EUROPEAN
SPALLATION
SOURCE

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Standards for ESS Beamlines — Optical Elements and Layout DRAFT

Executive Summary

This document summarises the standards and standard practices defined by the ESS Neutron Optics and Shielding Group (ESS-NOSG) pertaining to the neutron optical beams and associated hardware. Shielding is handled in a separate document [1].

Contents

1 Introduction

Standards in the design of neutron optical components are a key part of obtaining maximum return on investment for the instrument suite. This document seeks to describe common features to the guide systems at the ESS to avoid poor quality solutions or fragile optimisation maxima that are intolerant of deviations from the ideal system geometry.

2 Key Components

2.1 Slits and Apertures

The slits concept that will be used is shown in figure 1. Borated aluminium support structures will be cut in the shape of a wedge, with the neutron beam entering on the widest side. On the downstream face of the wedge, gadolinium foil will be adhered or clamped such that a protrusion of 3 mm exists. In this way, the beam aperture will be defined entirely by the gadolinium foil, and no scattering from the aluminium will be measurable. Note that whilst the protrusion tolerance is rather wide ($\pm$ 1 mm) the edge of the gadolinium foil will be cut to be straight to tolerances of around 0.1 mm typically.

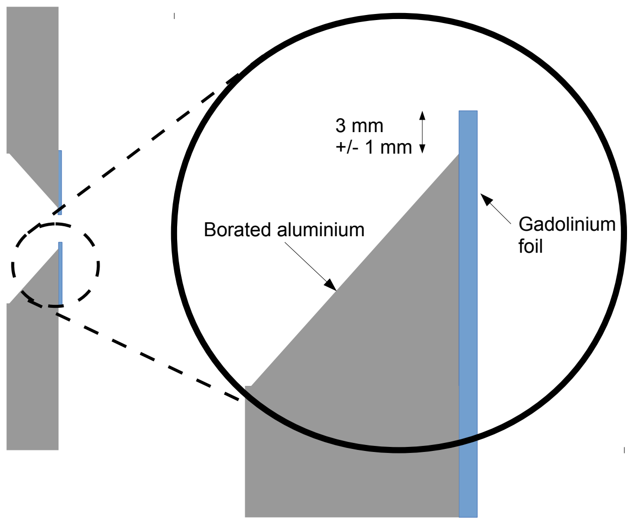

Figure 1: Standard slits concept. Borated aluminium plates cut in a wedge shape will be used, with gadolinium foil on the downstream side of the slit. The aperture will be defined purely by the protruding gadolinium foil, to reduce any scattering from the support structures.

3 Core Concepts of Beamline Design

3.1 Raised Platforms

The ESS guides are in many cases elevated a number of metres above the ground, to allow space for large detector banks without digging holes. To support the guides at this height, a raised platform will be used (e.g. concrete) either as a solid base or with bridges. The old method of supporting guides on steel legs is inferior for ESS stability needs and will *not* be used, wherever possible. The raised base concept is shown in figure 2 on page 5.

Figure 2: BASIS beamline at SNS, out of line of sight of the source. The shielding is relatively light, and the guides are supported on a raised concrete platform.

3.2 Support Beams

The guides will not be placed directly onto the raised platforms. Instead, box beams measuring 3, 5 or 10 metres will be used to straddle uneven variations in the floor foundations. The precise length of each box beam will be determined on a case-by-case basis, but they should be as long as possible to provide maximum stability of alignment within each section.

The box beams will be filled with concrete, borax, sand or some other material to avoid leaving a large, empty channel for fast neutrons to propagate.

3.3 Piling

The concept for piling and support of optical systems on piles is illustrated in figure 3 on page 6. The piles are arranged in pairs, 50 cm to 100 cm in separation, and a bridge is constructed between the piles. The shielding is supported via foundations that do not interact with the piles. In this way, ground subsidence is not affecting the alignment of the guides to the same degree, and it saves a lot of money compared to piling everywhere with sufficient specifications to support both the shielding and the optics.

