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SEQUOIA: A Newly Operating Chopper Spectrometer at the SNS

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Abstract. A fine resolution chopper spectrometer (SEQUOIA) recently received first neutrons at the SNS. The commissioning phase of the instrument is underway. SEQUOIA is designed to utilize neutrons of an incident energy (E_i) between 10-2000 meV. A monochromatic beam is provided on a sample, 20 m from the decoupled ambient temperature H_2O moderator, by filtering the white beam with a Fermi chopper located 18 m from the source. After interacting with the sample, neutrons are detected by an array of ^{3}He linear position sensitive tubes located on a vertical cylinder with a radius of 5.5 m. This contribution presents current results from the commissioning experiments and compares SEQUOIA's actual and predicted performance. These commissioning experiments include characterization of the beam by monitors, determination of the chopper phase offsets, and runs with V and $C_4H_2I_2S$. The predicted performance is provided by analytical calculations and Monte Carlo simulations.

1. Introduction

The SEQUOIA spectrometer at the Spallation Neutron Source, is a fine resolution, Fermi chopper instrument that can utilize E_i between 10 meV and 2 eV. The instrument received first neutrons on October 7, 2008. SEQUOIA is currently in its commissioning phase. This contribution describes its current status in commissioning.

Figure 1 shows a schematic view of the completed instrument with the major components labeled. The neutron beam originates from the decoupled ambient temperature H_2O moderator and travels 20 m to the sample position. A Fermi chopper, located 18 m (L_1) downstream of the moderator and 2 m upstream of the sample (L_2), monochromates the beam. Two Fermi chopper choices are available on a translation table for ease of changing energy range and resolution conditions. Fermi chopper 1 has 3.6 mm slits and a channel curvature of 1.53 m. Fermi chopper 2 has 2 mm slits and a channel curvature of 0.58 m. A T_0 chopper is located 9.8 m from the moderator. It blocks the highest energy neutrons generated when the proton pulse hits the target and neutrons that would be transmitted through additional openings of the Fermi chopper that occur during the 60 Hz time frame of the source. Neutron guide is utilized to provide a high flux of neutrons on a 5 cm by 5 cm sample. Details of the guide and T_0 chopper design are described elsewhere[1]. A cylindrical array of 1.2 m long by 2.5 cm wide detectors is located 5.5 m (L_3) downstream of the sample position. This detector array currently spans angular ranges of -30° to 60° in the horizontal and $\pm18^\circ$ in the vertical. The cylindrical arrangement provides more continuous detector coverage than a spherical geometry. The effect

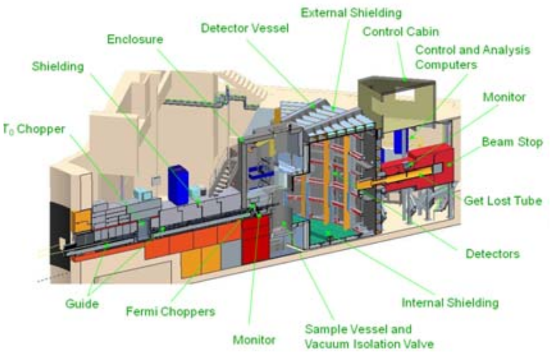

Figure 1. A Schematic view of the completed SEQUOIA

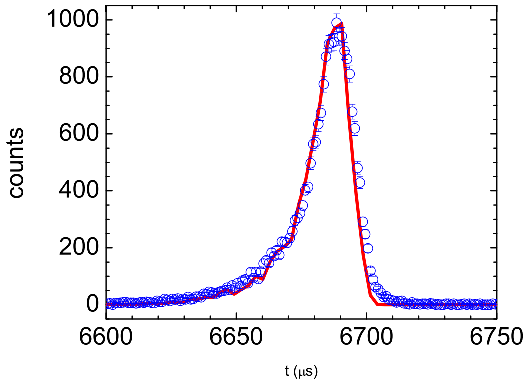

Figure 2. The signal observed in monitor 2 for E_i = 98 meV neutrons. The solid line is the results of a Monte Carlo simulation of the instrument in the same conditions.

of the cylindrical detector geometry on the resultant data was considered in detail. Lechner [3] showed that a cylindrical, pixelated detector array does not adversely effect the instrumental resolution for isotropic scatterers. Furthermore we used a McStas [4, 5] Monte Carlo simulation of SEQUOIA to examine the resolution effects of the cylindrical detector array. These studies showed that when pixel sizes in energy (ω) and momentum ($\mathbf{Q}$) transfer are much smaller than the instrumental resolution, the cylindrical geometry has a negligible effect on subsequent data processing. The 128 position pixels along the detector tubes and the $1\mu s$ timing resolution of the detector electronics provide more than sufficient pixelization. Longer detector tubes were considered for the detector array, but the chosen length preserves the ~1 cm pixel resolution and minimizes dead time effects in data collection.

