Digital data acquisition system for spectrometry with scintillation detectors

A digital data acquisition system developed by the ENEA (Ente per le Nuove tecnologie, l'Energia e l'Ambiente, Frascati) was put into operation and tested during utilization on the neutron reference fields of PTB's accelerator. Compared to the system used so far, spectrometric measurements can now be performed practically without quality losses for signal rates which are higher by up to a factor of 10.

A digital data acquisition system developed by the ENEA (Ente per le Nuove tecnologie, l'Energia e l'Ambiente, Frascati) was put into operation and tested during utilization on the neutron reference fields of PTB's accelerator. This system, which records analogue signals with a resolution of 14 bit and a sampling rate of 200 Msamples/s, allows signal rates - with almost identical properties in the recorded pulse height distributions - to be achieved which are higher by up to a factor of 10 than in the case of the electronic system used so far for the processing of analogue pulses.

The use of conventional analogue electronic systems for the measurement of single signals of radiation detectors is limited to relatively low counting rates. The processing time of a few µs causes losses by dead time and piling-up of signals which follow in close succession (pile-up). Even in the case of signal durations of clearly below 500 ns, only counting rates of hardly more than approx. $50 \cdot 10^3\ s^{-1}$ can be processed. The new digital data acquisition overcomes this limitation by continuous sampling of the detector signal. To reduce the resulting amount of data, periods without signal are directly separated from the actual signals by a fast, programmable integrated logic circuit (FPGA, Field Programmable Gate Array). Up to a maximum counting rate which depends on the data transfer rate of the PCI bus system used for transfer of approx. 80 Mbyte/s, this allows data acquisition practically without dead time. Subsequently, such a measurement is evaluated "offline" on a PC. The signals occurring in the case of organic scintillators with their different decay times, with the aid of which a distinction can be made between the results of neutrons and the results of photons, can afterwards be optimally separated and evaluated. Likewise, pile-up signals are recognized and analysed separately by the software.

The high temporal resolution and the bit depth are of fundamental importance for the intended applications in the range of spectrometry with organic scintillation detectors. The different decay times of the signals generated by neutrons and photons cause different signal patterns with characteristic differences in the range of approx. 15 ns to 90 ns after the signal maximum. The simultaneous measurement of events in the neutron energy range of approx. 1.5 MeV to approx. 20 MeV implies a dynamics of more than a factor of 50 in the resulting pulse integrals. Thus, only a system with high temporal resolution and bit depth with appropriate zero data reduction is suited to record pulse height spectra consisting of up to $5 \cdot 10^6$ single pulses. During the measurements at the PTB accelerator, the system was tested with counting rates up to $420 \cdot 10^3\ s^{-1}$. Up to approx. $150 \cdot 10^3\ s^{-1}$, the recorded pulse height spectra show no changes in the spectral signatures. With the counting rate maximally achieved so far, which has previously not been accessible with analogue systems, small changes result from non-linearities of the photomultiplier used. This is shown in the figure, in which the pulse height spectra of a scintillation detector are plotted for the measurement of 14 MeV neutrons which had been recorded with the digital data acquisition at variously high counting rates. The exact cause of these effects is at present being investigated.

Compared to the analogue electronics used so far, a slight broadening of the structures of the pulse height spectrum can generally be seen, which can be taken into account within the scope of a detailed characterization of the detector and which, thus, does not represent any limitation.

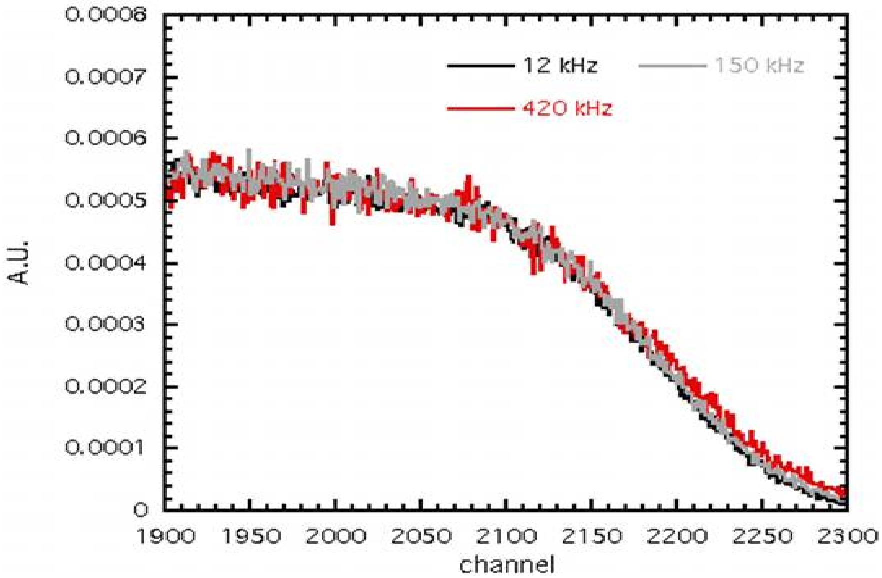

Figure: Pulse height spectra of a scintillation detector, recorded with the digital data acquisition at counting rates of $12 \cdot 10^3\ s^{-1}$, $150 \cdot 10^3\ s^{-1}$ and $420 \cdot 10^3\ s^{-1}$.

Contact person

A. Zimbal, Department 6.5, Working Group 6.54, e-mail: andreas.zimbal@ptb.de