ICANS-XVIII
18th Meeting of the International Collaboration on Advanced Neutron Sources
April 25-29, 2007
Dongguan, Guangdong, P R China

Initial Commissioning Results for the SNS Magnetism Reflectometer

H. Ambaye, F. Klose, R. Goyette, A. Parizzi, T. Chae

1. Introduction The SNS Magnetism Reflectometer is one of the first three operational SNS instruments. Its construction was completed in May 2006 and the first data sets were collected in July 2006, shortly after passing the instrument readiness safety review. The beamline commissioning proceeds in parallel to the power ramp up of the SNS accelerator. While the initial reflectivity measurements were taken with only 250 Watts of proton power, by mid November 2006 already 60 kW were made available making the SNS the most intense pulsed neutron source on a per pulse basis. In this paper, initial commissioning results for the Magnetism Reflectometer, in particular beam intensity/divergence measurements, tests of the polarized neutron equipment (supermirror polarizers, RF spin flippers) as well as transmission measurements of the bandwidth limiting chopper system are presented. In addition, an initial characterization of the cold moderator's emission time is also discussed.

The SNS Magnetism Reflectometer on beamline 4A shares a common primary beam port and shutter with the SNS Liquids Reflectometer (BL4B) from which it is separated by 4.8° in horizontal angle. Individual secondary shutters allow operating the two instruments independently. Figure 1 is a schematic representation of the Magnetism Reflectometer beamline.

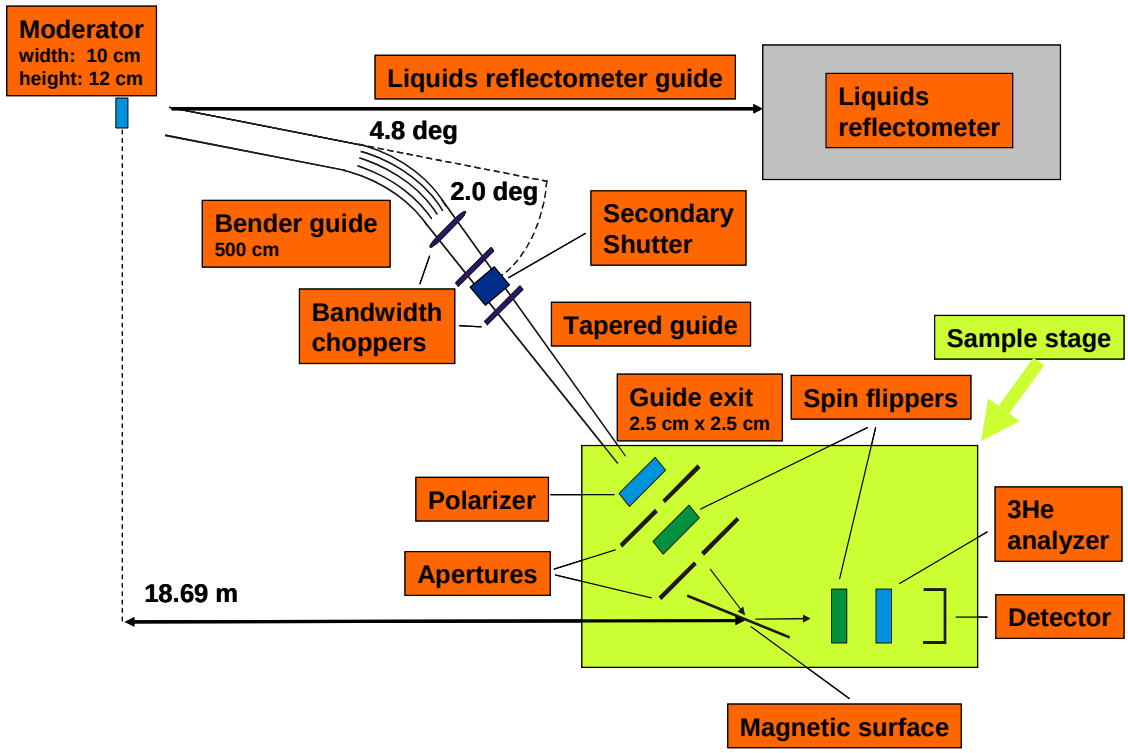

Figure 1: Layout of the SNS Magnetism Reflectometer (top view). Note that angles and distances are not to scale.