To reduce background by removing Al windows, the detectors are located inside a detector chamber that can be evacuated. This chamber is contiguous with the evacuated sample vessel. A large gate valve connects the two chambers to isolate them during sample change out. This valve expedites sample changes as the largest evacuated volume remains under vacuum. To further reduce background, the inside of the detector chamber is lined with 2.5 cm of ZHIP (Zero Hydrogen in Product) mix, boron carbide powder bound together with a non hydrogenous glue [2] and the outside of the detector vessel is covered with 10 cm of 5% borated polyethylene.

There are two ^{3}He beamline monitors in the beam path; they are located immediately downstream of the Fermi chopper (L_{m1} = 18.2 m from the moderator) and in the get lost tube (L_{m2} = 29 m from the moderator). Each monitor has an efficiency of 1×10^{-4} for 1 Å neutrons. These monitors were used to characterize the incident beam. The points in Figure 2 shows a typical pulse observed in the downstream monitor. This data was taken when the source was running at 700 kW and the detector and sample chambers contained air at atmospheric pressure. Fermi Chopper 1 was spinning at 600 Hz and phased to provide E_i=98.0 meV neutrons with $\frac{d\omega(\omega=0.0)}{E_i} = 2.0\%$ McStas Monte Carlo simulations were run, using the same simulation code as was used in reference [1], to compare the expected peak shape and intensity to the observations. The solid curve in Figure 2 is the results of this simulation once they are scaled for beam power, Al in the beam, air in the beam, and the energy response of the monitor. No arbitrary scale factor is included in the scaling. The peak position is adjusted in time to compensate for an electronic offset in the data acquisition chain. Similar response was also seen for the first monitor. This Monte Carlo simulation also monitors the flux at the sample position. Therefore by comparison

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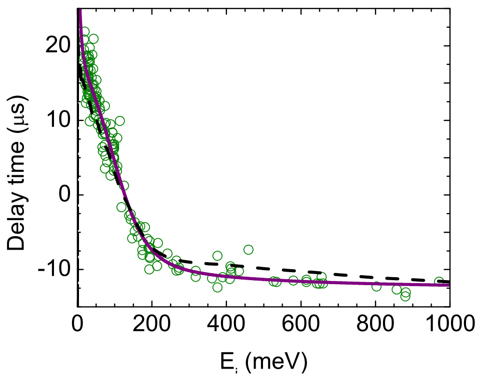

Figure 3. The points are the τ as described in the text. The solid line is a fit to Equation 1. The dashed line shows the prediction for the moderator as given in Ref. [6]

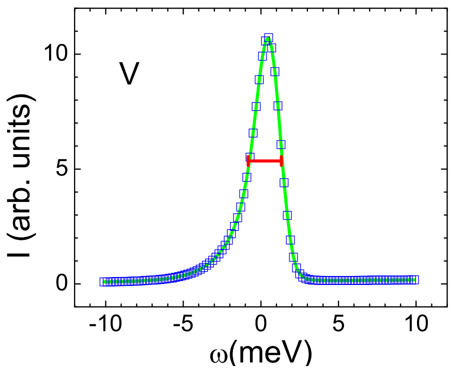

Figure 4. The incoherent elastic line in the neutron scattering spectrum from V for $E_i = 91.3$ meV. The horizontal errorbar gives the FWHM as predicted by equation 2

with the simulation, the time averaged flux on the sample is inferred to be $1 \times 10^5 n/cm^2/s$.

