutron spin polarization/analysis.

The workshop incorporated sessions devoted to relevant scientific areas using SANS, and attendees were invited to share recent scientific results, research interests, technical developments and current needs in the field. Invited speakers included national and international experts, both from academia and user facilities, as well as researchers for whom access to such capabilities could add significant new value to their research.

Workshop organizers:
Morten Ring Eskildsen, *University of Notre Dame*
Ken Littrell, *Oak Ridge National Laboratory*

3. Scientific drivers for enhanced condensed matter science SANS capabilities at ORNL

Developing increasingly advanced materials is of critical importance for the continued technological growth in the U. S. and of modern society as a whole. In the past, such developments have often preceded a fundamental understanding of how these materials work. In the future, studies combining materials synthesis, characterization and modeling will enable the ability to predict the composition and architecture of more advanced materials from a fundamental understanding of materials science. Such a reversal of the current paradigm is important, since the most significant advances are expected to be in precisely those materials that are the most complex to understand and control. As a result, the forefront of condensed matter research is often focused on the competition between delicately balanced order parameters, and the ability to control these through the application of magnetic and electric fields, temperature and pressure is essential. Control of at least two if not three or more of these variables simultaneously is critically needed in order to access novel states of matter. While many probes of non-uniform chemical and magnetic structures are available (e.g., Lorentz microscopy, x-ray scattering, ARPES, etc.), neutron scattering is unique in being able to provide information in the presence of sample environment required to control a multiplicity of order parameters.

Small-Angle Neutron Scattering is ideally suited for studies of large-scale structures, ranging from one to several hundred of nanometers in size. During the last several years there has been an increased understanding of the importance of studying "hard" condensed matter systems using SANS. Furthermore, with the advent of techniques such as pair-distribution-function scattering, USANS and spin-echo SANS, characterization of materials such as metal-organic-frameworks – a hybrid of organic and inorganic matter – that are at the nexus between ordered (hard matter) and disordered (soft matter) becomes possible. Such materials offer materials scientists near limitless opportunities to control structure and multifunctional behavior.

The field of neutron scattering was founded at ORNL and the U. S. remains the leader in pulsed neutron sources. However, the U. S. currently lags behind in the areas of state-of-the-art instrumentation and sample environment availability. As just a single example, one can consider the access to polarized beam SANS, which is currently only available at the NIST Center for Neutron Research and even there the community's access to sample environment is lacking in comparison to Europe. This has forced many North American users to perform experiments in foreign facilities, placing the U. S. "hard" condensed matter community at a severe competitive disadvantage. The construction of the Spallation Neutron Source and the upgrade of the High Flux Isotope Reactor (HFIR), and the plans for a second target station at SNS provide the U. S. with an opportunity to regain the leadership role in the field of neutron scattering. In order to be successful ORNL needs to exert leadership and apply a holistic view of neutron scattering from source to user.

Below, we summarize a number of key science drivers, organized according to specific themes identified during the workshop, that justify a significant strengthening of the SANS capabilities for condensed matter science at ORNL. A common property among these themes is that they continue to generate excitement in the scientific community, with results published in high impact publications in journals such as *Science*, *Nature*, and *Physical Review Letters*.

3.1 Topologically stable magnetic structures (skyrmions)

Magnetic skyrmions are topologically stable solitonic states that are stabilized by chiral interactions. Besides being of fundamental scientific importance, these states can be manipulated with electrical currents that are $\sim 10^5$ times lower than are required to move conventional magnetic domain walls and therefore also hold great potential for spintronics applications.

The initial discovery of a skyrmion lattice (SkL) was made in bulk MnSi using SANS. Since then, SkL's have been observed in a range of other conducting as well as insulating crystalline materials. Moreover, it has been shown that the SkL may be easily manipulated by applied electric or magnetic fields, electric currents and temperature gradients.