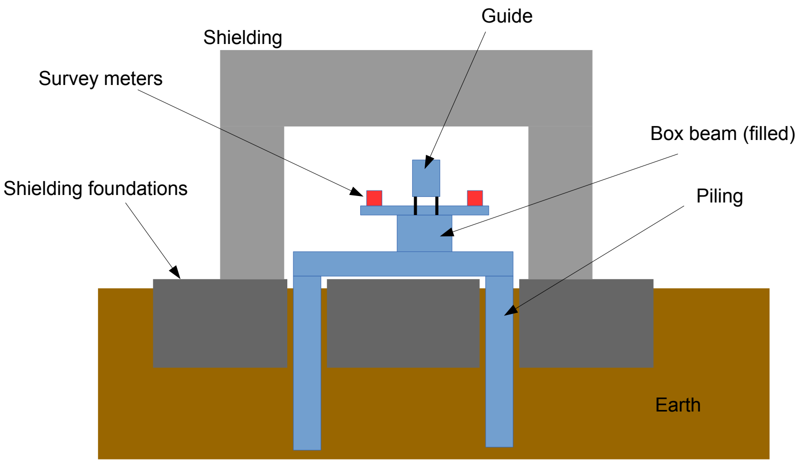

Figure 3: Concept for piling support of neutron guides, shown in cross-section looking down the axis of a neutron beam. The piles are arranged in pairs, 50 cm to 100 cm in separation, and a bridge is constructed between the piles.

3.4 Seamless Illumination

The fully enclosed ESS guides, i.e. excluding special focussing mirror concepts such as Selene, will employ the concept of *seamless illumination*. This idea is illustrated in figure 4. This is based on similar ideas at JPARC to introduce misalignment tolerances in the optics, but in the case of the ESS we extend the principle to increase the beam homogeneity at the sample position. The idea is simple, we merely reduce the dimensions of the exit optical components so that there are no visible gaps in the mirror from the point of view of the sample position.

Seamless illumination will be used at several key locations throughout the beamline. The choppers nearest to the sample are of prime importance, but also at regions where significant subsidence is to be anticipated. The current upper limit specifications of the ground are $\pm$ 3 mm shift elastic deformation within a timeframe of months, followed by $\pm$ 3 mm shift creep deformation over a period of a decade or so. This extreme deformation is not to be anticipated as a step funtion, but more of a sine-shaped curve and strongly dependent on the local shielding mass. As a result, the seamless illumination idea will be employed at several breaks in the beam delivery system near to choppers, shutters, the edge of the guide bunker, the hinged floor regions entering and leaving buildings.

Many of the guides will involve focussing optics near the sample position, in which case the above principle can still be employed. It is important to note that boron absorbing baffles are required on the outside of the narrower guide section

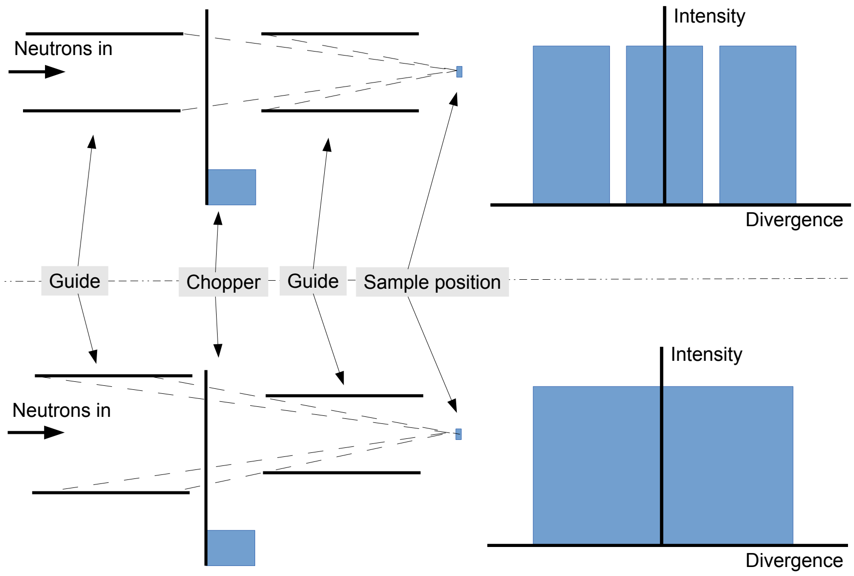

Figure 4: Seamless illumination. On the upper half of this figure, we show the conventional gap in the optical systems to allow other components (e.g. choppers, windows, shutters) to be installed, and the resulting gaps in the divergence that this causes. In the lower half of the figure, we employ seamless illumination to reduce the dimensions of the subsequent beam optics to fill the phase space and make a smooth divergence distribution.

to avoid unwanted background effects. Furthermore, the entrance of the guide must be covered with a borated aluminium protective frame to mitigate the risk of guide delamination at the entrance. The first piece of guide after the gap will be made from BORKRON glass.

