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Instrumentation for PSD-based neutron diffractometers at Dhruva reactor

S S PANDE, S P BORKAR, S PRAFULLA, V D SRIVASTAVA, A BEHARE, P K MUKHOPADHYAY, M D GHODGAONKAR and S K KATARIA
Electronics Division, Bhabha Atomic Research Centre, Mumbai 400 085, India
E-mail: sspande@magnum.barc.ernet.in

Abstract. Linear position sensitive detectors (PSDs) are widely used to configure neutron diffractometers and other instruments. Necessary front-end electronics and a data acquisition system [1] is developed to cater to such instruments built around the Dhruva research reactor in BARC. These include three diffractometers with multiple PSDs and four with single PSD. The front-end electronics consists of high voltage units, preamplifiers [2], shaping amplifiers, ratio ADCs (RDC) [3]. The data acquisition system consists of an interface card and software. Commercially available hardware like temperature controller or stepper motor controller connected over GPIB or RS232 are also integrated in the data acquisition system. The data acquisition is automated so that it can continue unattended for control parameter like temperature, thus enabling optimum utilization of available beam time. The instrumentation is scalable and can be easily configured for various instrumental requirements. The front-end electronics and the data acquisition system are described here.

Keywords. Data acquisition system; position sensitive detector; ratio ADC.

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1. Introduction

Neutron scattering is a widely used probe for the structure as well as dynamics of both crystalline and non-crystalline substances. In diffraction experiment one measures the number of neutrons scattered in the scattering plane as a function of angle (2θ) of the substances under study. This data consists of sharp peaks over and above the background in the case of crystals, whereas it will have very broad diffuse peaks in the case of liquids and glasses. This data is then used for modeling the structure of materials using various techniques.

In an experimental setup a monochromator crystal receives the polychromatic beam from the reactor and reflects a monochromatic beam. The monochromatic neutron beam gets diffracted or scattered from the sample. The scattering is detected with the help of PSDs. Sample parameters like temperature or magnetic field may be controlled for specific studies. Thus a typical experimental set-up

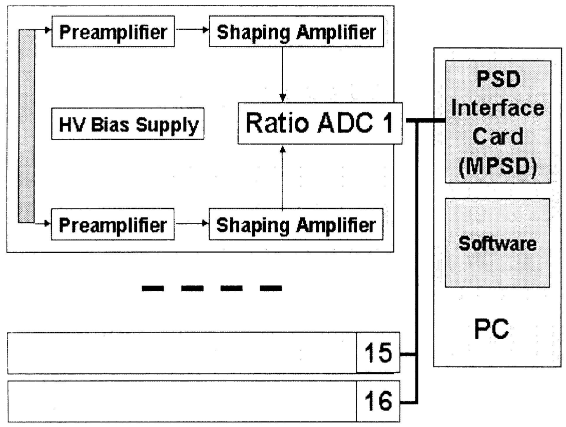

Figure 1. Instrumentation for PSD-based diffractometer.

consists of PSDs, neutron flux monitor, various motor controls and other stand-alone controllers.

The PSDs work on the principle of charge division. It has an anode wire of significant resistance per unit length in a gas-filled tubular casing. When a neutron causes ionization in the gas, the charge is collected at both ends of the wire and these two signals are simply related to the position of the interaction. The PSDs are developed at SSPD [4]. Through preamplifiers and shaping amplifiers the two signals are connected to a ratio ADC to derive the position value. In a single PSD system the PSD is moved using a motor and data is acquired at different positions. In order to achieve higher data throughput multiple PSDs are fixed at different positions and data is acquired simultaneously from all the PSDs. Throughput is further improved by using multiple PSDs at each position. Various instruments like the powder diffractometer, high-Q diffractometer, polarized neutron reflectometer, quasi-elastic neutron spectrometer, small-angle neutron spectrometer all use linear PSDs to detect scattered neutrons. This similarity is exploited to build a scalable and configurable data acquisition system to serve each of the instruments. Figure 1 shows the block diagram of instrumentation for PSD-based instruments.

