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Neutron Spectral Brightness of Cold Guide 4 at the High Flux Isotope Reactor

J.L. Robertson[1], B.L. Winn[2,1], E.B. Iverson[1], D.L. Selby[1]

[1] Neutron Facilities Development Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA

[2] Neutron Scattering Group, Condensed Matter Physics and Materials Science Department, Brookhaven National Laboratory, Upton, NY 11973-5000, USA

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Brookhaven National Laboratory
P.O. Box 5000
Upton, NY 11973-5000
www.bnl.gov

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[1] Neutron Facilities Development Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA
[2] Neutron Scattering Group, Condensed Matter Physics and Materials Science Department, Brookhaven National Laboratory, Upton, NY 11973-5000, USA

E-mail: robertsonjl@ornl.gov

Abstract. The High Flux Isotope Reactor resumed operation in June of 2007 with a super-critical hydrogen cold source in horizontal beam tube 4. Cold guide 4 is a guide system designed to deliver neutrons from this source at reasonable flux at wavelengths greater than 4 Å to several instruments, and includes a 15-m, 96-section, 4-channel bender. A time-of-flight spectrum with calibrated detector was recorded at port C of cold guide 4, and compared to McStas simulations, to generate a brightness spectrum.

1. Introduction

The High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory resumed operation in June of 2007 with a super-critical hydrogen cold source in horizontal beam tube 4. Neutron scattering instruments that view the cold source receive an enhanced neutron spectrum for wavelengths greater than 4 Å. A time of flight measurement that viewed the moderator directly, when nearest guide sections were removed,[1] compares well with previous MCNP model results, as shown in figure 1. Brightness was better than expected above 3 Å, with a 60% increase at 5 Å before the guide.

Cold Guide 4 is a guide system designed to deliver neutrons with wavelengths between 2 Å and 6.4 Å from this source at reasonable flux to several instruments, and includes a 15-m, 96-section, 4-channel bender with total deflection of 8^o, with a vertical trumpet. A typical neutron will bounce about 12 times in getting through the 8^o bend, so transmission through the bender depends strongly on the quality of the mirror coatings.

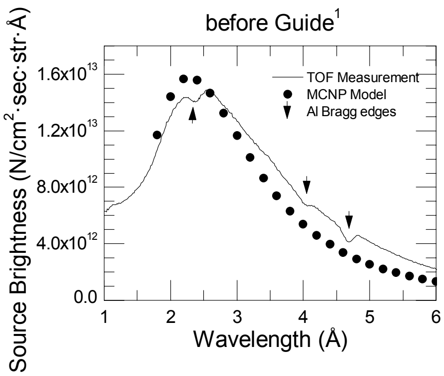

Figure 1. The spectral brightness of the HB-4 cold source at reactor power level of 85 MW and moderator temperature of 22.5 K as measured and modeled. The arrows indicate aluminum Bragg edges.

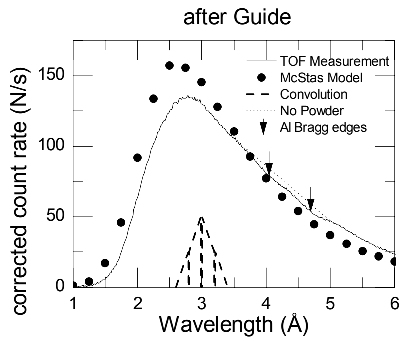

Figure 2. Neutrons per second at the detector as measured and modeled, for a reactor power level of 8.5 MW. The arrows indicate aluminum Bragg edges.

2. Experiment and Simulation

A time of flight spectrum with calibrated detector was recorded at port C of cold guide 4, using an apparatus described elsewhere[1]. We refer the reader to this report for experimental setup details. Differences between the current and previous setup are the use of 20 Hz instead of 60 Hz, a distance between middle of chopper to detector of 2.451 m instead of 2.473 m, and an detector aperture of diameter 9.5 mm instead of 10 mm. Figure 2 shows measured neutrons per second at the detector, compared to a McStas[2] simulation. This plot accounts for detector efficiency in the measured data. For the modelled data it accounts for (incoherent) attenuation in aluminium windows and in air, and beam reactor power. No attempt was made to account for the effects of Bragg scattering or multiple scattering by the air or aluminium.

For the simulation a crude convolution of wavelength accounts for the chopper slot time window (corresponding to 0.404 Å) compared to the scaler binning (corresponding to 0.016 Å). This convolution is represented on figure 2, which shows at λ=3 Å the relative contributions of various wavelengths due to the chopper (fixed slit and chopper slit have the same dimensions, hence the triangular form), and the location of the λ and $\lambda \pm 0.2$ Å parameters used to generate McStas model results for this convolution. The wavelength offset of measured data was roughly set using the dip in intensity at the (2 0 0) and (1 1 1) aluminium Bragg peaks, but with such a broad convolution in wavelength, the offset could easily be off by ~0.1 Å.

3. Results and Discussion

We measured an unexpected background signal at ~8% of peak measured flux, roughly independent of time. This background was not observed in the previous study at the HB4 beam tube. For the plot, it was subtracted from the data prior to scaling by detector efficiency for comparison, but it will be further analyzed. Measurements will not be repeated because a monochromator shield has been installed at the port.

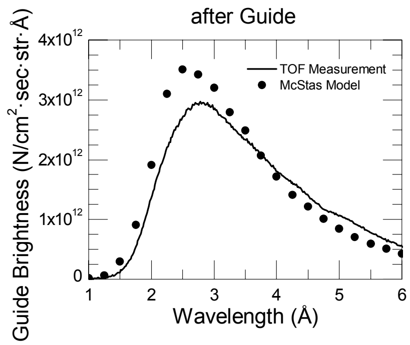

Figure 3. The spectral brightness at port C of cold guide 4, at reactor power level of 85 MW, as measured and modeled.

To obtain brightness at the end of the guide from measured neutrons per second at detector as shown in Figure 3, we first account, on both model and measurement, for the wavelength-dependent chopper transmission f_t due to finite disk thickness (0.01 m). Here $f_t = 1 - \lambda/\lambda_m$, where for 20 Hz $\lambda_m = 92.5$ Å. An analytical form of the acceptance in the detector is difficult due to the presence of both rectangular and circular apertures, but an approximation leads to an acceptance of 6.8×10^{-6} cm^2·str, the same acceptance used in the previous study[1]. We assume 100% power instead of 10% power, and correct for transmission through air and aluminium after exiting the guide. We account for the chopper duty factor of 0.005. For the measured data we again account for detector efficiency. Finally, no convolution is used in the McStas simulation, but no attempt was made to deconvolve the measured data.

We suspect that the septa may be misaligned, due to Si septa of varying thickness lying in oversized slots. On one assembly of 6 sections, we measured at each end a typical gap of ~40 mm or 8% of the width of the Si plates, and found the plates lying loosely in the slots. We therefore performed McStas studies to estimate flux loss from misaligned septa occlusion, and found that for this typical gap attenuation may be up to 50%, independent of wavelength. The model results shown assume no misalignment, and at 5 Å the measured signal is 26% above the new estimate, as compared to a 60% increase before the guide. The spectra at low wavelengths is more difficult to compare due to the uncertainty in the wavelength offset of the measured data, the steeper slope below 2.5 Å, and aluminium Bragg edges between 2 Å and 3 Å.

We wish to acknowledge the efforts of Ralph Moon, who developed the design concept of, and developed an earlier model for, all four guide systems[3] for horizontal beam tube 4 at HFIR. This experiment was supported by the Department of Energy's Office of Science.

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