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Digital data acquisition for fast neutron metrology: defining the digital light output parameter

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Abstract. The application of a CAEN DT5730 digitizer unit for fast neutron metrology and applications has been explored. The standard methods implemented to obtain a calibrated light output parameter from the integrated anode output has a high sensitivity to the selection of pulse integration time. We report on measurements made at the n-lab within the Department of Physics at the University of Cape Town which explored alternative approaches to determining the light output parameter with the digital acquisition system, aiming for a high degree of consistency.

1. Introduction

Fast neutron fields are found in a wide variety of contexts, for example at accelerator and medical radiation facilities, around nuclear power plants, in aviation and space flight. The essence of neutron metrology is to quantify both the fluence and energy distribution of these fields, which is complicated by the large range of energies, intensities, and directional characteristics in each unique scenario [1]. Neutron metrology and spectrometry communities are beginning to adopt modern digital pulse processing systems to complement, and eventually replace, the existing analogue data acquisition systems. A new digital data acquisition system for fast neutron metrology has been benchmarked against the standard NIM-based acquisition system [2] over a range of neutron energies and field intensities at the Accelerator for Metrology and Neutron Applications in External Dosimetry (AMANDE) facility [3], IRSN Cadarache, France. The measurements of neutron fields made at AMANDE highlighted that the method implemented to obtain a calibrated light output parameter from the integrated anode output has a high sensitivity to the selection of pulse integration time [4]. We report on further measurements made at the n-lab within the Department of Physics at the University of Cape Town which explored alternative approaches to determining the light output pulse parameter with the digital acquisition system.

2. Methodology

The n-lab features a Thermo MP-320 sealed tube neutron generator (STNG), which produces neutrons of approximately 14 MeV via the deuterium-tritium fusion reaction, and a 220 GBq ²⁴¹Am-⁹Be (AmBe) radioisotopic source producing a broad energy spectrum of neutrons from thermal energies up to around 11 MeV. For the work reported here, the reference detector used is a cylindrical EJ-301 liquid scintillator (50 mm diameter × 50 mm) optically coupled to an ETL 9214 12-stage photomultiplier tube (PMT) and base, supplied by Scionix, and operated at a negative bias of 1100 V. Measurements were made using a tightly collimated beam of neutrons with a circular profile and diameter of 0.8 cm. The reference EJ-301 detector was placed at 0° relative to the beam axis at a distance of 1.6 m from the centre of the



neutron source. The anode and dynode output signals from the detector were patched to the control area for acquisition and processing.

The digital system used in this study was a CAEN DT5730 desktop digitiser [5] coupled with the open-source acquisition software QtDAQ [6] developed at the University of Cape Town. The DT5730 is an eight-channel, 14-bit, 500-MS/s digitiser capable of full waveform acquisition in list mode. The PMT anode output was directly connected to the input of DT5730, operated with a trigger threshold of 30 mV. When used, the dynode output was connected to an Ortec 113 pre-amplifier with a capacitance of 100 pF and an Ortec 574 amplifier with variable gain and shaping times. Event waveforms were digitised and acquired in list mode for 1024 samples (2 μ s).

For each recorded event, a parameter Q_L was determined by integrating the digitised signal over a time approaching the full length of the pulse, typically around 500 ns. Measurements of the Compton edges of gamma rays from ^{137}Cs , ^{22}Na and AmBe radio-isotopic sources were used for scaling Q_L to a calibrated light output parameter L , according to the standard approach [2]. The relationship between Q_L and L is typically found to be linear over the energy range of the calibration sources. The light output L for electrons may thus be expressed in MeV, and by convention the scale for the light output spectra measured for neutron events is expressed on the same scale but here denoted as MeV electron equivalent (MeV_{ee}), and which may also be regarded as linear above the lower L threshold of 0.30 MeV_{ee} .

Each pulse was also integrated over a shorter time integral Q_S of 30 ns, and a pulse shape parameter S is then derived from the ratio of the long and short integrals [6] using $S = k(Q_S/Q_L) + c$ (with $k = 100$ and $c = 0$ for these data), which is the basis of the widely used charge comparison method of pulse shape discrimination. Signals arising from gamma ray interactions in the detector have a reduced slow decay component in comparison to those arising from neutron interactions. Therefore, a larger proportion of light output occurs within the shorter time interval for events induced by gamma rays (recoiling electrons), leading to higher S values of when compared to neutron-induced events (recoiling protons, deuterons, and alpha particles) of a similar light output. Figure 1 shows an example of a standard L - S plot produced from the measurement made with the EJ-301 detector for neutrons and gamma rays produced by the (a) AmBe source and (b) 14 MeV STNG. Loci corresponding to the different recoiling charged particles are clearly distinguishable.