In epilayers, the induced magneto-crystalline anisotropies help to stabilize skyrmionic states over a broad range of thermodynamic parameters and thus greatly increase the potential for applications. Furthermore, two possible skyrmionic states are possible. For an out-of-plane easy axis, magnetization of the skyrmion cores point out-of-plane and form a two-dimensional SkL. For an easy-plane anisotropy the cores are in-plane and form a skyrmion grating. In this latter case the magnetic solitons are embedded in the center of the film and as a result neutron scattering is currently the only technique that is able to directly observe these states.

Due to the long periodicity, SANS is ideally suited for an investigation of both in-plane skyrmion gratings and out-of-plane skyrmions lattices in a broad range of materials compatible with technologically relevant Si(111) substrates. This includes the investigation of the influence of strain, finite size effects, and surface states on the formation of skyrmion lattices. Such measurements will require the ability to study small samples as well as the application of DC and AC magnetic and electric fields, transport currents and heat gradients.

3.2 Multiferroics and other magneto-electrically coupled systems

Magnetic and electric fields, as well as applied pressure, affect properties of many materials, making them "functional" and hence useful for novel applications. Materials with coupled order parameters are of particular potential importance for novel technologies in electronic memory and energy applications. As an example, multiferroics combine electric polarization with magnetic order, making it possible to control magnetism by static electric fields, and vice versa. This functionality can find its applications e.g., in information recording and spintronic devices.

Small angle neutron scattering is well suited for investigation of magnetic and multiferroic materials even when no large-period magnetic order is present. Scattering from the magnetic, ferroelectric, and multiferroic domain walls is detectable by SANS, making studies of the statistical properties of the domains possible. In fact, it was of crucial importance in the discovery of local weak ferromagnetism in the prototypical multiferroic compound $BiFeO_3$.

While the great appeal of multiferroics is exactly the coupling between different order parameters, it also presents one of the largest challenges for further studies of these materials. In $BiFeO_3$, for instance, spins can be rotated by an applied electric field, magnetic domains may be switched by a modest uniaxial pressure, and the material can be rendered a ferromagnetic ferroelectric by strain or an applied magnetic field.

To make further progress requires access to sample environments that allow simultaneous experimental access to the entire relevant phase space, including electric and magnetic fields as well as pressure and strain, coupled with polarization analysis options. In particular the routine ability to apply pressure is currently not available at any SANS facility worldwide. Furthermore, since most applications will most likely be based on thin film devices, the ability to study such films with GI-SANS will be very important. In particular we note that thin films of $EuTiO_3$ may surpass $BiFeO_3$, (the only know room-temperature bulk multiferroic).

3.3 Magnetic inhomogeneities at the nano- and mesoscale

Nanoscale inhomogeneities in magnetic structure are widely observed in all manner of correlated electron systems, and are known to play a key role in dictating their macroscopic properties. A classic example is the perovskite manganites, where it is now widely understood that nm-scale magneto-electronic phase separation is commonplace and plays a key role in important properties of these materials, such as colossal magnetoresistance.

Small angle neutron scattering is a powerful and effective tool for studying inhomogeneities on the key nano- and mesoscales involved, and has the major advantage of being a bulk probe. In bulk crystals of the prototypical system $La_{1-x}Sr_xCoO_3$ for example, SANS studies played the key role in developing a model for the origin of magneto-electronic phase separation, highlighting the essential role of doping fluctuations, *i.e.* nanoscale chemical disorder [3]. More recently it was shown that magnetic inhomogeneity may be induced at interfaces in cobaltite heterostructures, even at compositions where it does not exist in bulk [7]. This work applied SANS to epitaxial thin films in combination with polarized neutron reflectometry, providing an explanation for the widely observed “dead layer“ effects in such heterostructures, as well as a path towards mitigating dead layer formation, important for oxide electronics [8].

Access to the instrumentation to enable routine cryogenic measurements in high magnetic fields will thus be able to answer important questions in this area across a wide variety of materials. Relatively simple innovations such as multi-sample changers for cryogenic systems could dramatically improve throughput. The ability to polarize beams and analyze polarization adds magnetic versus structural contrast (important for separating chemical/disorder effects from true electronic ones), as well as vector magnetization analysis, unveiling a whole new host of phenomena. Elastic/inelastic discrimination with energy resolution would allow us to do this while separating fluctuating and static short-range correlations. Finally, thin film and heterostructure measurements will be greatly enabled by grazing incidence SANS (GI-SANS) capabilities, which would fill a remarkable capability gap for areas such as thin complex oxide systems.

