

## **THE NEW DATA ACQUISITION SYSTEM MPD-32 FOR THE HIGH-RESOLUTION FOURIER DIFFRACTOMETER AT THE IBR-2 PULSED REACTOR**

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In the Laboratory of Neutron Physics a new high-performance data acquisition system (DAQ) is being developed in the framework of the project on creation of a high-aperture backscattering detector (BSD) for the high-resolution Fourier diffractometer HRFD.

The designed increase in the BSD aperture of 12.5 times and an increase in the neutron flux on the sample of 2-3 times due to employment of the new neutron guide, demand raising the neutron registration rate to  $\sim 3 \cdot 10^7$  n/s [1]. Time encoders, besides signals from the multielement scintillation detector BSD, also digitize pick-up signals from the chopper as well as of reactor startups that are transmitted to the computer in the list mode to be recorded on the disk for further processing. This has required development of new electronics and programs as the MPD-240-based DAQ system used today has the neutron registration limit on the level of  $\sim 10^6$  n / s.

Earlier, in order to increase the transmission capacity of data acquisition systems with a USB-2 interface for the IBR-2 spectrometers, the FLINK USB 3.0 was developed [2] to provide links between the modules having an optical interface with a computer according to the USB 3.0 protocol. This has solved the problem of increasing the performance of the DAQ systems for all the spectrometers except those for the HRFD that has undergone modernization. This work presents the results of development of a high-performance data acquisition system on the basis of MPD-32 blocks integrated into a common system of a high-speed interblock interface and a USB 3.0 computer interface with an optical fiber extender.

**Keywords:** Data acquisition system, high resolution, neutron diffraction, back-scattering detector.

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## 1. Introduction

The IBR-2 reactor is equipped with a unique complex of neutron spectrometers allowing a wide range of studies. At present, 18 spectrometers operate, or are in the final stage of development at the reactor. Fourteen are used for condensed matter research, two for nuclear physics research, one for radiation material science, and one for neutron activation analysis. This paper describes the results of development of the DAQ for the new large-area BSD detector at HRFD

The High-Resolution Fourier Diffractometer (HRFD) developed in the framework of collaboration between FLNP JINR (Dubna), PNPI (Gatchina) and VTT (Espoo, Finland) has been operating at the IBR-2 reactor since 1995.

Nowadays a wide-aperture backscattering detector [fig. 1] for the HRFD diffractometer is being developed in FLNP. In the past few years, some of the key HRFD units, that became morally obsolete or worn out, have been replaced. Specifically, in 2016 a new mirror neutron guide and a fast Fourier chopper were put into operation and in the previous years, there was complete replacement in the data acquisition and experiment control electronics [3].

Next priority in the HRFD development plan is the forthcoming replacement of the two existing backscattering detectors (BSD) by a new large-area scintillation detector with a total area of sensitive elements of about 13m<sup>2</sup>. The planned BSD aperture increase by a factor of 12.5 and an increase in the neutron flux on the sample by a factor of 2–3 due to the use of a new neutron guide require raising the neutron detection rate to ~ 107 n/s. This requires an increase in the throughput of data acquisition system up to 400 MB/s.

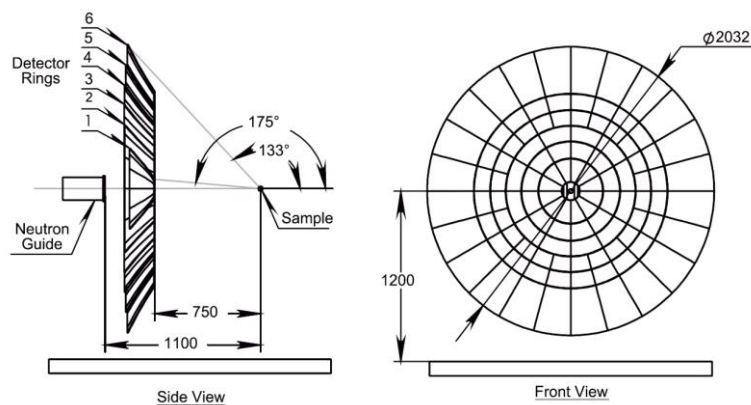


Figure 1. Wide-aperture back-scattering detector

## 2. Hardware

A general approach to developing new data acquisition systems for our spectrometers is to use and develop unified blocks, unified standards, and unified software. As a result, the systems installed on different spectrometers have a unified structure. Such unification can be realized because the main method is the time-of-flight method for measuring the energy of the detected neutrons. Also, scintillation, gas or position sensitive counters are used as detectors in all the spectrometer set ups.

