Document Type	Operation and Staging Plan
Document Number	ESS-0100652
Date	Mar. 14, 2017
Revision	2.0
State	Preliminary
Confidentiality Level	Internal
Page	1 (9)

Initial Operation and Staging Plan - ODIN

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SUMMARY

This Document describes the initial plan for the operation of the ODIN instrument. Future development plans already under consideration (staging) and one potential major upgrade are also presented.

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1. COMMISSIONING OF THE INSTRUMENT

1.1 Cold Commissioning

Although the actual installation and integration of the ODIN instrument will still be part of the design and construction phases, Phase 4,[1] a brief summary of this part is provided for completeness. Given the complexity of ODIN's chopper system and other technical systems, this part is a crucial, yet a straightforward step towards operation of the instrument. Tests include, but are not limited to, functional tests of all motion controllers and motors, tests of emergency stop buttons (e.g. for moving large and heavy equipment). The functional logic (e.g. cave door must be closed to open heavy shutter) of the PSS can be tested during cold commissioning as well.

1.2 Hot Commissioning

After all systems have been tested and integrated into the ESS infrastructure, testing and validation of the instrument with neutrons can begin. This *hot commissioning* will verify that the instrument can be operated safely and that all components are functioning within the foreseen parameters to fulfil the envisioned scope.

1.2.1 Radiation Safety evaluation

All beam monitors and radiation levels in and around the instrument will be evaluated and measured first. There are at least three "worst case scenarios" that shall be considered during radiation safety evaluations:

- Direct beam (all choppers, shutters and collimators in open or widest position) directed at the beam stop in the experimental cave.
- Direct beam (all choppers, shutters and collimators in open or widest position) on a strongly scattering sample in the experimental cave.
- Direct beam (all choppers and shutters open) on the smallest collimator opening in the optical cave.

The first case tests the beam stop, while the latter cases present the highest scatter from the most intense beam in the experimental and optical part of the cave, respectively.

1.2.2 Beam parameters and quality control

The Neutron Optics and Shielding group (NOSG) will provide guidelines and assistance in measuring the beam characteristics. The NOSG will provide a detailed plan and schedule for beam characterization.

Beam divergence, field of view and beam homogeneity can easily be measured e.g. with white beam imaging detectors that will be part of the instrument equipment. The flux at the sample position can be estimated depending on the used collimations, this will be compared to the measured values. Background radiation, such as gamma rays and fast neutrons, will be also measured by the instrument team.

Due to its sensitivity, Bragg-edge imaging will be used to determine the spectral quality: wavelength resolution and intensity distribution, thus providing essential information about the wavelength frame multiplication (WFM) system.

1.2.3 Initial data acquisition and quality assessment and control

Various, well-defined samples will be used to assess the overall quality of the imaging systems. During this process, data will be acquired and processed. The resulting 2D and 3D data can easily be compared to results from other facilities. The table below summarizes how the basic (non-staged), sample related, top-level requirements, set forth in [2], will be evaluated.

Top-level requirement (shortened)	Verification
1. Spatial resolution of 10 μm	Use of Siemens Star, see [3]
2. Spatial resolution of 50 μm at 70 ms kinematic measurements	Use of Siemens Star under same conditions if possible, otherwise determination of modulation transfer function (MTF), see e.g. [4] and refs. therein.
3. Spatial resolution of 55 μm at 1 μs stroboscopic measurements	Use of MTF, time resolution can be verified by detector clock and images/time.
4. FoV of up to 20×20 cm^2	Use of large area white beam detector to verify 75% of maximum intensity throughout FoV.
5. Spatial resolution of 100 μm with contrast equivalent to 10 ppm H_2 in steel.	Resolution: use of Siemens Star under similar conditions if possible, otherwise use MTF. Contrast: use of calibrated sample as described e.g. in [5].
6. Detect relative lattice distortions of 10^{-5}	Crosscheck with known samples from other facilities or techniques.
7. Visualizing crystalline phases with spatial resolution of 100 μm (3D)	Use of MTF.
8. Observe structural phase transitions with spatial resolution of 300 μm and time resolution of tens of seconds.	Use of Siemens Star under same conditions if possible, otherwise use of MTF.
9. Detection of grains and their orientation with spatial resolution of 100 μm (3D).	Use of MTF and crosscheck with other facilities/techniques.