3.5 Chopper and Shutter Traversal

Gaps in the guides are necessary to make space for choppers and shutters. Mishandled gaps can create substandard phase space mapping as described in section 3.4 on page 6. Here we show how this applies specifically to the issue of crossing large chopper gaps in more detail.

Choppers and shutters will be mounted on separate support structures to minimise the transmission of mechanical disturbances to the rest of the guide systems. Where necessary, they will be connected to the same vacuum system as the guides by using flexible bellows mating to a flange interface. This interface is handled by NOSG, ESS Chopper group and the guide vendors and designed during phase 2 of the instrument construction project. The concept is sketched in figure 5 on page 8.

4 Alignment Monitoring Tools

The guides will use one or more of the following technologies to actively monitor alignment during the lifetime of the facility.

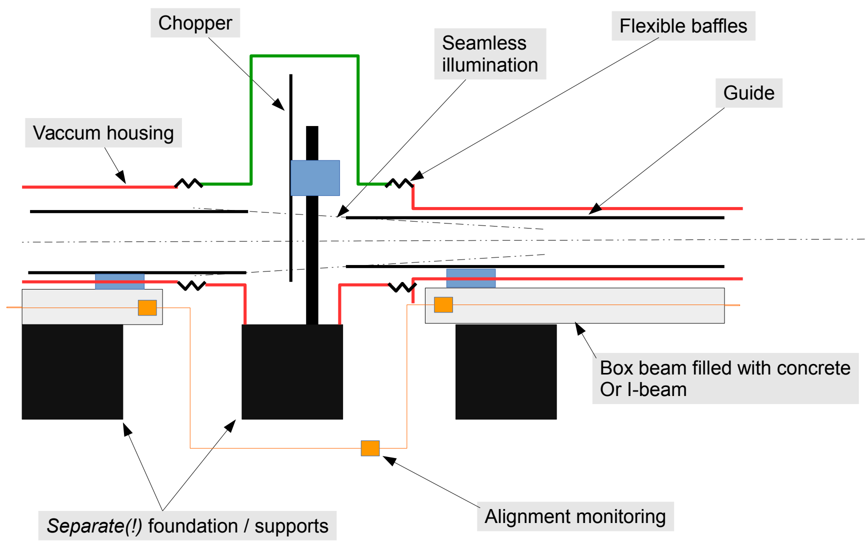

Figure 5: Application of seamless illumination to a chopper location.

1. Periodic laser tracking surveys, which may or may not coincide with other interventions.
2. Wire-capacitative alignment meters
3. Liquid-capacitative alignment meters

All of these are illustrated together in figure 6 on page 9.

5 Realignment without Shielding Disassembly

For some systems, the alignment accuracy requirement is quite stringent (much less than 50 μm). For these systems, a risk-mitigation strategy is in place to deal with the reality of realigning the optics on this system in key places, namely beam joints where subsidence is anticipated.

Above these points, stepped cylindrical shielding plugs will be craned out of guide holes to expose guide funnels to a standard bolt system (dimensions to be decided). The funnel guides a long hex bar wrench to the bolt to allow the alignment screws to be rotated without the need to unstack all of the shielding. This relies on the alignment monitoring systems in section 4 on page 7, since the realignment can be performed and monitored in real time with the full shielding load in place. This concept is sketched in figure 7 on page 9.