Measurements with the two monitors as a function of Fermi chopper phase, were used to determine the combination of the delay in emission of the neutrons after the protons hit the target plus the electronic offset (τ). Before the start of each measurement, the phase was set for a given E_i assuming $\tau = 0$ and L_1. The center of gravity of the neutron pulse in each monitor, corresponding to E_i, along with L_{m1} and L_{m2} provide the information to determine the actual E_i and τ. The results are shown as the circles in 3. Electronic offsets cause the observed negative τ for the highest values of E_i. The solid line is a fit of the empirically determined function,

$$\tau = \frac{1 + tanh(\frac{E_i - a}{b})}{2cE_i} + \frac{1 - tanh(\frac{E_i - a}{b})}{2dE_i} + f + gtanh(\frac{E_i - a}{b}) \qquad (1)$$

to the data. The resultant parameters are: $a = 92.0$, $b = 81.3$, $c = 1.3 \times 10^{-3}$, $d = -75.1$, and $g = -14.5$ The dashed curve is the expected τ from the MCNPX calculations shifted only by a constant to account for the electronic offset[6]. The expected and observed τ values agree.

Several standard samples were used in the initial characterization of the scattered beam. A vanadium rod, 1.12 cm in diameter, was used to test the energy resolution ($d\omega$) at zero energy transfer($\omega = 0$). A typical measurement with Fermi chopper 2 spinning at 600 Hz and phased for $E_i = 91.3$ meV is shown in Figure 4. The FWHM of this peak corresponds to $d\omega/E_i = 2.28\%$ which compares favorably to the predicted value of 2.35% given by the analytical function,

$$d\omega = m_n \sqrt{\left(\frac{v_i^3}{L_1} + v_f^3 \frac{L_2}{L_1 L_3}\right)^2 dt_m^2 + \left(\frac{v_i^3}{L_1} + v_f^3 \frac{(L_2 + L_1)}{L_1 L_3}\right)^2 dt_c^2 + \left(\frac{v_f^3}{L_3}\right)^2 dt_d^2}, \qquad (2)$$

where v_i and v_f are the initial and final velocities of the neutrons, respectively, dt_m is the time spread of the moderator [6], dt_c is the width of the time pulse through the Fermi chopper, and dt_d is the time spread from the detector and the sample widths given in quadrature[7, 8, 9].

The material 2,5-diiodothiophene ($C_4H_2I_2S$) has many rotational and vibration rotational energy modes. These sharp peaks in ω were used to characterize $d\omega(\omega)/E_i$. The data shown in Figure 5a were taken using similar instrument conditions as the V run; differing only by the sample size (5 cm x 5 cm x 2 mm flat plate) and orientation of 15° turned about a vertical axis. For a preliminary analysis, the FWHM/E_i of several of the peaks is plotted in Figure 5b. The solid curve shows the expected values as given by equation 2. The predictions and the results agree for most of the points. The exceptions are the 0 meV and 68 meV peaks. The measured $\omega = 0$ peak is expected to be narrowed because this analysis does not distinguish coherent and incoherent scattering. Measurements of the 68 meV peak on TOSCA also showed its width as greater than the instrumental resolution[10]; implying that the added width is from the sample and not the instrument.

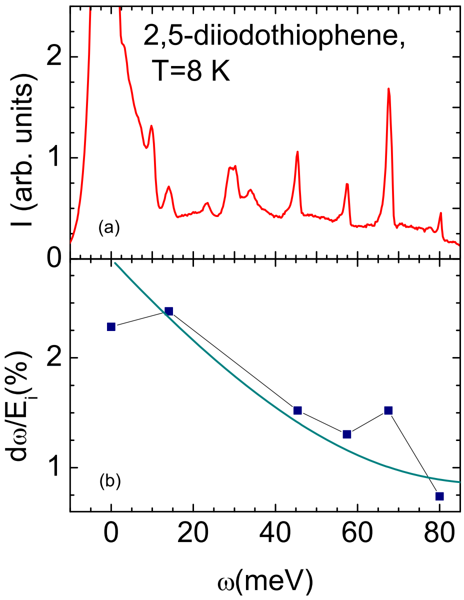

Figure 5. (a) The inelastic neutrons scattering spectrum for 2,5-diiodothiophene ($C_4H_2I_2S$) for E_i = 91.3 meV (b) The points are the measured FWHM/E_i and the solid line is the analytical prediction as described in the text.

A new Fermi chopper spectrometer is operational at the SNS. Experiments with the monitors have verified that the flux on sample is as expected. Experiments with standard samples have verified the instrumental resolution is as expected.

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