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Thermal Neutron Small-Angle Scattering Spectrometer (WIT)

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ABSTRACT

This paper describes the configuration and performance of a new time-of-flight (TOF) small-angle neutron scattering (SANS) spectrometer named WIT installed at the pulsed **thermal** neutron source (KENS) at the National Laboratory for High Energy Physics (KEK). We could verify that SANS spectrometer installed at the thermal neutron source could be feasible when adequate instrumental devices such as the slit system for thermal neutrons, the annular glass scintillator detectors, beam line and transmission monitors and a beam stopper were developed. A covered Q-range of WIT is from 0.02 to 0.1 A $^{-1}$.

I. INTRODUCTION

The SANS spectrometer is a special machine for investigating macro-structures, which is now one of the most important instruments for neutron scattering because of its application to wide scientific fields as solid state physics, chemistry, material science, polymer and biology. The demand for this machine is still increasing and most of the SANS spectrometers are installed at cold neutron sources.The type of TOF-SANS spectrometer installed at the cold neutron source has been already reported and it is working in many places. However, SANS spectrometers installed at the thermal neutron source are few in the world. They might believe as if SANS spectrometer would not work without the cold neutron source. It is true that cold neutrons are of great advantage to SANS. However, if a good collimated thermal neutron source and a high resolution PSD are available, SANS installed at the thermal neutron source might be a match for the one at the cold neutron source. Especially when this is applied for the TOF method where unmonochromated white neutrons are used, a very wide Q range is covered with a simultaneous measurement.

By developing several new instrumental devices such as the slit system for thermal neutrons, the annular glass scintillator detectors and beamline monitors made of scintillators and a special beam stopper, we have constructed a thermal neutron small-angle scattering spectrometer named WIT . The paper describes the overall layout and configuration of the spectrometer in the next section. Some instrumental devices newly developed for this spectrometer, such as the slit system, annular detectors, a beam stopper and data acquisition system, are discussed in this section. Then the performance of the WIT is given in III with experimental results obtained .

II. STRUCTURE OF WIT

The layout of WIT is given in Fig. 1. The spectrometer is installed at the H2 beam hole which is set in the thermal neutron moderator at KENS.

An incident slit system is settled inside the biological shield. We have used a converging pinhole collimator which was developed in INC spectrometer at KENS . The rectangular holes made by sintered B_4C plates and steels were alternatively placed at about 15cm interval to realize converging condition of focusing on the center of the detector position. The sizes of inlet and exit are 47 mm * 47 mm and 32 mm * 32 mm respectively. The distance between them is 2870 mm.

A specially designed beam monitor is set at the exit of the slit system. It is made of the powder of ^{6}Li glass scintillators. The size of the beam monitor is 60 mm x 60 mm.

A sample chamber is cylindrical, 500 mm in diameter. It is connected with a vacuum scattering chamber. Another sample container is put inside the sample chamber when it is necessary to carry out the measurement under an atmospheric pressure. A beam window of the sample container is made of a thin aluminum plate, 0.2 mm in thickness.

The scattering chamber is 1 m in diameter and 2.6 m in length. It is surrounded by borated resin of 10 cm in thickness for the shielding of neutrons and the inside wall of the chamber is coated with the B_4C powders in order to remove neutrons scattering from the wall. Moreover, in the chamber three disks which are made of solidified B_4C with resin (1 cm in thickness) and have holes in the center are settled as shown in Fig. 1. In the end of the scattering chamber vacuum is sealed by 2 mm thick aluminum, but at the center (100 mm in diameter) where direct neutrons pass 0.2 mm thick aluminum is used.

A detector house is connected with the scattering chamber. It is surrounded by borated resin of 10 cm in thickness for the shielding of neutrons. In the house light is completely cut off but it is not evacuated. There are two doors at both sides where we can access a beam stopper, a detector system and a transmission monitor in the house.

Annular ^{6}Li glass scintillators are used for the detector system, since the small-angle scattering pattern on the area detector is annular about the beam center for the case of the isotropic scattering sample. If an annular detector is provided in SANS, the data handling system including electronics becomes extremely simple. Since a large and continuous Q range is required, annular detectors with different radii are preferable. Details of the annular detectors are explained in this Proceedings.

In small-angle neutron scattering experiment, it is very important to measure neutron transmission of a sample, which is used as an absorption correction. In general, scattering and transmission measurement cannot be carried out simultaneously, because the detector system of each measurement is different. In the case of scattering measurement a beam stopper should be placed in front of the center of an area detector to prevent the detector from the damage of direct intense irradiation. In the case of transmission measurement the beam stopper must be removed and an attenuated neutron beam is used not to kill the center of the detector.