Neutrons from the moderator are guided to the sample position at 18.69 m distance via a combination of a channel beam bender and a tapered neutron guide. A two-dimensional multi-detector at a nominal 20.97 m distance from the moderator detects neutrons that are scattered by the sample. This detector is mounted inside a movable

shielding box, which will allow access to scattering angles up to 140º. Therefore, the instrument, in addition to being used as a reflectometer, can also operate in a high-angle diffraction mode. The wavelength is determined by time-of-flight (TOF). Three bandwidth choppers restrict the total bandwidth of neutrons in order to prevent "frame overlap".

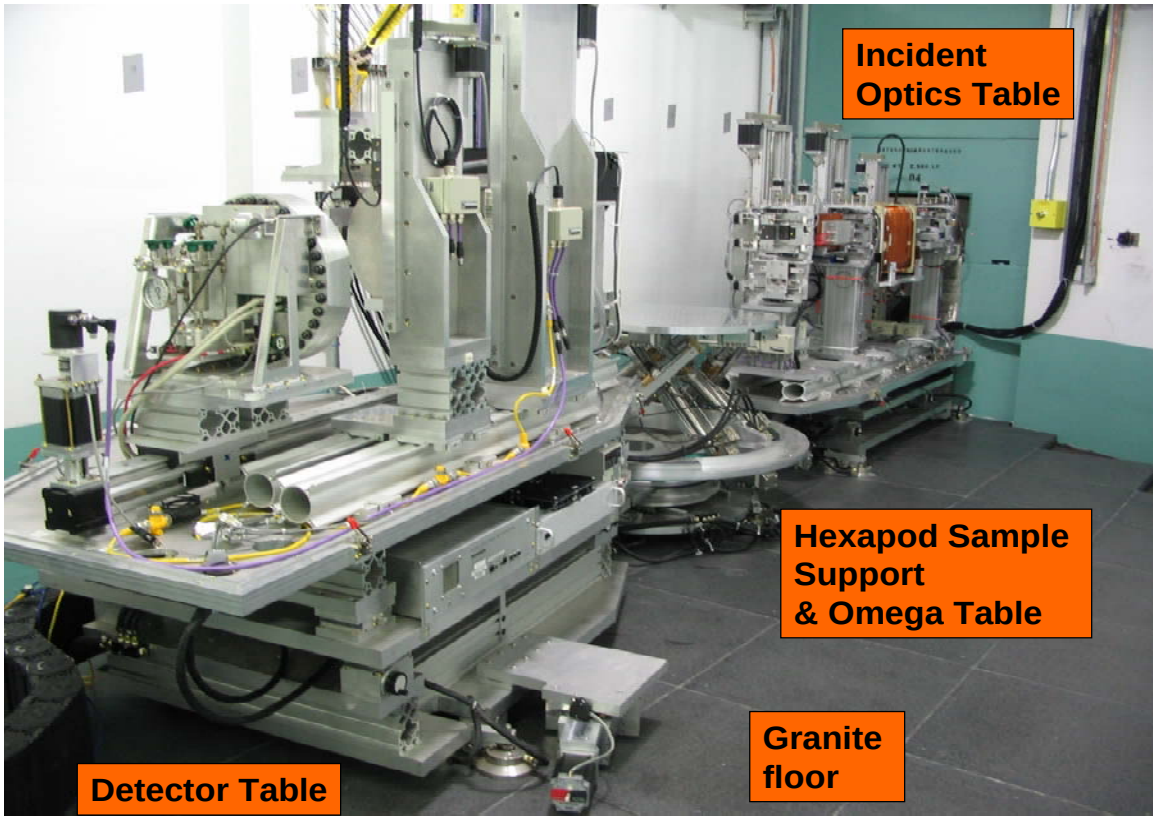

Figure 2: The sample stage of the SNS Magnetism Reflectometer

Figure 2 shows the sample stage of the SNS Magnetism Reflectometer (see also Fig. 1). The incident table carries the beam collimation systems and the polarized neutron optics. The sample environment is supported and aligned by a hexapod lifting stage. The horizontal scattering angle is set by an omega rotation table. The detector table carries the ^{3}He area detector as well as polarization analysis optics. A polarized ^{3}He analyzer and standard supermirror based optics can be moved in and out of the scattered beam according to the needs of the experiment.

2. Commissioning Results