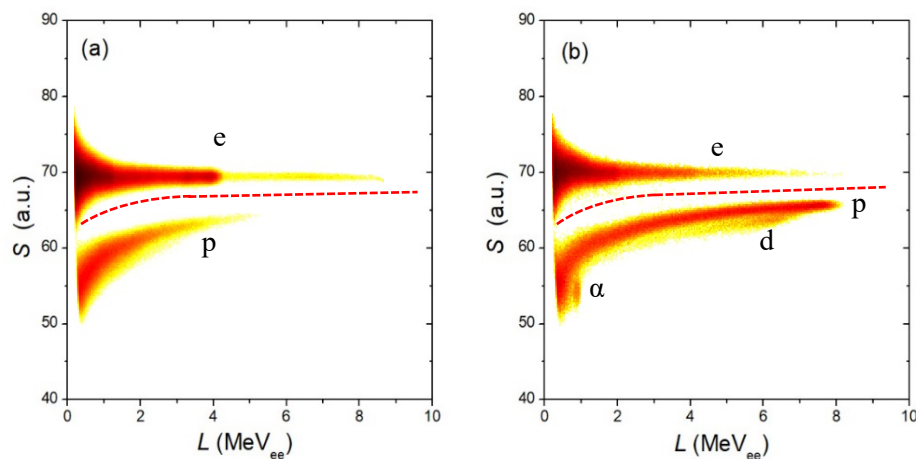


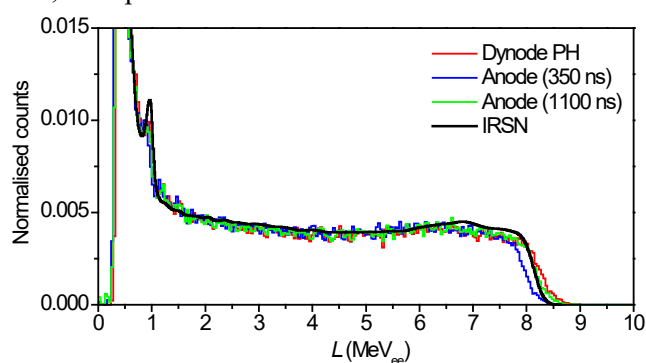
Figure 1. Event density as a function of light output L and pulse shape S parameters for events induced by neutrons and gamma rays in the EJ-301 scintillator from (a) an AmBe source; and (b) the 14 MeV STNG. Loci associated with recoiling electrons (e), protons (p), deuterons (d) and alpha particles (α) are identified. The dotted lines indicate the cuts used to separate events induced by neutrons and gamma rays.

Three different scenarios were considered to determine the light output parameter L : the voltage “height” of the dynode pulse after shaping and amplification through a pre-amplifier and amplifier; the time integral of the “raw” anode pulse with both an arbitrary integration time t_L of 350 ns and an optimised longer integration time. The optimised integration time was chosen by varying t_L until the measured edge of a monoenergetic neutron light output spectrum agreed, within one standard uncertainty, with the equivalent dynode pulse height spectrum.

3. Analyses and results

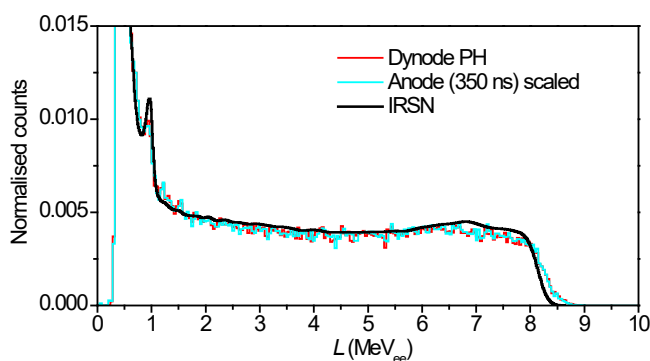
When acquiring both the fast anode output and the slow pulses from the dynode chain in list mode the size of the data file may become inconveniently large. A practical solution is presented here where both anode and dynode signals are only recorded for the purpose of calibrating the integrated anode pulse, with subsequent measurements only requiring the acquisition of the anode pulse. For the AMANDE analyses [2], the integration time t_L was chosen to ensure agreement between the integral of the anode and the dynode pulse height by comparing the location of the gamma-calibrated edge associated with monoenergetic neutrons. For the present n-lab measurements, this process was replicated, resulting in an optimised integration time of 1100 ns. Figure 2 shows the scaled and calibrated light output spectra measured with the EJ-301 for 14 MeV neutrons produced by the STNG for the three scenarios. The expected lineshape for 14 MeV neutrons is taken from the IRSN response matrix used for unfolding analyses [2]. It is interesting to note that the edge of the 14 MeV lineshape matches the edge of the dynode and anode (1100 ns) light output spectra, which are observed to have slightly inferior edge resolution to the lineshape. The light output spectrum produced using the anode output with an integration time of 350 ns underpredicts the light output parameter L relative to the dynode pulse height spectrum and response function for 14 MeV neutrons, as expected.

Figure 2. Light output spectra measured with the n-lab EJ-301 liquid scintillator detector and DT5730/QtDAQ system for neutrons produced by the 14 MeV STNG at the n-lab using the dynode pulse height, and anode integral with integration times of 1100 ns and 350 ns. The 14 MeV lineshape from the IRSN response matrix is shown for comparison.