2. Front-end electronics

The front-end electronics consists of two preamplifiers and two shaping amplifiers at the two ends of a PSD, an RDC and a HV bias supply for the detector. Signals from two ends of the PSD are fed through preamplifier and shaping amplifier to the RDC. All these units are indigenously developed and technologies of some of these units were transferred to ECIL.

The preamplifier is a charge sensitive preamplifier with low dynamic input impedance designed for use with linear PSDs. The low impedance is important in minimizing position-encoding error and also to maximize the encoding range. The shaping amplifier amplifies and shapes the preamplifier output pulses. The choice of shaping time and mode is effected by on-board switches. It is thus suitable for applications where shaping time need not be changed frequently. It provides continuously variable gain up to 1.5 K, four shaping time constants 0.5, 1.5, 3 and 4 s and a choice of Gaussian and triangular shaping modes. The high voltage supply is a slow rising, continuously variable supply designed to output ±2500 V and 1 mA current.

The ratio-to-digital converter (RDC) is a single width NIM module that converts the ratio of two input pulses directly to digital form. In the RDC, the two inputs A and B are DC restored, stretched and added. The sum A+B is used as reference of a ratiometric ADC that digitizes A if the SCA (on A+B) as well as prompt and delayed coincidence conditions are valid. Since a ratiometric ADC of the required resolution and speed is not readily available, it is synthesized using a 12 bit multiplying digital-to-analog converter (MDAC type 7541A) and successive approximation register logic (SAR). The differential non-linearity (DNL) was reduced by the usual sliding technique whereby a variable analog offset is added to the signal input of the ratiometric ADC and the corresponding digital number is subtracted from the SAR output. The RDC can also be operated as a conventional fast nuclear ADC.

3. PSD interface card

The PSD interface card (MPSD) is an ISA-based PC add-on card. It is designed to serve the requirements of different single- and multi-PSD diffractometers. MPSD can acquire data from sixteen uniquely identified RDCs over a single multi-drop FRC cable. Five different motor controls are also provided of which three are closed loop controls. For monitoring of the neutron beam flux a scalar is provided along with a lower level discriminator. The motor control and monitor signals are provided as both open collector and differential (RS422 compliant) with selectable jumpers. In the differential mode, MPSD can drive the RDCs and other control signals over a cable length of 90 m.

A transputer is used as the on-board processor on MPSD. It provides programmability, parallel processing capability and most importantly the real-time performance necessary to service different events. It has four links for communication one of which is used to communicate with the PC. The link interface of transputer is mapped in the IO space of PC. Peak speed of communication between transputer and PC is either 10 or 20 Mbits/s, which is selectable. The transputer is also provided with 512 kB of local RAM where a program can be downloaded from the PC and executed. All the hardware control required for data acquisition, monitoring, detector positioning, FMC positioning etc. is implemented by various control registers mapped in the IO space of the transputer.

4. Software

Data acquisition from a neutron diffractometer is the main function of the software. Raw data is acquired from multiple PSDs, each PSD spanning a smaller angular

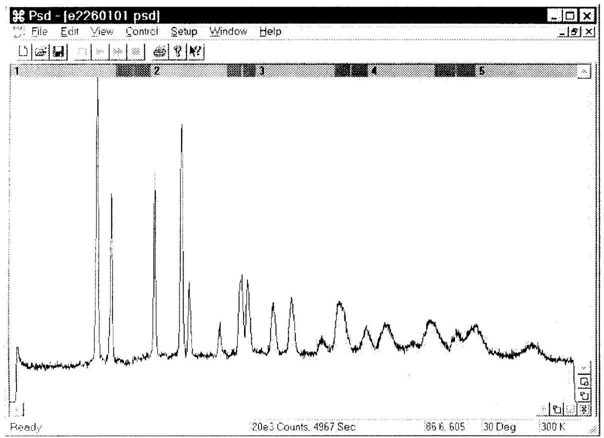

Figure 2. Diffraction spectrum of nickel powder.

region. PSDs being linear the raw data is not equiangular. So the data is transformed further to realize a large circular PSD. Data is displayed both graphically and as tables. Figure 2 shows the graphical display of data acquired on a multi-PSD setup. The data acquisition is also automated so that it can continue unattended for long time based on control parameters like temperature. This has helped in better utilization of available beam time. Software plays a key role in configuring the data acquisition systems for different diffractometers thus achieving the design goal of minimizing development efforts.