In order to properly relate TOF and wavelength as is needed for analyzing data, it is essential that the instrument-length and the timing of the data acquisition system are properly calibrated. One way to check this is to perform a high-angle diffraction measurement on a single crystal in $\theta/2\theta$ configuration. Such high-resolution experiment is also useful for experimentally determining the moderator's emission time structure because the latter is reflected in the shape of the TOF diffraction peak. During the measurement the Si (111) wafer (d-spacing of 111 planes: 3.1355 Å) was placed at the sample position with an incident angle $\theta = 24.867^o$ (estimated errors: +/- 0.005^o for the omega angle and +/- 0.03^o resulting from the limited beam collimation). The measured moderator – detector distance is 20.685 m (estimated error: +/- 0.02 m). Under these experimental conditions, the reflected neutron wavelength should be 2.6371 Å and the diffraction peak should occur at a TOF of 13788.7 µsec if the neutron pulse would be momentarily emitted by the source at t = 0 sec. The latter, however, is not the case for a coupled cold hydrogen moderator as the one used on BL4A. The expected emission time spectrum for a particular wavelength is rather non-symmetric and is characterized by a "tail" of late emitted neutrons. The tail neutrons are later emitted

because they make a detour through the moderator's reflector assembly and lose some energy before getting back into the moderator where they have a second chance for getting thermalized and emitted towards the instrument.

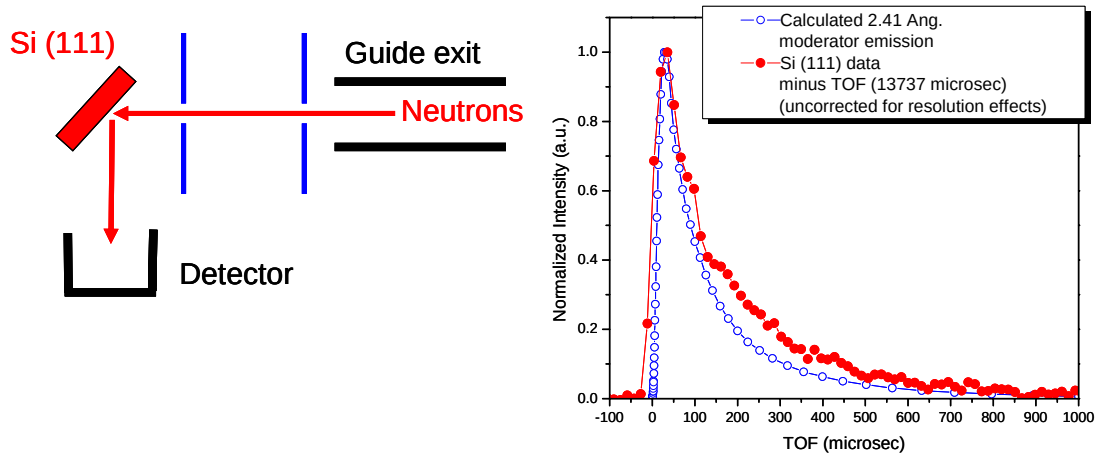

Figure 3: Experimental characterization of the coupled cold moderator's emission time. The measured spectrum corresponds to a neutron wavelength of 2.6371 Å.

