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Present Status of the 40M SANS Instrument Design at HANARO

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1. Introduction

The SANS technique non-destructively probes structures in materials on nano-meter length scales (1nm ~ 1,000 nm) and has been a very powerful tool in various scientific and engineering research areas of polymers including biopolymers, complex fluids, colloidal systems, protein folding and protein complexes, nano-magnetic materials including magnetic recording media, metals and alloys, ceramics and the flux-line lattice in superconductors. The HANARO cold neutron research facility project was launched on July 1, 2003. A state of the art SANS instrument was selected as a top-priority instrument by an instrument selection committee, which consisted of domestic users and HANARO personnel. In this study, the simulation results and the design of the new 40M SANS instrument are presented.

2. Simulation

The accessible q-range of the state of the art SANS at HANARO is estimated from simple calculations. In these calculations, both the length of the pre-sample flight path and the maximum sample to detector distance are assumed to be 20m, comprising a 40m long SANS instrument. All the configurations are set to be symmetric; the source to sample distance (L1) and the sample to detector distance (L2) are equal. For all the configurations except when L1=L2=20 m, the source aperture and the sample aperture are assumed to be 5 cm (A1) and 1.25 cm (A2) in diameter respectively. For the highest collimation (L1=L2=20m), the source aperture of 3cm is used. The accessible Q-ranges are 0.0019 – 1.00 $Å^{-1}$ for 5 Å, 0.0013 – 0.71 $Å^{-1}$ for 7 Å, and 0.0010 – 0.557 $Å^{-1}$ for 9 Å respectively. It should be noted that the entire Q-range for a given neutron wavelength can be accessed by only two instrument configurations (L1=L2=20 m and L1=L2=1 m), which is possible by the wide dynamic range of the large detector (1m x 1m). Furthermore, using the refractive focusing lenses, the minimum Q can be further decreased and a minimum Q of 0.0008 $Å^{-1}$ or less is achievable[1].

The characteristics of the 40M SANS instrument are simulated using VITESS[2]. The configurations of the guides and the 40M SANS instrument used in the simulations are shown in Table 1. Gi guide is the inpile straight guide with fixed length and G2 is the curved guide. G3 is the second straight guide before the velocity selector. GR means the removable guide sections and the L1 is the distance between the source aperture and the sample aperture. The length of RG+L1 of 20m is fixed.

Table 1. The parameters used in the simulation

Section	Length (m)	Cross section (cm^2)	Coating material	Guide
G1	4.8	25	m=2	Straight
G2	variable	25	m=2	Curved, Radius of curvature = variable
G3	variable	25	Nat. Ni, Ni-58, m=2	Straight
RG	0-18	25	Nat. Ni, Ni-58, m=2	Removable Straight guide
L1	2-20	-	-	-

Based on the MCNP calculation results, the neutron spectrum of the cold source is assumed to be a two temperature distribution of 26.3K with a total integrated flux of $7.7x10^{12}$ n/cm^2sec and of 125.2K with a total integrated flux of $6.4x10^{13}$ n/cm^2sec. The neutron fluxes at a sample position with various collimation distances and wavelengths are shown in figure 1.

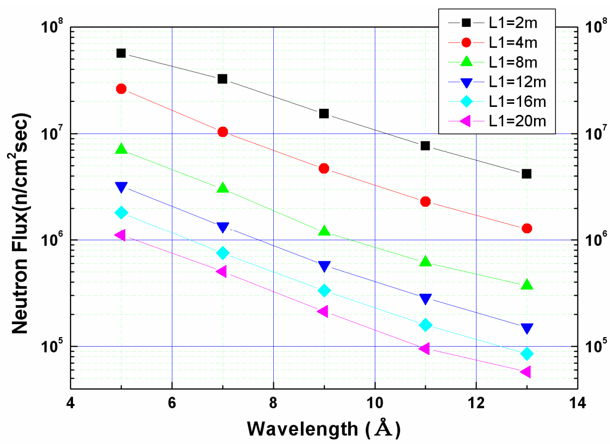

Figure 1 The simulated neutron flux at a sample position(n/cm2 sec) for collimation distances in the range of 2-20m with various wavelengths. The radius of the curvature and the length of the G2 guide are 1200m and 24m, respectively. A source aperture A1 of 5 cm and the sample aperture A2 of 1.25 cm in diameter were used.

3. Design of the instrument

The longer the instrument length, the smaller the minimum Q. However, using a very long wavelength neutron or constructing an excessively long SANS instrument to decrease the minimum Q will provide a low neutron flux, multiple scattering and gravity effects. Moreover, for a long instrument we need to invest a lot of money and sacrifice in the space of the guide hall. The length of the state of the art SANS at HANARO is determined to be 40m.

The bunker is located adjacent to the CG1B guide. Inside the bunker, the shutter, neutron velocity selector, the guide and the neutron monitor will be installed sequentially from the reactor. The guide will be installed at two-position translation tables. One position will be used for the guide inserting after the neutron velocity selector and the other position will be reserved for future additions to the instrument. The velocity selector stage should be equipped with tilting capability.

The collimation system of the 40M SANS comprises of the aperture/attenuator setup, several sections of the neutron beam collimators and a beam tube from the reactor. A neutron beam collimator for SANS consists of apertures and a number of removable neutron guide sections. The beam tube will be inserted after the last collimator section. Several types of beam tubes will be provided depending on the sample stage setups. Each guide section should have at least three positions, the guide, the aperture, and the empty position. It is preferred to have an additional position for an additional source aperture with a different size or other future options. The standard coating materials of the removable guides will be natural Ni. Because natural Ni has a better reflectivity and cost benefit, it is preferable to use natural Ni as the coating materials.

The sample stage should have a standard sample chamber, which can be under a vacuum or inert gases. It should also have a rotation and translation sample table on which various sample environments can be placed. It is recommended that they both be positioned at the same location with an easy mechanism to switch places. The standard changer should be able to hold at least 10 samples at once and the sample position should be controlled by a computer control.

Currently most of the SANS instruments (including NG3/NG7 at NIST) in the world use 64 x 64 cm^2 He-3 gas detectors and the D22 at ILL uses a 100 x 100 cm^2 detector. The new SANS instruments at ORNL and at ANSTO are designed with 100 x 100 cm^2 detectors[5]. The larger 2-dimensional detector provides a larger dynamic Q-range for one instrument configuration, thus reducing the experimental time. The solid angle covered by a 100 x 100 cm^2 detector is 2.4 times greater than that of a 64 x 64 cm^2 detector. Therefore, a 100 x 100 cm^2 detector has been decided on for the 40m SANS at HANARO. The detector carriage should be designed to allow a variable sample to detector distance ranging from 1m to 20 m and an offset up to 50 cm, a half of the active detector dimension.

Recently, it was reported that the refractive multiple biconcave focusing lenses are a very cost effective way to improve the Q resolution of the SANS experiments[1]. The refractive focusing optics are to be install at the last guide section of the 40M SANS at HANARO. The transmission polarizer and spin flipper were installed in the SANS instrument V4 at HMI and they are being successfully used for studying magnetic materials[3]. This option is also considered for an installation and the empty space in the first guide section will be used for this option.

All the instrument controls required for the instrument configuration setup and sample changer should be automated, carefully sequenced and interlocked with a quick shutter to minimize the moving time and unnecessary neutron exposure to a detector. As sample environments, circulating thermal bath, heating block, furnace, orange cryostat, closed cycle refrigerator and electromagnet are considered.

4. Conclusions

The guide and an instruemnt simulation were performed using Vitess and the optimum design of the 40M SANS instrument are performing based on the simulation results.

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