3.4 Magnetic domain structure and dynamics

An example of a problem requiring investigation of the domain properties is the search for hard magnets, i.e. magnets with large energy product (large coercivity, in particular). Hard magnets are essential for modern transportation and clean energy generation technologies. Magnetic domain evolution in high applied magnetic fields (exceeding 10 Tesla, in some cases), is of key interest in such investigations.

3.5 Functionalized nanoparticles

While the use of nanoparticles in biomedical, data storage, and other device applications continues to grow, it remains a challenge to directly measure the relevant magnetic spin configurations and domain structures for collections (ensembles?) of particles. As a result, much remains unknown about how the nanoparticles are performing their function. In particular, predicting the nanoscale magnetic morphology and response to externally applied magnetic fields can be a challenging endeavor, complicated by many factors including material choice, shape, crystallinity, and intra-particle dipolar coupling.

Using SANS with neutron spin polarization analysis, it is possible to unambiguously separate the structural scattering, magnetic scattering from moments parallel to an applied magnetic field, and scattering from moments perpendicular to an applied magnetic field. This provides a detailed analysis of the average magnetic morphology within each nanoparticle, even for circumstances in which the net magnetic moment sums to zero. Importantly, SANS experiments can reveal how the magnetic coherence within each nanoparticle is affected by both coating and internal magneto-crystalline anisotropy, which has significant implications for dynamic applications such as MRI contrast imaging. Recent experimental work has determined the magnetic structure of Fe_3O_4, $CoFe_2O_4$, and $MnFe_2O_4$ nanoparticles without *a priori* assumptions concerning the nature of the ordering; the work has indicated how different coatings of $CoFe_2O_4$ and Fe_3O_4 nanoparticles are able to preserve the net moment in the presence of an applied magnetic field. However, only relatively few such measurements have been performed, leaving large potential for further studies of the magnetic structure of nanoparticles.

Many applications of magnetic nanoparticles rely on their dynamic properties that include, for example, inducing local hyperthermia to kill cancer cells in-situ. The ability to perform inelastic SANS measurements in the presence of magnetic fields would therefore open up entirely new possibilities for experiment that are not feasible at existing neutron sources. Using the time structure of the STS would make this possible, and create a unique possibility for studies of nanoparticle dynamics, with the additional benefit of covering a wide Q-range with a single (or few) instrumental setting(s).

3.6 Unconventional superconductivity

One of the grand challenges in condensed matter physics is to provide a microscopic understanding of the superconducting state that extends beyond the classic Bardeen-Cooper-Schrieffer (BCS) theory. New theories are needed in order to understand the emergence of superconductivity in a wide range of important materials, including ones where the superconducting state coexists with local magnetic moments, high-T_c's, heavy-fermions, triplet superconductors, pnictides and chalcogenides, and non-centrosymmetric materials. A first step towards a theoretical understanding is detailed knowledge of the superconducting order parameter, which, in many materials, is still missing.

When a type-II superconductor is subjected to an applied magnetic field it is threaded by vortices, each carrying one quantum of magnetic flux ($\phi_0 = h/2e$), providing a unique probe into the nature of the superconducting state in the host material. In materials with modest or low vortex pinning the vortices, due to their mutual repulsion, arrange themselves in to a regular array – the vortex lattice (VL). The VL leads to a modulation of the magnetic induction (B) with

a period determined by the applied field magnitude (decreasing from 144 nm at 0.1 T to 14 nm at 10 T). As a result SANS is ideally suited for studies of the VL.