Figure 3 shows the predicted moderator emission time spectrum for a neutron wavelength of 2.41 Å in blue symbols (see www.sns.gov) and compares it with the experimental TOF spectrum obtained in the Si (111) diffraction experiment (red symbols). In order to match the emission peak, it was necessary to subtract 13737 µsec. This is very close to the predicted TOF of 13788.7 µsec which had been calculated for the ideal case. The overall shapes of the emissions match well, although, particularly in the region between 100 and 500 µsec, the experimental emission is significantly longer than the theoretically predicted.

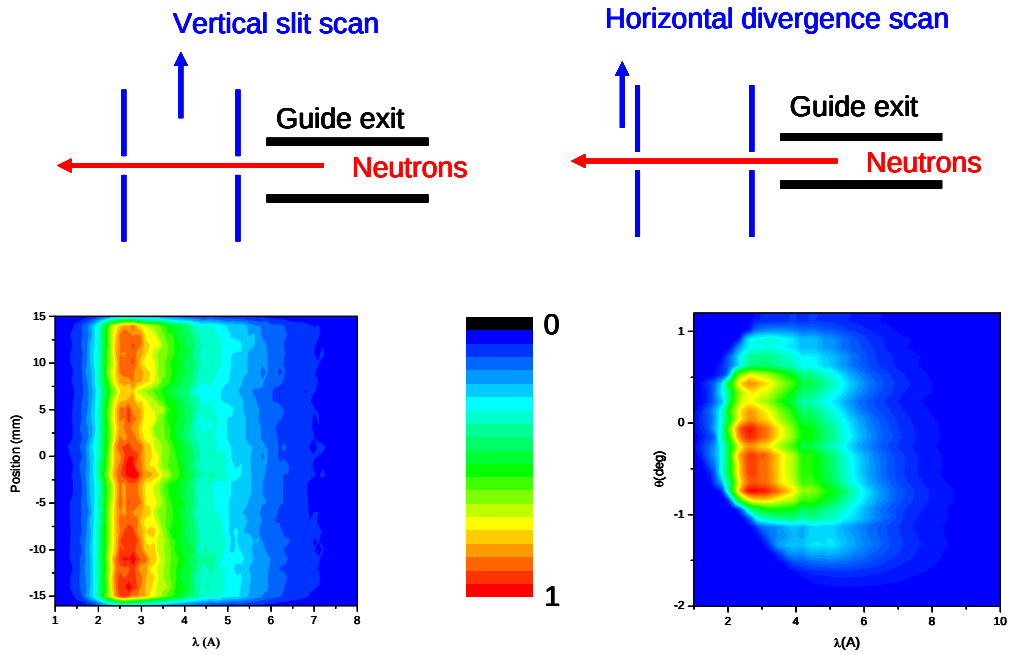

Figure 4: Experimental characterization of the neutron beam profile. The intensities are shown as a normalized contour plot (red: maximum intensity; dark: zero intensity).

In order to verify the homogeneity of the neutron beam profile at the sample position, vertical and horizontal slit scans were measured. In these scans, both upstream and downstream apertures are moved in parallel. In the non-collimated direction the slit opening is 25 mm while the beam is restricted to 1 mm in the collimated direction. The left part of Fig. 4 shows an example. As can be seen, in the vertical dimension, the guide (exit dimensions: 27 mm x 27 mm) emits a fairly homogeneous spectrum over the maximum assumed sample size of 25 mm x 25 mm. The spectrum peaks close to a wavelength of 3 Å. Below λ = 2 Å wavelength, the neutron bender rapidly cuts off the intensity. As expected (not shown here), also due to the upstream bender, the beam profile is more jagged in the horizontal direction.