6 Suppliers

Standard supply partners for supermirror coatings and related products will be:

1. Swiss Neutronics AG (Switzerland)

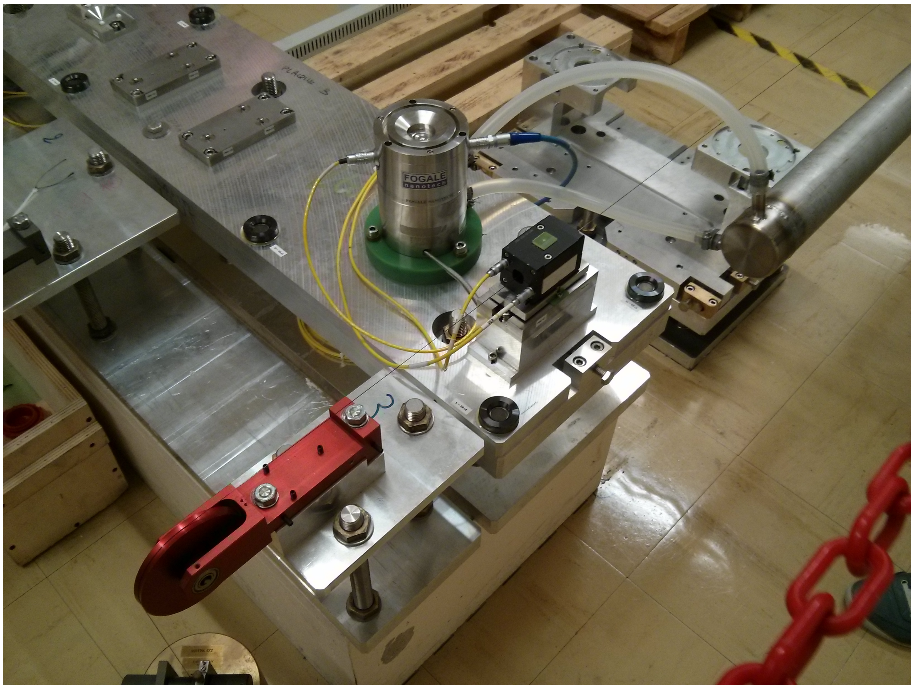

Figure 6: Laser tracking fiducial cups (black discs), wire-capacitative meter (red pulley and black block) and water-capacitative meter (aluminium cylinder with hoses connected) installed on the CERN CLIC prototype. CLIC exceeds the ESS alignment requirements by a significant margin, and these technologies will be ample for our needs. Many thanks to R. Hall-Wilton and M. Anastasopoulos for their tour of this facility.

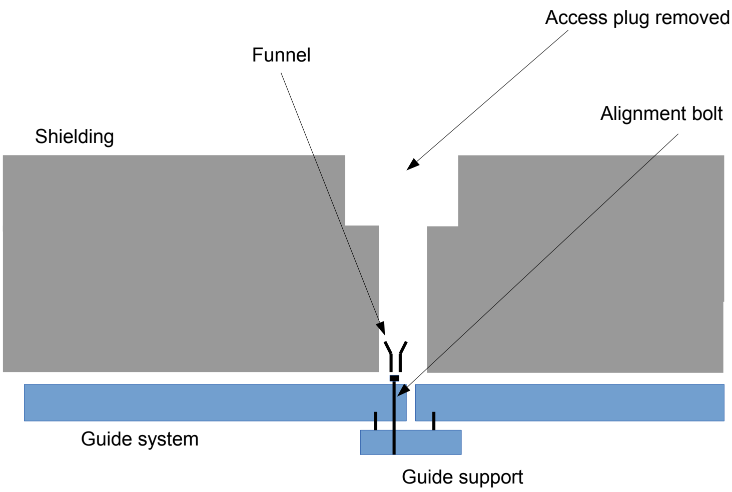

Figure 7: Realignment concept that does not require unstacking the shielding.

- Supermirrors on glass
- Supermirrors on polished metal substrates
- Multi-channel guides and benders
- Associated hardware to mount and align neutron guides
- Vacuum systems around the guides.

2. S-DH (Germany)
   - Supermirrors on glass
   - Supermirrors on polished metal substrates (if fully developed and validated)
   - Curved replica optics
   - Multi-channel guides and benders
   - Associated hardware to mount and align neutron guides
   - Vacuum systems around the guides.
3. Mirrotron (Hungary)
   - Supermirrors on glass
   - Supermirrors on glass-ceramic
   - Supermirrors on glass-metal sandwiches
   - Multi-channel guides and benders
   - Flexible "Mirrobor" borated sheeting with no outgassing
   - Associated hardware to mount and align neutron guides
   - Vacuum systems around the guides.

