Lifetime measurement with $LaBr_3$ (Ce) Detector

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Introduction

$LaBr_3$(Ce) detector, known as BrilLanCe 380, is the best scintillator available till date for the applications related to gamma ray spectroscopy [1]. Very high light output (~ 63000 photons / MeV) and a low decay time (~ 20 ns) make it superior even compared to germanium detectors in several applications [2, 3]. The detector has been used to measure the nuclear level lifetimes from ns down to few ps [4, 5]. The measurement based on Perturbed Angular Correlation Technique has also been benefitted by the improved time and energy resolution of this detector [6]. This has been very important achievement specifically for the nuclear structure studies as the measurement of level lifetime and transition moments gives a direct insight into the structure of a particular nucleus. The selection of a photomultiplier tube with a reasonable gain and transit time is a very crucial parameter for a meaningful timing measurement with this detector. The XP2020/URQ is one such widely used photomultiplier which has been used in our measurement at an operating bias voltage of 2500 Volts [7]. The timing information is generally extracted by slope method when the lifetimes are of the order of few or tens of ns. The measurement of lifetimes of the order of few ps uses the Mirror Symmetric Centroid Difference (MSCD) technique which is only possible with a detector like $LaBr_3$ (Ce) [4]. In order to study the performance of XP2020/URQ coupled $LaBr_3$(Ce), it is important to measure several known lifetimes of different ranges. The involved γ energy gate is one of the crucial factors in the success of timing spectroscopy. The γ–γ cascades with close lying transition energies pose a difficulty in such measurements because of the moderate resolution of $LaBr_3$ (Ce) detector, thus defining a limitation. The data collection with a high statistics and the adopted analysis technique may overcome this difficulty. Specifically, in the measurement involving MSCD technique, the clean selection of energy is of utmost importance as the involved centroid shift in the timing spectra is of the order of a few channels even when the measurement is done with maximum resolution of the available Time to Amplitude Converter (TAC) modules.

In the present work, the ns order lifetime of 244 keV level of ^{152}Sm, 482 keV level of ^{181}Ta and 80 keV level of ^{134}I have been measured in which the $LaBr_3$(Ce) detector has been used for the first time. The lifetime of these levels were measured with scintillators like NaI, BaF_2, plastic etc. and the electron spectrometers, thus introducing a variation in the results. The present measurement has been able to extract the lifetime of these levels with much reduced error. The measurement technique for the lifetimes of the order of few ps has also been explored for some known levels as well as emphasizing the cascades with two close lying energy transitions. Lifetimes of 344 keV level of ^{152}Gd, 512 keV level of ^{106}Pd, 114.1 keV level of ^{146}Eu have been measured using the MSCD technique. The criticality of the timing measurements with a complicated energy spectra obtained from the detectors has been explored.

Experiment

The excited energy levels of ^{152}Sm & ^{152}Gd, ^{106}Pd, ^{181}Ta have been obtained from the decay of ^{152}Eu, ^{106}Ru and ^{181}Hf sources respectively. The energy levels of ^{146}Eu has been obtained from the EC decay of ^{146}Gd, producing the source from ^{144}Sm (α, 2n) reaction. The excited state of ^{134}I has been explored from the decay of ^{134}Te which has been obtained from the ^{238}U (α, fission) reaction. Both the above reactions were performed with 40 MeV alpha beam from the K=130 cyclotron at Variable Energy Cyclotron Centre, Kolkata. Two $LaBr_3$ (Ce) crystals of size 30 mm × 30 mm, coupled to UV sensitive XP2020/URQ PMT, were arranged face to face in a close geometry. The NIM standard amplifiers and slow-fast coincidence timing electronics have been used for the processing of the dynode and anode pulses respectively from the PM tube. The negative anode pulse has been used for timing information whereas the positive dynode pulse has been used for the information in energy. Data collection has been done by using CAMAC ADCs and LAMPS data acquisition system.

Data Analysis and Results

The lifetimes of the 121 keV level of ^{152}Sm, 482 keV level of ^{181}Ta and 80 keV level of ^{134}I have been measured using the slope method analysis. The lifetime of the former two levels comes out to be 1.490±0.002 ns and 10.32±0.06 ns respectively. However the result shows a wide variation from the known lifetime of the 80 keV level of ^{134}I. The TAC spectrum and the fitted slope for the 482 keV level of ^{181}Ta have been shown in Fig. 1. The measurement of ps order lifetime has been explored for 511 keV level of ^{106}Pd, 344 keV level of ^{152}Eu and 114.06 keV level of ^{146}Eu, using the 0.7 ps lifetime of the 1173 keV level of ^{60}Ni as the prompt reference. The measurement was done with the 50 ns range setting of the TAC module. For the 114 keV level of ^{146}Eu the involved γ–γ cascade is 114.06-114.88 keV. The selection of gamma gates in the $LaBr_3$ energy spectrum has been crucial to measure a lifetime which is of the order of used time per channel (TPC). A Gaussian fitting technique has been used for the selection of γ rays from a data with a very high statistics. This has been shown in Fig. 3 for explaining the energy selection procedure. The selection of this order has been possible because of the energy resolution of $LaBr_3$(Ce) and the high statistics gathered in the experiment. The obtained ps order level lifetimes are given in Table 1.

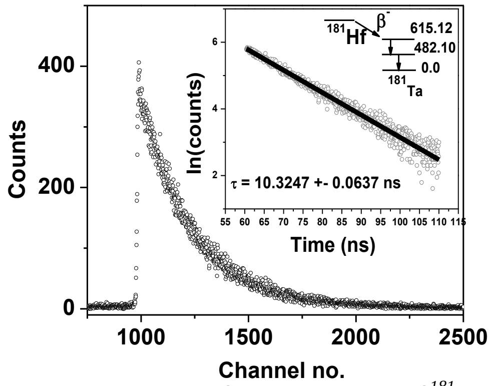

Fig. 1: The TAC for 482 keV level of ^{181}Ta

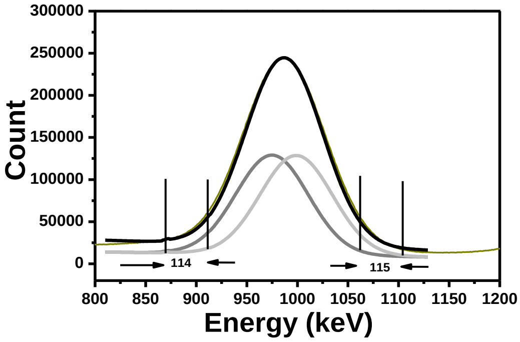

Fig. 3: The selection of 114.06 keV and 114.88 keV transitions from the obtained single peak has been demonstrated. The peak has been fitted with two Gaussians of same FWHM to reproduce the experimental data.

Table 1: The obtained picosecond lifetimes in the present work

Nucleus / Level Energy	Lifetime (present work)
^{152}Gd	
344.1 keV (2^+)	32.4 ± 1.7 ps
^{146}Eu	
114.1 keV (3^-)	5.38 ± 2.36 ps
230.0 keV (2^-)	8.38 ± 2.19 ps

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