Recent VL SANS studies have been used to provide information about the location and dispersion of gap nodes in KFe_2As_2 and UPt_3, the field and temperature dependence of the two superconducting bands in MgB_2, and intimate details about Pauli limiting and Pauli paramagnetic effects on the vortices in $TmNi_2B_2C$ and $CeCoIn_5$. In all cases the SANS measurements provided detailed information about the order parameter, thereby constraining theoretical models of superconductivity in the given material. Even more recently, a novel approach to VL SANS measurements was applied to Sr_2RuO_4, commonly considered a paradigm for spin-triplet *p*-wave superconductor, and raised serious question about equal spin pairing in this material.

As new superconducting materials continue to be discovered, there is also a continuous opportunities to provide experimental clues towards a comprehensive theory for superconductivity. Empirically, many of the scientifically most interesting materials have very low critical temperatures and/or high upper critical fields, or are only rendered superconducting by the application of pressure. In order to fully explore the superconducting phase diagram in a wide range of superconductors the availability of adequate sample environment is indispensable.

3.7 Complex, non-equilibrium states of matter

Understanding irregular motion or inhomogeneous dynamics in disordered systems is an important topic that cuts across many areas of physics. Most disordered systems involve nonlinear phenomena or non-equilibrium states, can be either structurally homogeneous or inhomogeneous, and are in general very complicated. However, despite their complexity, they may share some universal features or characteristics and often one basic concept can be applied to many different systems. For example, the concept of jamming can be used as a framework to understand the liquid-solid transition of systems as diverse as granular materials, structural glasses, entangled polymers, colloidal gels, supercooled liquids, foams, emulsions, and bubbles.

Recently, it was observed that at the ordering temperature the domains of a spiral antiferromagnetic Dysprosium epitaxial film behave very much also like a jammed system and their associated fluctuations exhibit behavior which exhibit some of the universal characteristics of jammed systems, such as non-exponential relaxation and Vogel-Fulcher type freezing. Here, the measurements were carried out using X-ray Photon Correlation Spectroscopy.

Another, and very different example, is the discovery of long-lived, highly ordered metastable vortex lattice phases recently discovered by SANS. Here it was possible to use a stop-motion (or stroboscopic) technique to image the VL as it was driven from the metastable phase to the VL ground state by successive application of low-amplitude AC magnetic field cycles. This showed a transition characterized by a crossover between multiple power laws, representing an entirely new kind of collective vortex behavior. Moreover, since the vortices are inherent quantum structures, the VL may provide an ideal mono-disperse system for such jamming studies.

The examples above demonstrate new and important examples of complex dynamics on length scales that are ideally suited for SANS measurements. In the case of magnetic domains such measurements will require a polarized beam and spin analysis. In the longer term, it exemplifies the great scientific potential that would become available at a coherent neutron source. In the case of the metastable VL phase dynamics, the ability to perform spatially resolved measurements with a resolution of the order 10-100 μm (Scanning-SANS microscopy) is needed to complement the previous measurements.

3.8 Summary

In the previous sections we have discussed the main scientific drivers for "hard" CM studies using SANS identified during the workshop. Most of the systems discussed may be characterized as "quantum materials", which, due to the potential for technological breakthroughs, are currently a high priority for the Department of Energy and other funding agencies.

Another property that is common to most of the problems discussed is the high experimental complexity required to address them, and which will be discussed in the next part of this report. As a result, while these will not be high throughput measurements they are more likely to be high impact. One way to characterize this is an emphasis on innovative experiments rather than routine measurements, making it essential to provide institutional support and space for creative exploration.

4. Workshop recommendations

Based on the scientific drivers outlined in the previous section, the workshop participants identified a number of improvements that would position ORNL as the world leading facility for condensed matter science using SANS. These are organized in three categories, all of which are considered critical to grow the condensed matter science SANS community and which should be pursued in parallel. The recommendations are the main outcome of the workshop.