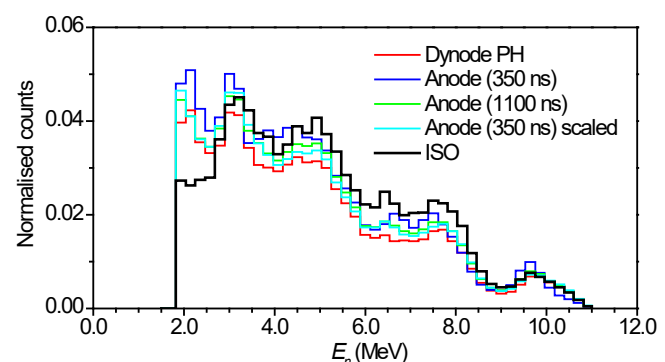
Alternatively, it is possible to scale the anode integral to the dynode pulse height for any sensible integration time provided both values are known for each triggered event. The uncalibrated light output spectrum measured for neutrons produced by the STNG for the anode integral with an integration time of 350 ns was matched to the dynode pulse height spectrum by minimising the sum of the square of the residuals over the full range. Re-binning and scaling the resultant data to preserve the uniformity and structure of the spectrum results in the calibrated light output spectrum is shown in Fig. 3, together with the dynode pulse height spectrum.

Figure 3. Light output spectra measured with the EJ-301 liquid scintillator detector and DT5730/QtDAQ system for neutrons produced by the 14 MeV STNG at the n-lab using the dynode pulse height, and anode integral with integration times of 350 ns, scaled to the edge of the dynode spectrum. The 14 MeV lineshape from the IRSN response matrix is shown for comparison.



To demonstrate the validity of the two approaches over a broad range of neutron energies, measurements were also made using the neutrons produced from the AmBe radioisotopic source. Figure 4 presents the neutron energy spectra measured for the AmBe neutron source using an unfolding analysis, for the different scenarios. The MAXED package [7] was used for the unfolding and the ISO-recommended neutron energy distribution for AmBe [8] was used as the default spectrum and is included in Fig. 4. The deviations of the measurements from the ISO-recommended spectrum are a result of the geometry of the source and detector used in the measurements. All four measurements are within reasonable agreement with each other, although the neutron energy spectrum using an arbitrary integration time of 350 ns shows a general shift towards lower neutron energies, which is most noticeable in the 9.0 - 11.0 MeV, and 3.0 - 5.0 MeV regions. The measurements using the longer (1100 ns, optimised) and shorter (350 ns) anode integration times are virtually indistinguishable from each other after the scaling is applied.

Figure 4. Unfolded neutron energy spectra from measurements of neutrons produced by an AmBe source for light output spectra derived from the dynode pulse height, anode integrals with integration times of 1100 ns, and 350 ns (both unscaled and scaled). The ISO-recommended spectrum for AmBe is included.



4. Conclusion

Neutron-induced scintillator-based measurements made at the n-lab were used to investigate methods of calibrating the light output parameter determined from the integral of the anode pulse relative to the standard method of using the pulse height of the dynode signal. Selecting an optimal integration time and scaling the light output spectrum for any sensible integration time have been demonstrated to be viable options for both mono-energetic and broad energy spectrum neutron fields up to 14 MeV. The present implementation of these methods require that the anode and dynode events are acquired simultaneously for a series of reference gamma ray sources, and a source of mono-energetic neutrons, as part of the initial calibration procedure. All further measurements do not require the acquisition of the dynode pulses, thus reducing the storage requirements for list mode acquisition and removing the deadtime and pile-up complications associated with acquisition of a second channel for the dynode. It is also noted that the distinct features present in the AmBe neutron energy spectrum could be utilised as a neutron calibration source, removing the requirement for a source of mono-energetic neutrons for calibration in the future.

References

- [1] Thomas DJ, Nolte R and Gressier V 2011 *Metrologia* **48** 225–238
- [2] Sole C, Buffler A, Hutton T, Leadbeater TW, Babut R, Gressier V and Petit M 2022 *IEEE Trans. Nucl. Sci.* **69** 1780-1788
- [3] Gressier V et al. 2004 *Rad. Prot. Dos.* **110** 49–52
- [4] Sole C 2022 *A new digital data acquisition system for neutron metrology* M.Sc. thesis, Department of Physics, University of Cape Town, Cape Town, South Africa
- [5] *User Manual UM3148, DT5730/DT5730S 8 Channel 14 Bit 500/250 MS/s Digitizer* 2021 CAEN SpA, Viareggio, Italy
- [6] Comrie A, Buffler A, Smit FD and Wörtche H 2015 *Nucl Instr Meth* **A772** 43-49
- [7] Reginatto M, Goldhagen P and Neumann S 2002 *Nucl Instr Meth* **A476** 242-246
- [8] International Standards Organisation 1999 *Neutron reference radiation fields* ISO 8529-1