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Performance of the Neutron Detectors of the WISH Diffractometer at ISIS

The performance of the position sensitive neutron detector array of the WISH (Wide angle In a Single Histogram) diffractometer is discussed. WISH is the new, long-wavelength, neutron diffractometer for magnetic studies that is now being commissioned at the second target station at the ISIS pulsed neutron source. The detector array consists of 760 3He-based, position sensitive wire tubes. These are arranged in a semi cylindrical shape with a radius of 2.2 m centred at the WISH sample position. Each tube is one metre long, has a diameter of 8 mm and is filled with 3He at 15 bar. The WISH detector requirements include 50% neutron detector efficiency at a wavelength of 1 Å, good gamma rejection and a position resolution better than 8 mm FWHM along the length of the tubes. The hardware and signal processing that allow these requirements to be fulfilled are described. In particular digital signal processing has proved an effective means of dealing with detector offsets and has resulted in a highly stable detector array which is easily assembled and maintained. The results obtained from preliminary tests on prototype detectors are reported together with pulse height and position resolution prior to and post installation. Finally some diffraction patterns from powder and single crystal samples are given. The quality of this data shows that this detector array will allow WISH to make a significant impact in neutron scattering investigations of magnetic materials in the near future.

Summary (Additional text describing your work. Can be pasted here or give an URL to a PDF document):

ISIS is the pulsed neutron source operated by the Science and Technology Facilities Council at the Rutherford Appleton Laboratory in the United Kingdom. Neutrons are produced by spallation, whereby a high intensity pulsed proton beam is sent onto a heavy metal target. Neutron beams are used by a broad user community to study materials at the atomic/molecular level. ISIS consists of two target stations: the first has been operational for more than 20 years, the second one started operation in 2008 with seven beam lines now under commissioning or starting their user program. WISH (Wide angle In a Single Histogram) is one of these seven new instruments.
WISH is a long-wavelength diffractometer primarily designed for powder and single crystal diffraction investigations of magnetic and large unit cell systems, with the option of enabling polarised beam experiments. Neutrons scattered by the sample are detected by a semi-cylindrical array of position sensitive detectors, 2.2 m away from the sample. The detectors have to determine the position of the detected neutrons with a precision better than 8 mm FWHM and a dead time shorter than 5 µs. The detector array consists of 760 3He filled resistive wire tubes, each with an active length of one metre and a diameter of 8 mm. Neutrons are detected through the reaction:

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n+3He→3H+p.
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A 3He pressure of 15 bar is used to provide a detection efficiency of 50% for 1 Å wavelength neutrons. Argon is added inside the tube to reduce the path of the triton and the proton which reduces the wall effect and increases the spatial resolution. The tubes are arranged vertically and are supported at four equidistant points in order to keep them straight to within 300 µm. This requirement is crucial to keep the wire centred on the long axis of the tube, thus enabling safe operation of the detectors.
Signals induced on the resistive wire are read out at both ends of the tube and the interaction position along the tube is determined from the relative amplitude of the signals at the ends. The signal is read out at each end of the tube by two fast bipolar preamplifiers with differential outputs. These signals are digitized at a sample rate of 33 MHz and processed by a code implemented in an FPGA. The FPGA code is divided into two parts: a Gaussian filter and a neutron/gamma discriminator. The Gaussian filter is used to reduce noise components and to remove offsets of the signals. A base line restorer is also implemented to minimise signal pile up at high rates. The neutron/gamma discriminator is based on the analysis of the signal shape on its rising edge. For accepted signals the position along the length of the tube is calculated. The digitisation and signal processing are performed by a custom made ADC board designed for WISH. Use of digital signal processing has reduced signal offsets leading to a highly reproducible processing system which is easy to set up and maintain.
The code implemented in the ADC board was developed from tests of prototype detectors on the ROTAX neutron beam-line at ISIS using a commercial digitizer. These tests were performed to find the working point of the detector in terms of high voltage and were used to determine the parameters of the code to be implemented in the ADC. Parameters that have been optimised are: the integration and differentiation time of the Gaussian filter, the base line restorer and the cuts for the neutron/gamma discrimination. Results obtained with the

commercial digitizer and the ones obtained with the final ADC were compared and will be described.
All 760 tubes were assembled on the support panels and then illuminated with neutrons from an Am-Be source. Pulse height and position spectra were collected in order to check that the preamplifiers at both ends were working properly and that the tubes were accurately aligned on the supports. Examples of these spectra will be shown together with some anomalies observed during these tests. The same tests were repeated once the detectors were installed on the beam line to measure the uniformity of response of the detectors in their final position.
On the beam line the position resolution of the detectors was measured using a gadolinium mask with nine equidistant slits perpendicular to the length of the tubes. The position resolution was measured on 6840 points. An average position resolution of 7±1 mm FWHM was measured on the whole array. This result is well within the requirements of the WISH instrument. The slit measurement was also used to calculate a small correction which is applied to the position calculation along the length of the tubes. Once commissioning had been completed, diffraction patterns from powder and single crystal samples were recorded and some examples will be shown.

The mechanical design of the detector array, the test procedures adopted and the digital signal processing have all resulted in a large area detector which fully meets the requirements of the WISH diffractometer. The detector array has been relatively easy to assemble, set-up and maintain. After successful commissioning of the complete instrument, the user programme on WISH is now underway. The quality of the data demonstrates WISH will make a significant impact in neutron scattering investigations of magnetic samples.

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