4.1 Increase ability to manipulate states of matter

The following recommendations are primarily directed at improving the availability and support of sample environments necessary for condensed matter experiments:

1. Purchase of a new SANS cryomagnet for use on the HFIR GP-SANS. The currently existing magnet is barely functional, requiring a disproportionate amount of liquid helium as well as labor to operate. As a result it is only operated for a few weeks per year, severely constraining the number of experiment that requires the application of a magnetic field. A design study for a replacement cryomagnet has been carried out and action on this can therefore be taken immediately. The designed replacement will furthermore be able to accommodate a currently available dilution refrigerator insert, allowing measurements at up to fields of 11 T and temperatures down to ~50 mK. For comparison, a similar magnet available at the Paul Scherrer Institute is used during 57% of available beam days (2009-10 data). Considering the order of magnitude higher neutron flux at HFIR, such an investment in sample environment will elevate ORNL to a position as the world's leading facility for SANS measurements at high fields and low temperatures.
2. Increase technical support for cryogenic equipment and magnets. With increasingly complicated sample environment comes the need for highly qualified technical support to ensure reliable operation. Specifically, the sample environment group needs to further develop their in-house expertise in magnet environments. Typically, the group works with their scientists to develop specifications and requirements for purchasing off-the-shelf magnets with fields in the 5 – 16 T range for neutron scattering from various vendors. While the sample environment group has some experience with operating these magnets from companies like Oxford Instruments and Bruker, it falls short when problems arise with the magnets and the group has limited expertise to diagnose and trouble-shoot. While the sample environment group should not get into the business of designing new high-field superconducting magnets, they do need to develop experience in diagnosing problems related to operations.
3. Increase technical support and testing capabilities for auxiliary equipment. Innovative experiment often requires customized capabilities such as the application of electric (AC and/or DC) and AC magnetic fields, in-situ measurements of resistivity or susceptibility, MOKE, etc. While it is recognized that ORNL will not be able to develop all possible options, there should be support for users who themselves want to bring auxiliary equipment for use in their experiments. Furthermore, an on-site test laboratory where such equipment could be integrated with ORNL sample environment before the start of the experiment is highly desirable, as it will ensure an efficient use of beam time.

4. Extend instrument software to allow integrated control of user-provided auxiliary equipment. As the complexity of experiments grows, more specialized equipment will be brought on site, and the ability to effectively interface such equipment with the instrument control software is necessary for an efficient use of beam time. This should include both an automated control of the equipment as well as the storage of additional experimental variables with the SANS data files for efficient analysis and data reduction.
5. Develop a compact pressure cell for SANS measurements in magnetic fields. The application of pressure is not often used in connection with neutron scattering due to the relatively small sample volume of pressure cells and the large increase in background scattering such cells create. SANS, however, is one area where the recent development of diamond anvil cells for x-ray scattering may be exploited, especially in connection with focusing capabilities. Based on the design study for a new SANS cryomagnet it is estimated that it should be able to accommodate a diamond anvil cell with a 1 mm beam size and pressures up to 20 GPa.
6. Develop a rapid sample changer for SANS measurements in magnetic fields for studies of thin films or nanoparticles, where a wide range of sample configurations are often investigated. A vertical translation sample stick would allow users to load multiple samples and rapidly switch between these, allowing for a much more efficient use of beam time, and eliminating the need for time consuming cool downs for each individual sample.

4.2 Provide state-of-the-art SANS instrumentation

The following recommendations seek to enhance and develop instrumentation at ORNL that is suitable for "hard" condensed matter SANS studies:

1. Further develop the instrumentation capabilities of the GP-SANS for the needs of the "hard" condensed matter community. Specifically, magnetic studies require the use of a polarized neutron beam as well as polarization analysis of the scattered neutrons. It should also provide the routine ability to perform experiments on thin film samples and grazing incidence SANS capability.
2. Design and build a compact SANS instrument at the HFIR dedicated for the unique requirements of the "hard" condensed matter community. In addition to polarized neutron capabilities mentioned above, such an instrument should also incorporate focusing capabilities (lenses or, more ideally, nested axisymmetric mirrors) to allow the use of small samples, to perform spatially resolved measurements (SANS microscopy) or to enhance resolution in reciprocal space. By building a compact SANS instrument at HFIR now, the community will be enabled to grow and become strong before the STS is built, and at the same time allow the development of instrumentation techniques (such as focusing, high resolution detectors, etc.) that will be required for a SANS machine at the STS. Here, it is essential that the design is carried out by a beam line scientist with expertise in condensed matter studies using SANS (most likely a new hire).
3. Convene a network of hard matter experts to develop the scientific case and specifications for SANS instrumentation at the STS, ideally in parallel with the construction of a compact SANS outlined above. Such an instrument should be as compact as possible in order to preserve the large dynamic *Q* range offered by the low

