I-4. SANS BATAN: Improvement the Neutron Intensity by Focusing Optics

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I-4.1. Introduction

A small-angle neutron scattering (SANS) technique has been pointed out as a major tool which provides essential information about the fundamental structures of materials in the nanometer scale, 1 – 100 nm. The 36 meter SANS BATAN spectrometer (SMARTer) as the second largest SANS spectrometers in the Asia-Oceania nowadays was installed at the end of 49 meter guide tube of the 30 MW multi-purpose reactor G.A. Siwabessy (RSG-GAS) in Serpong, Indonesia. Until 2004, the spectrometer was not well utilized due to a shortage in staff members, instrument failures, and an undefined long-term research program. Then, a five-year in-house work plan was proposed to replace, change, and upgrade gradually the instrument (i.e. electronics, mechanics, computer software).

In the last three years, the spectrometer has been revitalized and gradually developed on the control system, experiment methods, data collection, and reduction with the intention of improving its performance [1,2]. Many good results confirmed by Dr. P.S. Goyal of BARC, India, Dr. J. Kolhbrecher of PSI, Switzerland and Dr. P. A. Timmins of ILL, France as IAEA expert missions to BATAN in 2005, 2006, and 2007 respectively have been taken from SANS BATAN spectrometer. A nearly monodisperse dilute solution of polystyrene latex standard sample was characterized at several experimental settings, Fig. 1. From Fig. 1, it is noticeably showing the smeared scattering pattern with a shorter neutron wavelength, 0.39 nm (3.9 Å) compare to a larger wavelength, 0.57 nm (5.7 Å). The appearance of the oscillation is more pronounce with a good resolution using a larger wavelength. It can be verified that SANS spectrometer is more powerful (high resolution with high intensity) using a larger neutron wavelength or cold neutron.
Whereas the neutron source is produced from the low-medium flux neutron of 30 MW thermal reactor RSG-GAS which operates regularly at 15 MW, one half of its maximum power, the spectra of the Maxwellian distribution has a maximum neutron flux at a neutron wavelength c.a. 0.1 nm (1 Å). Consequently, the neutron flux at a larger wavelength ~ 1 nm (10 Å) decreases theoretically by magnitude of three [3]. In Fig. 1 showed that the intensity decreases by magnitude of one as the neutron wavelength increases from 0.39 nm (3.9 Å) to 0.57 nm (5.7 Å). This circumstance may not be accepted for a neutron scattering experiment, especially for SANS. For that reason, it is significantly needed to improve the neutron intensity as well as the resolution by designing the new collimator system using a focusing device. The implementation of the focusing device, such as optical lenses or magnetic lenses, the neutron flux or intensity will be gained theoretically by one or two order of magnitude and also improving the minimum $Q$ (momentum transfer) of conventional SANS[4,5]. Those improvements are definitely required to benefit the instrument itself and for researchers to do the scientific works.

References:


I-4.2. The works have been done

Mapping the neutron flux at a various configurations of the spectrometer which is the first work plan of the research contract has been carried out. The neutron flux or intensity at the sample position as a function of collimation length, a distance from the sample position to neutron source (Fig. 2), with a different neutron wavelength has been measured by a gold foil method, Neutron Activation Analysis (NAA). The collimation length which varied for 1.5, 4, 8, 13, and 18 m contributes to the optimum result of the neutron scattering distribution, due to the beam divergence. Meanwhile the effect of neutron wavelength on neutron intensity was
studied at 5.7 Å (3500 rpm), 3.9 Å (5000 rpm), and 3.2 Å (3500 rpm) at a fixed collimation length.