The beam divergence close to the guide exit was measured by keeping the upstream slit at a fixed position and scanning the downstream slit in vertical and horizontal directions. The movement of the downstream slit's position can be converted into an angle. The right part of Fig. 4 shows the measured beam divergence in the horizontal direction. As expected from Monte Carlo beam transport calculations, intensity was found between +/- 1°. Note that the intensity distribution is not symmetric for positive and negative angles, which needs to be further investigated.

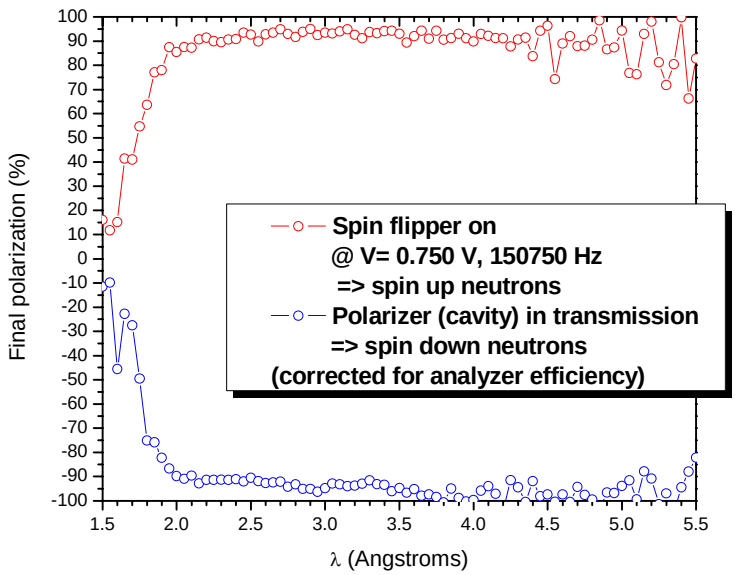

Figure 5: Wavelength-dependence of the neutron beam polarization with the gradient radio-frequency spin flipper off (blue symbols) and on (red symbols).

Preliminary tests have been carried out in order to determine the efficiency of the polarized beam components (polarizer, guide fields and spin flipper). A polarizing bender cavity was set up such that the polarizing m= 2.5 supermirror coating intersects the neutron beam at an angle of 0.41°. In this configuration a spin-down polarized neutron beam is created in transmission for neutron wavelength larger than 1.75°. A polarization analyzer was placed at the sample location in order to determine the efficiency of polarizer. Figure 5 (blue symbols) shows the wavelengths-dependence of the polarizer efficiency (the data have been corrected for the wavelengths-dependence of the analyzer efficiency). It can be seen that the beam polarization exceeds 90% above 2 Å neutron wavelength and > 95% above 3.7 Å. The red symbols display the final beam polarization after the radiofrequency spin flipper was switched on (the data are also corrected for the analyzer efficiency). If the spin flipper would perform perfectly, the final beam polarization should just change its sign. The measured polarization values show that the spin flipper performs very well for the short wavelength part of the spectrum but looses some efficiency towards the long-wavelength side. This may be an indication that the guide fields need some improvement (we are investigating

and will test new guide fields and different combinations of parameters – frequency fine-tuning, coil shape and position and amplitude – during the next commissioning cycle).

During the measurements that are presented so far in this article there was no need to spin the bandwidth limiting choppers since the accelerator was running at 5 Hz or 15 Hz where frame overlap is not an issue. The need for the chopper usage becomes, however, very important when the accelerator operates at 30 Hz or 60 Hz. "Frame overlap" neutrons from adjacent pulses need to be eliminated. The nominal instrument length of the magnetism reflectometer is 20.97 m, i.e. the wavelength band used for data collection when the accelerator operates at 60 Hz is $\Delta\lambda = 3.14$ Å as can be obtained from the equation, $\Delta\lambda=3956.034/Lf$, where L is the instrument length and f is the chopper frequency. It has been determined earlier that three neutron bandwidth limiting choppers are required (located at 6.20 m, 8.00 m and 10.32 m downstream the moderator) in order to ensure proper frame definition under a wide range of experimental conditions. Depending on experimental needs, the utilized wavelength frame can be changed in a continuous way by properly selecting the phases of the choppers.