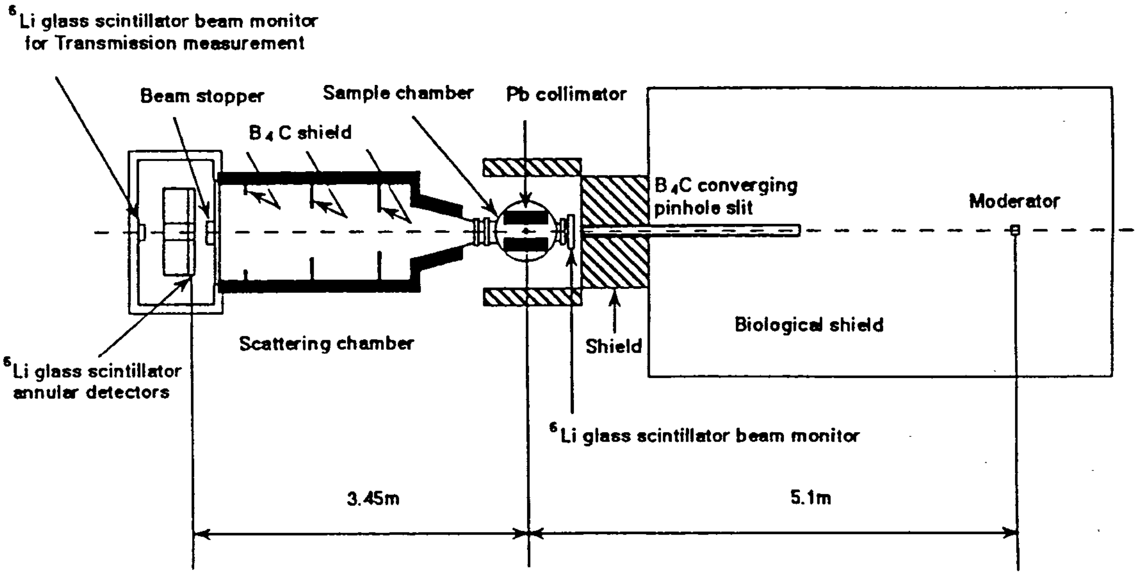

Fig. 1. Overall layout of WIT.

We have specially designed and settled a new beam stopper which enables us to measure both scattering and transmission simultaneously. The schematic layout of the beam stopper is shown in Fig. 2. In the center of a cylinder (155 mm in diameter and 150 mm in length) which is made of B_4C powder solidified by epoxy resin, a hole of 5 mm in diameter is drilled as transmitted neutrons pass through. Moreover, in our case it is not necessary to attenuate incident beams, because the transmitted neutrons are detected with another Li glass scintillator and the dead time of the glass scintillator is estimated to be less than 500 nsec.

The wavelength dependences of trnsmission have been measured both with and without the new beam stopper and both results have coinside within statistical errors.

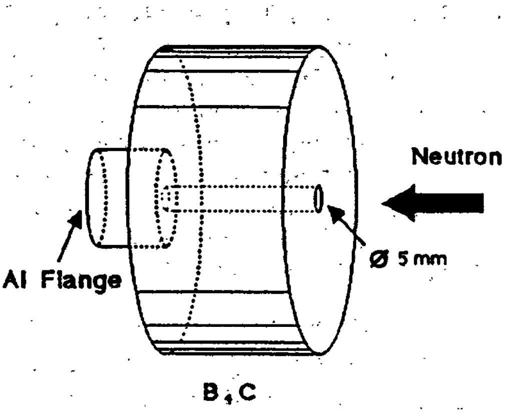

Fig. 2. The schematic layout of the beam stopper.

The realization of the simultanious measurements of scattering and transmission provides several benefits, those are,

1) to save the maschine time,
2) to remove the nuisance to mount and then dismount the beam stopper, and
3) to avoid the unexpected change of sample status which might occur while scattering and transmission measurements.

A block diagram of the data processing system for the annular detector is shown in Fig. 3. The signal from the photomultiplier is directed to the amplifiers, and their outputs are fed to a pattern discriminator module, which is specially designed to be applied to the annular detector. The function of the pattern discriminator is as follows: Suppose that the neutron irradiates the scintillator at acertain point, P. Ascintillation event occurs and scintillation photons transmit through the acrylic resin to the neighbouring photomultipliers, for example, A and B as shown in Fig. 4. Since the scitillation event is stochstic, there are several possible combinations of the photomultipliers, for example, A,B,C and H, but there is little possibility that photomultipliers A, B and D accept photons. All the possible combinations of the photomultipliers (called as a pattern) that accept photons simultaneously is written in the read-only-memory (ROM) in the module. This procedure corresponds to a kind of the coincidence among more than two photomultipliers, and this diminishes the electric noise of the photomultipliers.

