Application possibilities of Acqiris digital card DP240 for positron lifetime measurement

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Abstract. Based on existing knowledge, a software for the digital positron lifetime (LT) spectrometer has been designed at the Slovak University of Technology. As a digitizer, Acqiris DP240 card was used. Start and stop timing signals have been digitised separately with sampling rate 1GS/s in 8 bit resolution. This sampling rate was not sufficient; therefore a joined delayed channel mode with 2GS/s sampling rate was used. Next applications for the study of advanced materials for nuclear industry are foreseen.

1. Introduction

Digital positron lifetime measurement systems start to be a standard part of positron annihilation laboratories [1,2]. It is due to evolution in fast ADC digitizer cards and significant lowering of their prices. Using digitizer cards in positron annihilation spectroscopy (PAS) LT systems, one gets new possibilities in measured data processing, automatic measurement setup, offline data correcting depended on other measurement parameters like temperature or magnetic field influence. From analogue setups in digital systems new task in software for detector data processing development is needed. The first role of the new software is to replace the task of analogue modules like SA (single channel analyzer), CFD (constant fraction discriminator), TAC (time to amplitude converter) and MCA (multi channel analyzer). The second role is to add new possibilities like automatic measurement setup and offline data filtering. The significant advantage of digital measurement is possibility to use different approximation methods without need to repeat measurement like in analogue system. For example, a small change in the window or in constant fraction (CF) value in an analogue system requested the repetition of measurement. In a digital system it is possible by software change using the same acquired data. This approach seems to be much more efficient.

2. Digitised dynode timing signal

The shape of two dynode signals obtained by digitizing with 1GS/s is in figure 1. While this type of voltage divider was used in [1], the same signal shape is expected. For lower sampling rate provided by Acqiris DP240, the second signal minimum is not adequately visible in our case. In spite of lower
sampling rate we developed two setups, one with separated start and stop signal and second with joined delayed channel mode, with 2GS/s sampling rate.

![Figure 1. Two dynode pulses from two stop events sampled at 1GS/s with base line and pulse interval definitions.](image)

3. Hardware
Hardware is based on existing analogue Fast-Fast setup [3] (see figure 2A). It consists of BaF$_2$ scintillators, XP2020Q photomultiplier tubes, voltage dividers with dynode outputs [4]. Two Ortec 583 constant fraction discriminators and Ortec 414A fast coincidence unit were used as trigger source for the digitizer card. In this case 2 channel mode with 1GS/s sampling frequency is done. As digitizer, Acqiris DP240 card was used.

4. Software for digital system with Acqiris DP240
It was found that off-line analysis method is reasonable for ability to develop various methods for time extraction without repeating measurement every time. Therefore the developed software was divided into two parts: data acquisition part and data analysis part.

The size of measured data (400 MByte for 1 million events and 2GS/s sampling rate) with external signal triggering is acceptable.

4.1. Data acquisition part
Data acquisition program was based on Acqiris C example source GetStartedVC distributed with digitiser card. Program was developed as command line tool. Needed parameters for the card setting were obtained from graphical tool – AcqirisLive distributed with acquisition card. All input parameters were stored in configuration file.
4.2. Data analysis part

Two channel mode with separated Start and Stop pulses digitized with sampling rate 1GS/s were first preferred for measurement, but after number of experiments it was found that this mode is not suitable for the combination of BaF₂ detectors with dynode outputs with non typical dynode signal shape. From figure 1 rising edge in sampled pulse can be seen. Base line of signal was counted as average from first ten points. Timing information was extracted using digital constant fraction method [6]. Signal minimum was found after parabolic approximation in 3 points. First point of this approximation is one sample before minimum, second is minimum sample and third is one sample after minimum. Timing information was counted as constant fraction 20% in parabolic approximation from 4 points in rising edge. For higher sample rates more approximation points can be used. Resulting spectrum from separated start and stop digitised signals with 1GS/s sampling rate is shown in figure 3. This
spectrum was not usable for fitting in LT program [5]. Experiments in using different approximation methods with 1GS/s sampling rate and dynode outputs did not satisfy our requirements. Therefore the new setup with joined channel mode was used (figure 2B). Higher sampling rate was suitable to make precise approximation from more points in joined mode, but joining delayed two pulses together had disadvantages in noise increasing. Our dynode pulse has long periodic response; therefore at least 100ns delay between pulses was used. Regardless of long delay part of periodic response from start pulse was added to stop pulse and this brings the above mentioned noise to sampled stop pulse. The resulted spectrum obtained from joined channel mode can be seen in figure 4.

5. Results and discussion

Digital system with 2GS/s sampling rate in channel joined mode was tested in simultaneous measurement of two materials: Si and Ni with analogue and digital system. Results in table 1 were obtained by two components’ fitting in program LT 9 [5]. A higher noise in digital system is the reason for joining two channels together.

![Figure 4. Ni spectra obtained with digital PALS and 2GS/s joined channels mode.](image)

Table 1. Results from simultaneous measurement on analogue and digital PAS LT system.

| Setup   | Material | $\tau_1$ [ps] | $\tau_2$ [ps] | $I_1$ [%] | $I_2$ [%] | FWHM [ps] | Bckg / signal |
|---------|----------|---------------|---------------|----------|----------|-----------|---------------|
| Digital | Si       | 222.2 ± 2.0   | 1690±150      | 97.34±0.12 | 2.63±0.12 | 230.4     | 2.09%         |
|         | Ni       | **110.6 ± 0.2** | 3910±370      | 98.81±0.05 | 1.19±0.05 | 214.9     | 2.89%         |
| Analogue| Si       | **222.9 ± 1.7** | 1609±43       | 97.40±0.08 | 2.60±0.08 | 244.4     | 0.05%         |
|         | Ni       | **118.3 ± 0.5** | 3310±83       | 96.06±0.07 | 3.94±0.07 | 210.6     | 0.04%         |

6. Conclusion

The new data acquisition and analysis software was developed. It was confirmed, that the parameters of the Acqiris DP240 card and measurement detector system with BaF2 and dynode outputs were not suitable to obtain significantly better results in comparison to the previous analogue measurement system. At least 2GS/s sampling rate was needed to have enough data to make pulse shape approximation without disturbing sinusoidal addition in output spectra. Results are comparable to others digital systems like [1] and [2]. Based on our current study, only acquisition cards with higher sampling rate (at least (4GS/s)) can be considered as suitable for better values of the time resolution and decreasing the spectrum background noise.

References

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