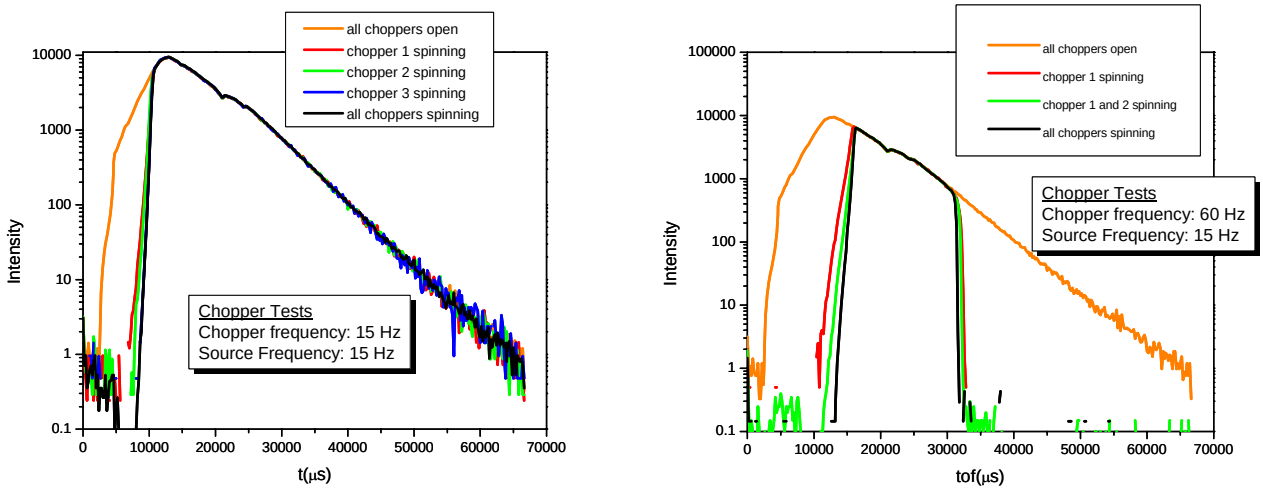

Figure 6: Chopper transmission measurements: The left plot shows the TOF spectrum when the choppers spin at 15 Hz while the accelerator is operating at 15 Hz. The right plot shows the spectrum when the choppers spin at 60 Hz while the accelerators operates at 15 Hz.

Figure 6 displays results of the chopper transmission tests. The left plot shows the chopper transmission when the source as well as the choppers operate at 15 Hz. In this case, neutron pulses are created every 66.7 msec and the frame size is $\Delta\lambda=12.58$Å. The orange line displays the beam transmission when all three choppers are stopped open. Note that the bender guide cuts off the intensity very sharply below 4000 μsec ($\lambda=0.77$ Å). The red, green and blue data sets were recorded when chopper 1, chopper 2 or chopper 3 were spun at 15 Hz and the others were parked in their open position. The black data set was recorded when all three choppers were in operation. The chopper phasing was chosen such that the created frame starts at 10000 μsec ($\lambda=1.91$ Å), i.e. the frame reaches from $\lambda=1.91$ Å to $\lambda=14.49$ Å. Note that there is no indication of increased background noise which could potentially result from the prompt pulse at t = 0 s. The right side of figure 6 displays results for 60 Hz chopper frequency while the source was operating at 15 Hz. For 60 Hz, the usable frame is 16.7 msec (or $\Delta\lambda=3.14$ Å) wide. The chopper phasing was chosen such that the chopper system transmits neutrons from TOF = 16 msec to 32 msec. It can be seen that the more choppers are spinning, the sharper defined are the resulting frame boundaries.

In summary, the initial commissioning results for the SNS Magnetism Reflectometer are very promising and it is expected that the instruments will be able to start operating in the user program in fall 2007.