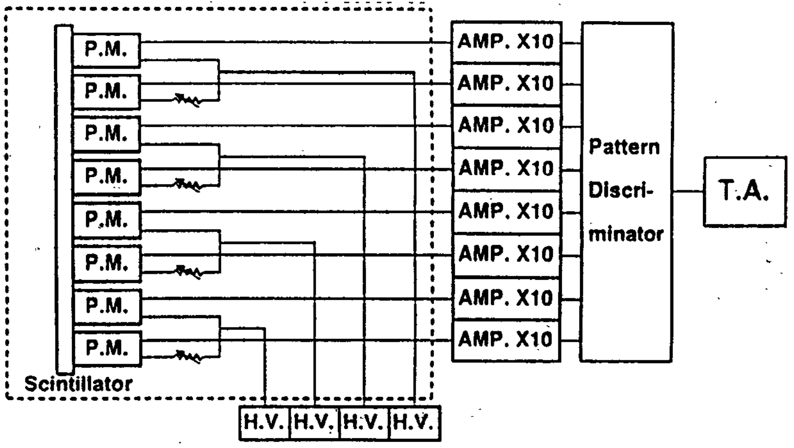

Fig. 3. A block diagram of the data processing system for the annular detector.

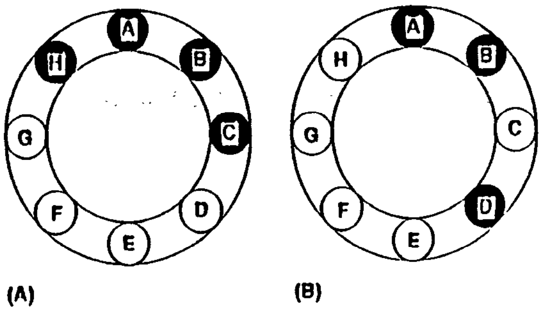

Fig. 4. Illustration how the pattern discriminator works.

A type of the transmission monitor is the same as the one of the beam monitor above mentioned. The transmission monitor can be shifted vertically and horizontally about ± 3 cm in length as to measure beam profiles and to define the beam center.

III. SEVERAL EXPERIMENTAL RESULTS USING WIT

SANS measurement of SiC is a good example to know the qualification of WIT. Fig. 5. shows I(q) of SiC, where the data of different annular detectors were processed separately and overlayed. The agreement among I(Q)'s obtained with different annular detectors is found to be very good. The detailed method how to process raw data will be reported separately elsewhere.

Lysozyme is one of the most typical biological materials as a sample to test a contrast variation method for SANS measurement.

SANS measurement was made for a lysozyme sample in aqueous solution of different D_2O/H_2O ratio i.e. 100%, 90%, 66%, 12% and 0%, where a unit of the ratio is mol%. The mean excess scattering density r was determined using ÷I(0) vs D_2O/H_2O ratio . The obtained Guinier plots are shown in Fig.6. A radius of gyration R_g of lysozyme is calculated and compared with those reported in the literature. WIT is found to be feasible on the structural study of biological materials.

IV. CONCLUDING REMARKS

The TOF small-angle scattering spectrometer WIT installed at the KENS **thermal** neutron source has proved to be a feasible machine, having provided good results for the studies of biology and material science.

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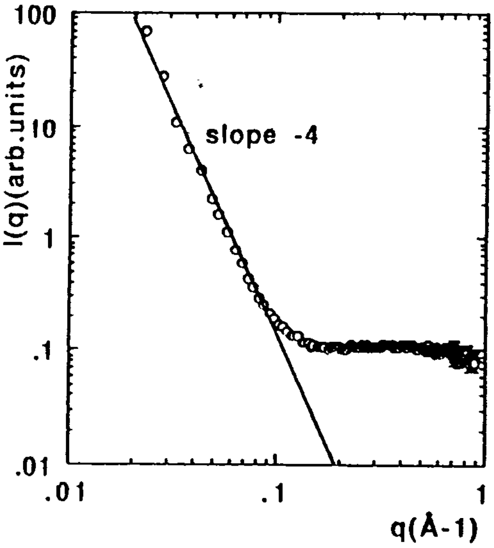

Fig. 5. The obtained I(Q) of SiC.

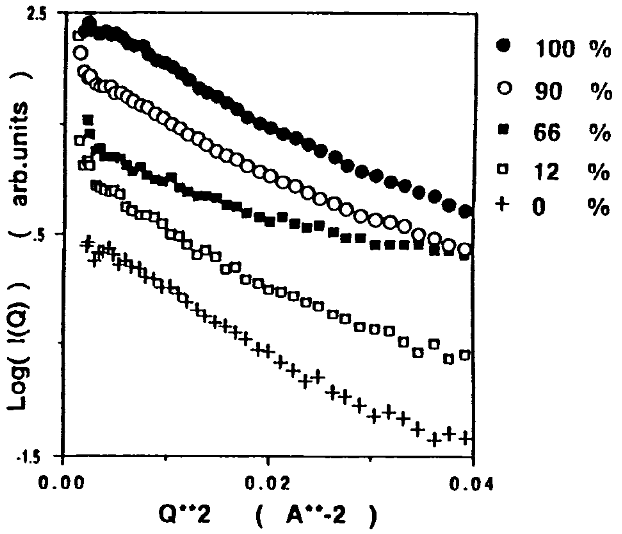

Fig. 6. Guinier plot of lysozyme in aqueous solution at different D_2O/H_2O ratio.