1.2.4 Early Science during QA/QC

The quality assessment and quality control activities (1.2.2, 1.2.3) will be performed mostly with standard samples but offers also an important opportunity to start the group intern science program with samples of interest to the group and the neutron imaging community. (Since the field is developing, no detailed plan can be given).

2. USER OPERATION

Although ODIN can be operated in a vast variety of modes the following principal generic steps are required performing a measurement (summarized from [2]):

I. instrument preparation and cold verification

- setting the primary instrument parameters (choppers, slits, pinhole etc
- installing the specific required detector solution
- setting up and connecting all auxiliary equipment required (flight tubes, spin manipulation devices, gratings, polarisers, analysers, sample environment etc.)
- Controlling all functions of the set-up devices as far as possible without beam.

II. hot set-up verification

- checking spectra, flux and beam position by recording neutron images
- checking and adjusting alignment and functionality of auxiliary equipment
- calibration and characterisation of auxiliary equipment for readiness to measure (polarization quality, spin turn efficiency, modulation visibility etc.

III. prepare sample for measurement

- given the large range of different samples that can be measured in imaging the offline but on-site sample preparation cannot be described in detail.

IV. sample set-up

- sample(s) mounting on beamline
- sample(s) position check and potential correction remotely
- potential realignment manually
- signal check by recording images
- decision on measurement protocol including exposure times – potential additional check with beam

V. measurement

- sample exposure
- data collection
- a script is controlling the measurement parameters (single exposure or a complex scan of various parameters)
- the collected data of each individual step is stored and displayed quasi-live on the computer screens in the control hutch or on whatever device connected
- the feedback of displayed or subsequently examined data is suited to change the measurement steps or to interrupt a measurement to allow for changes with respect to one of the previously described steps.

VI. sample removal
- the sample is scanned for activation
- sample removal, by hand or with remote tools (activation)
- sample storage (activated/non-activated)
- (at a later stage sample screening by radiation safety staff to decide upon sample removal from site)

VI. data analysis
Note: preliminary analysis might take place during a measurement campaign however, typically the real data analysis takes place elsewhere and is in its procedure and resources independent of the instrument system.

3. STAGING

The initial scope for the instrument was determined during the scope setting meeting in October, 2016. It is important to note that this initial scope already fulfils all technical high-level requirements, while not fulfilling all scientific requirements. As a result, all equipment and utilities needed for the full scope will have to be installed in (and around) the experimental cave; no bunker access or access to the shielded guide will be needed for the foreseen staging upgrades. The staging concerns some optional installations that serve specific advanced imaging techniques, which ODIN is especially suited for and for most of which ODIN can be expected to outperform any existing and currently planned imaging instrument. These methodical options include grating interferometry, polarized neutron imaging and spin-echo modulated dark-field imaging. It is common praxis that such options are optimized and added during operation of an instrument out of operations budget and funded projects. While capabilities to test and implement such methods will certainly be available through the consortium and other collaboration partners, final optimized set-ups have to be produced with the means outlined. In this way these planned installations are not limited to methodical additions but allow for upgrades with respect to the ever evolving state of the art of imaging technology; this includes regular updates of the detector suite, potential focussing optics (e.g. Wolter-optics) etc. This ensures that ODIN will continue to be a world-leading instrument for imaging applications. In the following the main methodical additions foreseen are outlined shortly, as they are required for key parts of the approved science case of ODIN.