repetition rate of the STS. Importantly, it should add capabilities that are currently unavailable or inefficient at steady state facilities but would be natural for a pulsed source: pump-probe, stroboscopic measurements, inelastic measurements in the presence of a magnetic field and measurements under pressure. Ad addition, the group should also evaluate recent technique developments (MIEZE, SESAME, etc.) to determine to which extent they would enhance the capabilities of a STS SANS instrument for condensed matter science. Finally, the prospects of coherent neutron scattering should be explored, as this would open up a range of measurements presently only possible with x-rays (e.g. speckles).

4. Facilitate a combination of ORNL strengths in neutron scattering and high performance computing. This could potentially address very high-profile problems that will otherwise not be solved in the near future.
5. Construct a state-of-the-art SANS instruments for the SNS STS dedicated for "hard" condensed matter studies. It is foreseen that the SNS STS instrument suite will include multiple SANS machines. At least one of these should be dedicated to "hard" condensed matter experiments and include the features outlined above, and should be able to accommodate the sample environment listed in Sect. 4.1.

4.3 Enhance support for condensed matter science SANS studies

The following recommendations aim to enhance organizational support for the growing "hard" condensed matter SANS community:

1. Restructure the peer review process for SANS beam time proposals to reflect that these come from distinctly different user communities. Currently, the GP-SANS instrument is associated with the Chemical and Engineering Materials Division, and beam time proposals are evaluated primarily by members of that community. As a result the workshop participants felt their proposals may be compromised by non-experts reviews. In particular, "hard" condensed matter proposals will often push the boundaries of both technique and understanding and require substantially more beam time than other measurements (often expressed as the difference between "experiments" and "measurements"). Despite the lower throughput in comparison to soft-matter studies, "hard" matter experiments nevertheless produce high impact publications. Restructuring the review process in a way that recognizes the difference between the communities that utilize the GP-SANS is therefore highly desirable. Alternatively a structural reorganization could be considered, partially or completely assigning the GP-SANS to the Quantum Condensed Matter Division.
2. Add a beam line scientist with a "hard" condensed matter background to the GP-SANS instrument team. Such a person will understand, and be the champion for, the kind of scientific drivers identified in Section 3, and therefore better suited to support and nurture this user community and develop new instrument capabilities.

Appendix A: Workshop agenda

Workshop on new directions and opportunities for Small-Angle Neutron Scattering in Condensed Matter Science

Oak Ridge National Laboratory
Building 8600, Room C-156

Thursday, July 24, 2014

Time	Event
10:00 a.m.–4:00 p.m.	Arrival and Check-in at ORNL Guest House
4:00–6:00 p.m.	Tours of SNS and HFIR for early arrivals
6:00 p.m.	Dinner on your own