The data acquisition system could be constructed based on one or two types of basic electronic modules, one of which (De-Li-DAQ) processes and accumulates data from a one- or two-coordinate PSD, and the other (MPD-240) collects data from multielement detectors [4].

Nowadays, the MPD-240 DAQ (Fig. 2) is used on HRFD for high resolution data acquisition. The MPD-240 unit allows event-by-event data acquisition (list-mode). In this case, during on-line measurements the MPD-240 system provides transmission of raw data from the reactor pulse, chopper pick-up signals, and from an array of detector elements for their subsequent off-line processing.

To input the data from the reactor pulse and the pick-up signals, there are made additional inputs on the front and back panels of the unit. To input the detector signals, one 32-channel discriminator module is used.

Such MPD-240 data acquisition systems are now used on three Fourier diffractometers, HRFD, FSD, and FSS.

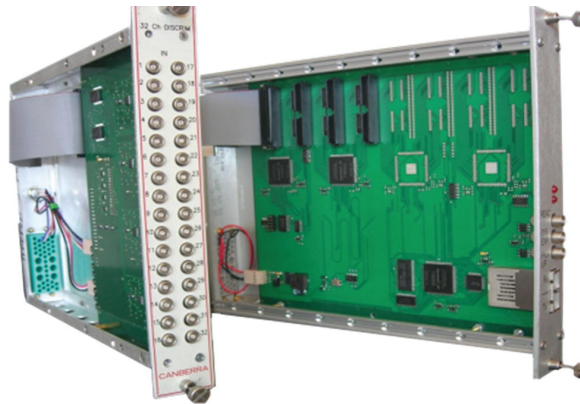


Figure 2. The MPD-240 and the 32-Chanel Discriminator

This DAQ has a hardware limitation on the neutron registration rate of 106 n/s. Thus, it cannot provide high resolution data acquisition from the BSD under development. This issue requires development of a new high performance DAQ with a bandwidth of transmission channels of 400 MB/s.

To this end, a new MPD-32 module (Fig. 3) is being developed at FLNP. The MPD-32 module combines the functions of a 32-channel discriminator and a time-of-flight encoder of detector signals. New MPD-32 modules can be made by upgrading 32 existing channel discriminator modules. The digital part is constructed on the basis of two FPGA, one of which is the time-of-flight encoder FPGA and the other is the communication controller FPGA.

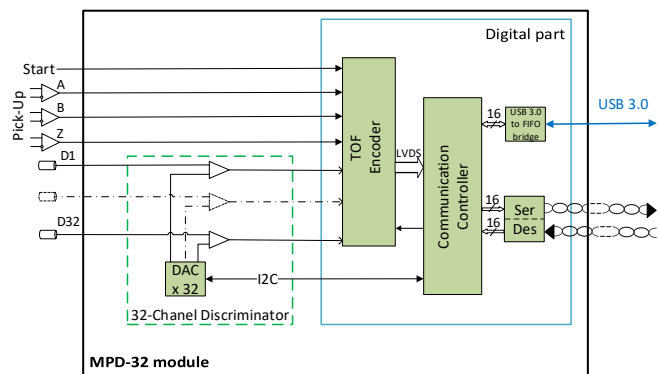


Figure 3. The MPD-32 with a 32-chanel discriminator

Signals from preamplifiers of detectors pass through an analog-digital functional block which receives, discriminates and transmits signals to the time-of-flight encoder FPGA. The TOF encoder FPGA is used to encode signals from 32 detector elements, to register their appearance time, to convert the received data from parallel to serial bit stream form, and to transfer them through the LVDS port to the communication controller FPGA at a speed of about 800 Mbit /s. The communication controller FPGA performs the functions of receiving and buffering data from all detector elements and of transferring the generated data packets to the computer memory via a fast serial link or via USB3.0. Fast serial links are used to integrate several MPD-32 modules into a common DAQ system with the required number of channels. The structure of MPD-32 module is shown in figure 3.

