Electronics for LaBr scintillator detectors in INGA

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Introduction

The nuclear lifetimes measurement of excited nuclear states is used for extracting nuclear structure information. This requires fast timing coincidences between detector signals for the measurement of lifetimes. Such techniques require measurement in sub-nanosecond time range. In recent times *$LaBr_3(Ce)$* scintillators coupled to fast photo-multiplier tubes have emerged as an ideal γ-*ray* detector for performing such experiments. Apart from providing sub-nanosecond (< 500 *ps*) time resolution, it also provides reasonably good energy resolution (~ 3 % @ 662 *keV*). Signal processing electronics of *$LaBr_3(Ce)$* needs to be compatible so as to extract fast timing and good energy resolutions from them. We report the development and performance of custom designed preamplifier units to process signals from *$LaBr_3(Ce)$* scintillators coupled to photo-multiplier tube (PMT). Two versions had been developed: charge sensitive preamplifier (CSPA) for energy measurements and a fast timing amplifier (FTA) for timing measurements. Fig.1 shows the signal processing scheme of the detector.

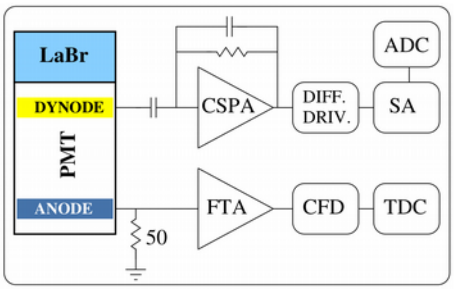

Fig.1: Signal processing layout for *LaBr*.

CSPA unit is used to process the signals from dynode and FTA is used to process the anode signal. The salient feature of the developed preamplifier units is that they have low power consumption, compact in design and assembly, and are modular in nature and thus can be easily adapted for multi-detector arrays which require multichannel readout systems.

CSPA

The CSPA has been developed as a high density hybrid using SMD components. This unit is required to make the fast signals from PMT dynode compatible with spectroscopy amplifiers. Dynode signals decay very fast (time constant ~ 15 *ns*) and cannot be directly fed to the spectroscopy amplifier. CSPA has a conventional design with a JFET at the input stage followed by a common base amplifier forming a folded cascode configuration [1]. A darlington emitter follower at the output stage drives the signals through 50 Ω loads. The net power consumption is ~ 160 *mW* at ± 12 V. The design is similar to the earlier designs developed for silicon and CsI detectors [1], except for their low gains as PMT signals are very strong. In the present case, the sensitivity was kept at 4.5 *mV/pC* (*Si equi.*). For a PMT voltage of 1000 V, a sensitivity of about 500 *mV/MeV* for γ-rays, thus giving a dynamic range of ~ 8 MeV. The decay time is 220 μs. Fig.2(a) shows an assembled unit. The energy signal of the CSPA units are fed to differential driver unit [1] which drives the signals to Mesytec MCF-16 spectroscopy amplifier followed by peak sensing ADC.

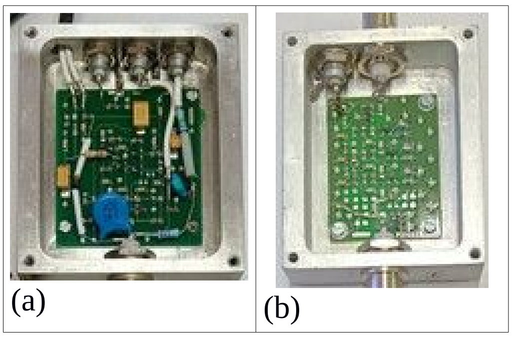

Fig.2: (a) Assembled CSPA unit.
(b) Assembled FTA unit.

FTA

As in case of CSPA, the current sensitive FTA has also been fabricated has a high density hybrid using high frequency bipolar junction transistors (BJT). The design utilizes common emitter amplifier stages in collector feedback bias mode (for high frequency operation) with an emitter follower at the output stage, and has an input impedance of 50 Ω. It is used to process signals from PMT anode. It has a voltage gain of ~ 5 and a net power consumption of ~ 350 *mW* at a voltage bias of +12 *V*. For a PMT voltage of 1000 *V*, the gains are ~ 800 *mV/MeV* thus giving a dynamic range of 6 MeV for γ-*rays*. Fig.2(b) shows an assembled FTA unit. The output is fed to high resolution CFD units. Ortec 935, Canberra 454 and Phillips 715 models of CFD were found to be most compatible for generating best possible time resolutions (< 500 *ps*).

Measurements

The preamplifier units were thoroughly tested with cylindrical $LaBr_3(Ce)$ of thickness and diameter 1.5" x 1.5" coupled to 2" Hamamatsu PMT model R2083 using radioactive sources. Energy resolutions of 2 % and 3 % respectively were observed for 1332 *keV* (^{60}Co) and 662 *keV* (^{137}Cs) γ-*rays*. Rise times of 5 *ns* were observed from the FTA output. A time resolution of ~ 300 *ps* (FWHM) was observed with ^{60}Co source. Fig.3 shows the energy spectrum with ^{152}Eu source displaying well resolved energy peaks.

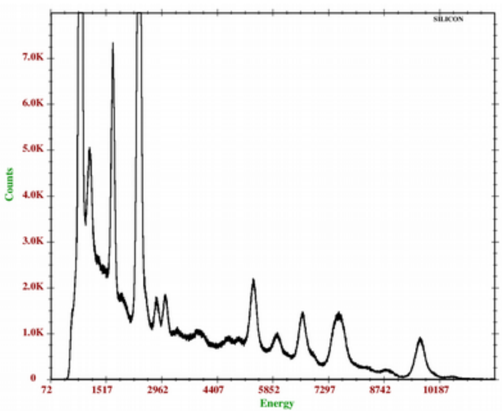

Fig.3: ^{152}Eu spectrum with *LaBr*.

The use of preamplifier units facilitates signal transmission through long cables (~ 15 *m*) from INGA beam-line to the data room. At the same time it allows operation of detectors at lower PMT bias, which otherwise can introduce non-linearities at higher bias.

It was observed that without preamplifier units, a PMT voltage of about 1500 V is required to achieve the required strengths of the signal. Use of these preamplifier units also improves the signal-to-noise ratio thus enhancing the resolution of the system. A bipolar signal is observed (with large undershoot) if the dynode signals are directly fed to spectroscopy amplifiers. This is due to small decay times (few tens of *ns*) of dynode signals, while the spectroscopy amplifiers require decay times of 25 – 50 µs to generate gaussian shaped unipolar pulse with proper pole-zero cancellation. Quality of both anode and dynode signals deteriorate significantly when driven through long cables impacting resolutions. On the other hand, preamplifier units drive the signals through long cables while preserving the fidelity of the signals. The CSPA output was also fed directly to the CAEN VME digitizer, and required results were produced, thus proving the CSPA compatibility with digital signal processors. The CSPA units has also been tested with other scintillator detectors such as *BGO*, BaF_2 and *BC501* (liquid for neutron detection) and required performances were obtained. More results will be presented.

Future perspective

For processing signals of larger number of detectors, an eight channel FTA unit has been designed in a single width NIM format for processing anode timing signals. A sixteen channel CSPA unit has been designed for processing dynode energy signals.

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References :

[1] A. Jhingan et al., Nucl. Inst. & Meth. Phys. Res. A 786 (2015) 51.