The suppliers above have a track record and are trusted partners to fabricate large quantities of optical systems.

Other suppliers are welcome to bid on neutron guide contracts. Before their bids will be accepted, certain quality assessments will be made on their work, which will involve precision measurements on prototype mirrors performed in a partner laboratory of the ESS. Part of this quality assessment will involve neutron reflectivity measurements. The potential supplier must:

1. Fabricate a supermirror of m=4 that matches or exceeds the quality of the existing vendors for neutron reflectivity. The reflectivity will be measured by an independent trusted partner of the ESS-NOSG, chosen by ESS-NOSG, under conditions specified by ESS-NOSG [**?**].
2. Allow an inspection of entire premises for the supermirror manufacture by ESS-NOSG, and provide a demonstration of their fabrication and assembly processes. The vendor's IP will be respected and will not be compromised during this inspection.
3. Demonstrate excellent internal practices, covering areas such as tracking of components, documentation and quality control.

4. Demonstrate a fabrication rate that is capable of maintaining a sufficiently high rate of supermirror production without significant degradation of quality for the contracts in question. At least one of the first orders from the supplier will also face additional scrutiny and many components from the test run will be chosen at random for an additional quality assessment.

Any costs in the neutron beam measurements for assessment will be borne by the potential supplier. No expenses will be incurred by ESS-NOSG.

7 Putting It All Together

This section shows how both the shielding and optics concepts should be merged into a single concept. This section appears in both the Shielding Standards document and the Optics Standards document.

In figure 8 on page 11 we show how the shielding and optical ideas come together into one common concept. Three collimator blocks are used within the bunker and line-of-sight (LOS) to minimise fast neutron escape down the axis of the beamline. The collimator blocks are coupled very closely to a copper substrate guide, with steps in the outer planes following the $10\times$ rule. Between the collimator blocks, expansion areas are used to allow the particle showers to expand before the next collimator block is encountered. This allows the system more closely to follow an inverse-square law. Multiple zigzag reflections of the fast particles in a confined space actually transports them very efficiently rather than attenuating them, so we need to allow them to expand.

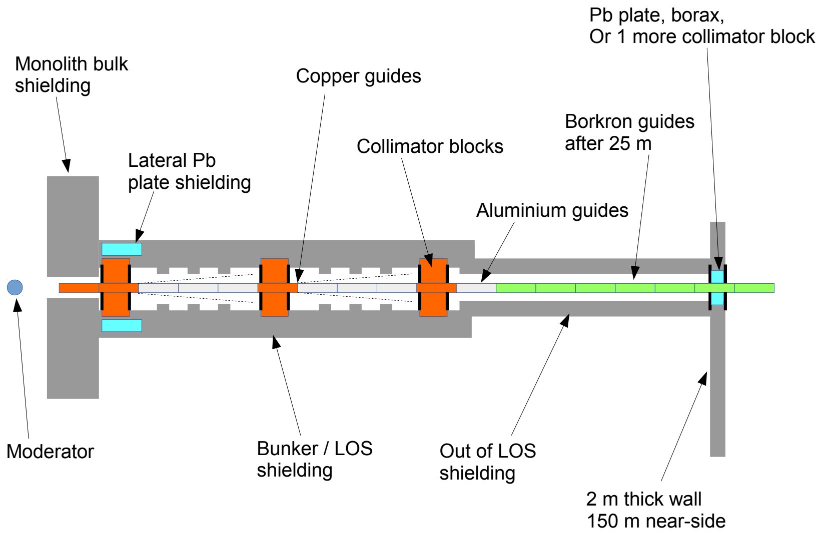

Figure 8: Top-down schematic of a beamline with ESS-compliant shielding surrounding it. The neutron source is on the left, the instrument is on the right. For completeness, we also show the 150 m wall traversal for the long instruments.

References

[1] P M Bentley. Standards for shielding of neutron beamlines and instruments at the ess. Technical report, European Spallation Source ESS AB, 2014.