Main features of MPD-32:

MPD-32 allows one to organize the data acquisition system that meets the requirements of all types of multipoint detector systems of neutron spectrometers at the IBR-2M reactor;

- MPD-32 combines a discriminator and an encoder for 32 analog inputs;
  - USB3.0 interface with an optical fiber extender;
  - High speed (2.5 Gb) interblock linking;
  - Range of analog input signals  $0 \div 2V$  p-p, with selectable polarity;
  - Programmable thresholds of discriminators in the range of  $30 \div 400$  mV with 8 bits ADC;
  - Maximum number of detector elements 32 for one MPD-32 in the system;
  - Maximum detection rate =  $3 \times 10^7$  events/s;
  - Events are recorded in absolute time of experiment, max. exposure time =  $4.5 \times 10^6$  s (length of time counter = 48 b);
  - Registration of service signals with the same accuracy as that of detector elements: such as start of reactor, start/end of time window, end of exposure, etc.;
  - Registration of additional 6 external signals for example PICK-UP Fourier chopper signals on the HRFD diffractometer;
  - Time digitization rate – programmable (maximum 62.5 MHz).
- Some functions and parameters are the same as those of MPD-240 [5].

### 3. Architecture of the new DAQ system

The architecture of the MPD-32-based DAQ system is constructed on the basis of 8 modules integrated into a common system to ensure operation of 216 PMTs of the BSD. The number of modules can be 8 at minimum or 12 for more convenient determination of signals from 12 sectors of the detector. One sector of BSD provides operation of 18 PMTs. Figure 4 shows the structure of the data acquisition system for the detector under development [6].

Every module will be made to suite any type of spectrometers with multi-point detectors at the IBR-2 reactor and can be used as a «master» or «slave» module.

The «slave» modules can be connected successively through the High-Speed Fast Serial Link which provides inter-block data exchange at the speed 2.5 Gb/s.

The «master» module is connected to the computer via a USB 3.0 fiber optic extender. Such extender allows operation of the USB 3.0 interface in the super speed mode with a fiber of up to 300 meters long as required for the IBR-2M spectrometers.

The data from the TOF Encoder FPGA is formed into packets containing the detector number and the module number. In the case when 12 modules are used, their number matches the number of sectors. The Encoder digitizes the pick-up data of the chopper signal and of the reactor start signals for subsequent spectra processing using the RTOF correlation method. Then the generated packets are transferred to the FIFO leveling buffer of the Communication Controller FPGA.

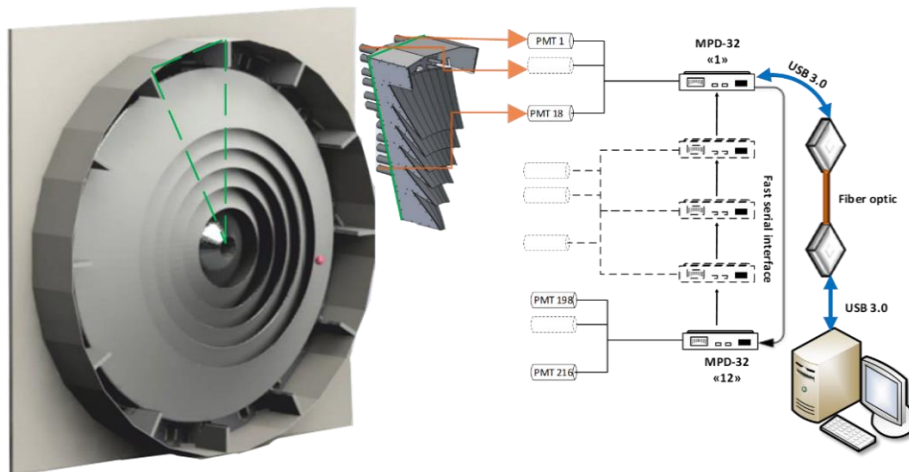


Figure 4. The variant of the architecture the DAQ system for BSD

## **4. Conclusion**

Development of MPD-32 is one of the main tasks in connection with meeting the needs of the new wide-aperture detector on the HRFD neutron spectrometer that is to be further optimized for operation on other IBR-2M reactor spectrometers. To date, five test samples have been developed for software and communication interface debugging.

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