Friday, July 25, 2014

8:00–9:00 a.m.	Breakfast at ORNL Guest House
9:00–9:30 a.m.	**Morten Eskildsen / Ken Littrell**—*Welcome*
9:30–10:00 a.m.	**Ken Littrell**—*Small angle neutron scattering on condensed-matter systems at ORNL neutron scattering facilities*
10:00–10:30 a.m.	**Chris Redmon**—*HFIR Sample Environment*
10:30–11:00 a.m.	BREAK
11:00–11:30 a.m.	**Valery Kiryukhin**—*Local weak ferromagnetism in ferroelectric $BiFeO_3$*
11:30 a.m.–12:00 p.m.	**Chris Leighton**—*Nanoscale Magnetic Inhomogeneity in Complex Transition Metal Oxides and Alloys Probed via Small-Angle Neutron Scattering*
12:00–12:30 p.m.	**Mike Fitzsimmons**—*Studies of interface magnetism in thin films—the next Blue Ocean opportunity for SANS*
12:30–2:00 p.m. *Working lunch*	**Mike Fitzsimmons**—*Retrospective on Scattering from QCM Systems at LANL*
2:00–2:30 p.m.	**Paul Miceli**—*The Influence of Quantum Mechanics on Crystal growth: Nanoscale Physics Investigated by In Situ Synchrotron X-Ray Scattering*
2:30–3:00 p.m.	**Wenge Yang**—*In-situ high pressure small angle x-ray scattering study on the grain growth during phase transition*
3:00–3:30 p.m.	**Athena Safa-Sefat**—*Tuning of Crystals on Atomic Scales*
3:30–4:00 p.m.	BREAK (refreshments served)
4:00–4:30 p.m.	**Alan Tennant**—*ORNL Neutron Sciences Overview*
4:30–5:30 p.m.	Discussion 1
5:30–6:00 p.m.	Travel to Riverside Grille
6:00–8:00 p.m. *Working dinner*	**Steve Nagler**—*The beginnings of neutron diffraction*

Saturday, July 26, 2014

8:00–9:00 a.m.	Breakfast at ORNL Guest House
9:00–9:30 a.m.	**Bruce Gaulin**—*SANS and critical phenomena associated with spiral and ferromagnetic order in Tb metal*
9:30–10:00 a.m.	**Andreas Kreyssing**—*Probing Fractal Magnetic Domains on Multiple Length Scales in $Nd_2Fe_{14}B$ by Small-Angle Neutron Scattering*
10:00–10:30 a.m.	**Hongyu Guo**—*Jamming behavior in an antiferromagnetic system*
10:30–11:00 a.m.	BREAK
11:00–11:30 a.m.	**Morten Eskildsen**—*Vortex Lattice Metastability and Power Law Dynamics in MgB_2*
11:30 a.m.–12:00 p.m.	**Hazuki Kawano-Furukawa**—*SANS experiments to study the superconducting pairing states*
12:00–12:30 p.m.	**Boris Khaykovich**—*Focusing SANS using axisymmetric mirrors: demonstrations and opportunities*
12:30–2:00 p.m. *Working lunch*	**Andreas Kreyssig**—*A History of the ORNL – AMES QCM Collaboration*
2:00–2:30 p.m.	**Dave Mandrus**—SANS Studies of Helimagnetic Metals
2:30–3:00 p.m.	**Henrik Rønnow**—*In-situ dynamics of magnetic meso-structures – electric field controlled skyrmions and spin-glass avalances*
3:00–3:30 p.m.	**Ted Monchesky**—*Probing the magnetic structure of MnSi thin films with neutrons*
3:30–4:00 p.m.	BREAK (refreshments served)
4:00–4:30 p.m.	**Yumi Ijiri**—*Determining magnetic morphologies in ferrite nanoparticle assemblies*
4:30–5:00 p.m.	**Kathryn Krycka**—*Roles of surfactant coating and surface-specific magnetic response in ferrite nanoparticles*
5:00–6:00 p.m.	Discussion 2
6:00–7:30 p.m. *Working Dinner*	**Kathryn Krycka**—*Perspectives on running a high impact but high maintenance user program for a minority community on a high throughput instrument*

Sunday, July 27, 2014

8:00–9:00 a.m.	Breakfast at ORNL Guest House
9:00–11:00 a.m.	**SNS and HFIR Tours**
11:00–11:30 a.m.	**Draft Workshop Report**
11:30 a.m.–12:30 p.m. *Working Lunch*	**Ken Littrell**—*Summary of Workshop and lessons learned*
12:30–1:30 p.m.	**Ken Littrell and Morten Eskildsen** (Moderators) *Next steps, where do we go from here—roundtable discussion*
1:30 p.m.	Adjourn

Appendix B: List of participants

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