3.1 Grating Interferometry Set up

Grating interferometry is the currently most used approach in dark-field contrast neutron imaging providing small angle scattering information combined with real space imaging. The ToF approach, however, which aims at quantitative spatially resolved SANS measurements requires the set-up to perform for a broad wavelength range. Although a grating set-up is optimized for a single wavelength, recent measurements have proven that a significant wavelength range can be utilized for quantification. Hence, a grating set-up has a significant potential and extended science case at a ToF instrument as compared to continuous sources, but might require several sets of grating to be available. Precautions have to be taken in the initial scope to provide the interface on the installations in the cave for a reliable and quick installation, alignment and de-installation of the set-up for optional use in single experiments.

3.2 Polarized Neutron Imaging

For polarized neutron imaging the ToF approach promises the potential of quantification of even complicated magnetic fields, which is hardly possible at any other source due to flux and efficiency limitations. A complete set-up includes: spin polarizer and analyser, guide field set-up and the required field shielding covering the set-up, spin-flippers (adiabatic and non-adiabatic) including such to be ramped with the ToF spectrum of a pulse and crossed for polarimetric approaches. All these components will be installed as potential add-on along the beam path in the endstation covering the last 5-10m from pinhole to the detector. Also for this installation precautions have to be taken for easy installation and alignment, but also the magnetic environment has to be designed and chosen carefully from the very beginning.

3.3 Spin Echo Modulated Dark Field Imaging

The SEMSANS set-up, which profits from and requires a polarization and analysis set-up just like polarized neutron imaging (see above), is an alternative and complimentary approach to the grating set-up for flexible quantitative ToF SANS imaging. This is a very new methodical development driven by ESS and provided the first spatial resolved SANS studies in imaging geometry, not requiring any scanning, and hence to acquire corresponding quantitative structural information simultaneously on a large field of view. It s resolution range in the SANS regime complements that of the grating approach (10^2-10^3nm) and is currently in the range of 10-10^2nm. However, development has just started and expected to change this picture still until ODIN becomes operational.

3.4 Complementary X-ray Tomography Set up

An x-ray imaging set-up has proven to be a useful tool for complimentary studies. The x-ray can be used in an adjunct lab and when necessary also *in-situ* together with the neutron imaging to enable direct comparison of neutron and x-ray data. A 90° set-up will allow taking data from the same sample simultaneously, thus making 4D data comparisons possible.

3.5 Diffraction Supported Neutron Imaging (Upgrade Option)

Due to specific applications in e.g. engineering materials and strain investigations complementary detector coverage in scattering geometry can become an important option. This is reflected in the concept of the IMAT instrument at ISIS, but also BEER and HEIMDAL aiming vice versa for imaging detectors in their diffractometers. Hence, detector banks with collimators can be considered for a major upgrade of the instrument at some stage, pending experiences at e.g. IMAT and the development at BEER and HEIMDAL. A close collaboration with these instruments with respect to imaging should be achieved and resources, like in particular ToF imaging detectors and sample environment can be shared in an efficient manner as already planned. However, the design and layout of the ODIN experimental cave is taking the option of later installation of diffraction detectors into account regarding size, shielding and installations. An early installation of partial scattering detector coverage is also considered and might be complimentary to these at the diffractometers in terms of collimation, spatial resolution detector distance etc. Specific solutions are still to be explored in the context of methodical and technological development.

4. REFERENCES

[1] Process for Neutron Instrument Design and Construction: ESS-0051706
[2] Concepts of Operations for the ODIN Instrument: ESS-0053465
[3] C. Grünzweig, *et al.*: Review of Scientific Instruments **78**, 053708, (2007)
[4] K. Rossmann: Physics in medicine and biology **9**, 551-557, (1964)
[5] M. Grosse *et al.*: Nuclear Instruments and Methods **A 651**, 253, (2011)

DOCUMENT REVISION HISTORY

Revision	Reason for and description of change	Author	Date
1	First issue	Elbio Calzada, Michael Lerche, Manuel Morgano Markus Strobl	2017-01-20
2	Revision of TG2 panel implemented	Michael Lerche	2017-03-14