![Figure 2. A schematic drawing of a 36 m SANS BATAN spectrometer in Serpong, Indonesia](image)

The flux measurements were also performed at the end of neutron guide (just before the velocity selector) and after the selector (just before the collimation system). These data correspond to the intensity of the white and the monochromatised neutron beam, respectively. The gold foils mounted at a certain diameter of cadmium plate and then were exposed with neutron beam at a various positions, collimation length and neutron wavelength. The gamma-ray from the activated gold foils was then measured using an HPGe detector gamma-ray spectrometer and analyzed using a multi-channel analyzer (MCA). This measured gamma-ray count rate is useful to calculate the activity of $^{198}$Au in each gold foil. With the purpose of calculation the activity of the activated $^{198}$Au, the efficiency of HPGe detector, irradiation time, cooling or decay time, radioactive half-time of $^{198}$Au isotope, number of atoms and neutron cross section are required. From the activity of $^{198}$Au calculation, then the neutron flux or intensity at SANS spectrometer with several setting configuration can be distinguished.

![Figure 3. The neutron flux profiles after the velocity selector (MVS) and at sample position as a function of collimation length.](image)

From the flux measurement showed that the flux of the white neutron beam at the end of the neutron guide (just before the velocity selector, MVS) is $6.57 \times 10^8 \text{ neutron cm}^{-2} \text{ s}^{-1}$. After the velocity selector the neutron intensity which is defined as 0 m of collimation length will be depending on the speed of selector, i.e. 3.2 Å (7000 rpm), 3.9 Å (5000 rpm) and 5.7 Å (3500 rpm), Fig. 3. It noticed that the monochromatised neutron intensity generally decreases by magnitude of one than the white beam. As the collimation length increases from 1.5 m to
18 m, the neutron intensity decreases exponentially. In total, the intensity of all monochromatised neutron wavelengths decreases by magnitude of two using the longest collimation length configuration 18-meter. In the other hand, the longer neutron wavelength 5.7 Å decreases by magnitude of one compared to the shor ted neutron wavelength 3.2 Å at the longest collimation length configuration.

From the neutron intensity mapping at SMARTer can be concluded that in obtaining the highest as possible of neutron intensity without losing the resolution, the neutron source has to close as possible to the sample. This circumstance is very difficult to be accomplished by a conventional SANS (pinhole SANS). Therefore, a focusing SANS has to be developed in improving the intensity as well as the resolution.

The Monte Carlo calculation program (McStas) has been installed at the Neutron Scattering Laboratory of BATAN and then applied for testing and practicing. Vanadium sample can, Debye Scherrer sample model and Maxwellian distribution profile model have been simulated with the intention of being familiar with the program.

**I-4.3. Objectives**

The overall objectives of this CRP are:

1. To stimulate and initiate the improvement and development of 36 m SANS BATAN.
2. To explore the possibility of applying the focusing devices on the collimation system of 36 m SANS BATAN.
3. To establish SANS experiments in materials science & biology research in the wide-scattering-vector-range.

**I-4.4. The proposed works**

The proposed works that have to be done in the coming years:

1. Workshop / Training Course / On Job Training (OJT) on Monte Carlo calculation program – theory and applications, through IAEA's TC program, i.e. IAEA Expert Mission for local neutron scattering scientists (2009). The Monte Carlo calculation program for development of neutron instrument has to be exposed initially to the local scientists.

2. A simulation using a Monte Carlo calculation program to calculate the theoretical intensity and profile patterns at SANS spectrometer with a various configuration (2009 – 2010).

3. Joining either the NPI in Czech Republic or JINR in Russia for enhancing the knowledge and experience of one Indonesian neutron scattering scientist on designing and developing the new focusing lens of SANS BATAN (2010).

**I-4.5. Expected Outputs:**

The outputs from this CRP will be:

- Neutron flux characteristic map at 36 m SANS BATAN spectrometer.
- Analytical calculation of the optimum design of optical focusing devices at 36 m SANS BATAN spectrometer.
- Implementation and performing of the optical focusing devices at 36 m SANS BATAN spectrometer.
- Monitor count normalization / absolute scale for all SANS measurements.
- Scientific publications, journal papers, and institutional report and presentation at national and international meetings.

**I-4.6. Conclusions**

From this work and collaboration under the CRP project, we would like to stimulate and initiate the improvement and development of 36 m SANS BATAN spectrometer and also to explore the possibility of applying the optical focusing devices at the collimation system.