Software comprises a front-end Windows 98 application on PC and a transputer program on the MPSD card. The front-end application provides entire user interface required for data acquisition, control, presentation and system setup. The transputer program developed in OCCAM performs data acquisition and control operations and it serves various requests of the front-end program. A device driver named VTRANSPD is also developed to support the communication between PC and transputer. Different commands are sent from PC to the transputer where they are executed and the results are returned back to the PC.

5. Applications

This instrumentation is being used with three multi-PSD diffractometers and four single PSD instruments. They are:

Powder diffractometer for polycrystals	5 × 1 PSDs
High-Q diffractometer for liquids, glasses and polycrystals	5 × 1 PSDs
IUC powder diffractometer (IUC-PD)	4 × 3 PSDs
Polarized neutron reflectometer	1 PSD, moveable sample
Quasi-elastic neutron scattering spectrometer	1 PSD
Powder diffractometer	1 PSD, moveable detector
Small-angle neutron scattering spectrometer	1 PSD

The powder diffractometer for polycrystals is built at the beam port T-1013 in the Dhruva reactor hall. The total angular range for this diffractometer is 140°. Five PSDs each of 1 m length are housed inside a detector shield. It is used to investigate both structural and magnetic phase transitions of materials as a function of temperature, pressure, magnetic field etc. The studies will be important to characterize new materials being synthesized. The high-Q diffractometer is built at the beam port HS-1019. Except for the monochromator its configuration is same as the powder diffractometer. This diffractometer is being used to study the structural correlation in amorphous materials, H-bonded liquids and complex glasses like waste storage glasses. The IUC-PD employs twelve PSDs arranged in four banks of three detectors each. This will result in a higher data throughput. It will also achieve better resolution over a wide range of scattering angles with improved intensities.

The data acquisition system also supports instruments with either movable PSD or moveable sample. In the single PSD powder diffractometer data is acquired at different positions for a given monitor value. In the polarized neutron reflectometer the sample is rotated using a dedicated controller connected on RS232 and data is acquired at each position. The quasi-elastic neutron scattering spectrometer and the small-angle neutron scattering spectrometer are basic instruments with single PSD, the movements of the different components are not coupled.

6. Conclusion

The instrumentation, which includes the front-end electronics and the data acquisition system, is being used for various linear PSD-based instruments. It can be scaled easily for instruments with up to sixteen linear PSDs. Various dedicated controllers and allied instruments are also integrated in the data acquisition system. The data acquisition system provides adequately for long unattended acquisition based on control parameters like temperature. The acquired data is also converted to equiangular data. Some basic analysis features may be incorporated in the software to further improve the productivity of the instruments.

References

[1] S S Pande, S P Borkar, A Behere and M D Ghodgaonkar, *Proceedings of Symposium on Intelligent Nuclear Instrumentation (INIT 2001)*, 2001, p. 53
[2] P K Mukhopadhyay and P Shenoy, *Proceedings of the Symposium on Advanced Instrumentation for Nuclear Research (SAINAR)*, 1993, p. L2-1
[3] P K Mukhopadhyay, P Shenoy, V B Chandratre and K R Gopalkrishnan, *Proceedings of the DAE Symposium on Nuclear Physics*, 1992, **35B**, p. 458
[4] S K Paranjpe and Y D Dande, *Pramana – J. Phys.* **32**, 793 (1989)