2022 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) | 978-1-6654-8872-3/22/$31.00 ©2022 IEEE | DOI: 10.1109/NSS/MIC44845.2022.10399012

Temporal Response of Ultrafast Inorganic Scintillators for Future HEP Applications

Chen Hu, *Member, IEEE*, Liyuan Zhang, *Member, IEEE*, and Ren-Yuan Zhu, *Life Member, IEEE*

***Abstract*–Future high energy physics experiments require ultrafast inorganic scintillators. Our previous investigation measured temporal response for various inorganic scintillators to pico-second X-rays at APS of ANL. In this paper we report temporal response of ultrafast inorganic scintillators to 511 keV γ-rays and 5.49 MeV alpha-rays from a ^{22}Na source and an ^{241}Am source respectively by using an MCP-PMT based test bench. 0.5 and 1.1 ns decay time is observed from BaF_2 and Lu_2O_3:Yb respectively. The BaF_2 result is also compared to 1.2 ns decay time observed at APS. Temporal response of other ultrafast inorganic scintillators, such as ZnO:Ga, Ga_2O_3, YAP:Yb, YAG:Yb and Cs_2ZnCl_4 etc., are also reported.**

I. Introduction

Ultrafast scintillators are required for future high energy physics (HEP) experiments at the energy and intensity frontiers to mitigate high rate, pile-up and radiation-induced noise. Our previous investigation measured temporal response of various inorganic scintillators to 27 pico-second X-rays at the advanced photon source (APS) of Argon National Laboratory (ANL). [1, 2]. BaF_2:Y crystals, featured with an ultrafast decay time, the highest light yield in the 1st ns and a suppressed slow light, are promising to break the *ps* timing barrier for a time of fight (TOF) system and for ultrafast calorimetry. In this investigation, we report temporal response of various ultrafast inorganic scintillators to 511 keV γ-rays and 5.49 MeV alpha-rays from a ^{22}Na source and an ^{241}Am source respectively by using an MCP-PMT base test bench. Ultrafast inorganic scintillators of BaF_2, BaF_2:Y, Lu_2O_3:Yb, ZnO:Ga, Ga_2O_3, YAP:Yb, YAG:Yb and Cs_2ZnCl_4 etc. are measured at the Caltech HEP crystal laboratory. Their rise time, decay time, and full width at half maximum (FWHM) were measured. The BaF_2 data was also compared with that obtained at the APS of ANL.

II. Experimental Setup

Fig. 1 shows a schematic of the test-bench used to measure temporal response to 511 keV γ-rays from a ^{22}Na source with a coincidence trigger. A Hamamatsu MCP-PMT R3809U and a Photek MCP-PMT240 were used for trigger and signal respectively. A 2.5 GHz Agilent MSO 9254A was used to collect and process the signal with a sampling rate of 20 GS/s.

Manuscript received December 5, 2022. This work was supported by the U.S. Department of Energy, Office of Science, Office of High Energy Physics, under Award Number DE-SC0011925.

C. Hu, L. Zhang, R.-Y. Zhu are with the HEP, California Institute of Technology, Pasadena, CA 91125, USA (e-mail: zhu@caltech.edu).

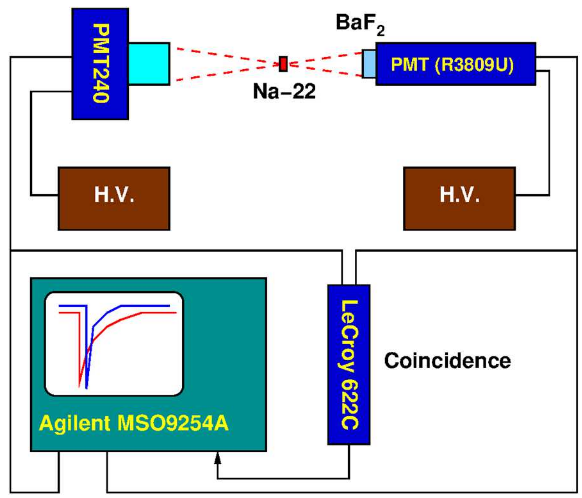

Fig. 1. A schematic showing the setup for temporal response of samples to 511 keV γ-rays from a ^{22}Na source with a coincidence trigger.

III. Results and Discussion

Fig. 2 shows temporal response measured by a Photek MCP-PMT110 for a BaF_2:Y (top) and a BaF_2 (bottom) crystal responding to 27 ps X-ray pulses of septuplet X-ray bunches with 2.83 ns spacing at APS [3]. The observed long decay time of 1.2 ns was puzzling, and was attributed to the 15 m long cable used between the MCP-PMT and the Tektronix 7154C oscilloscope [3].

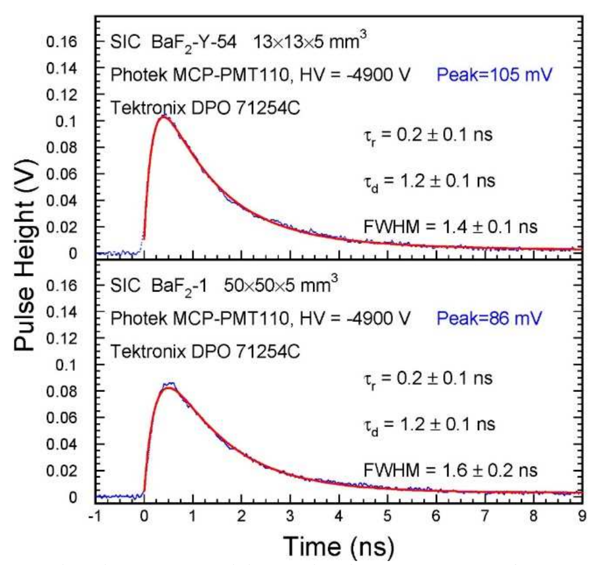

Fig. 2. Pulse shape measured by a Photek MCP-PMT210 for a BaF_2 of 50×50×5 mm^3 responding to *ps* X-ray pulse at APS.

Fig. 3 shows the temporal response of a BaF_2:Y (top) and a BaF_2 (bottom) crystal samples measured with the test bench, showing rise, decay and FWHM of 0.2, 0.5 and 0.9 ns. They are limited by the instrument response function (IRF), which was measured by fitting Cerenkov light pulse from a PbF_2 sample and agrees well with the Photek 240 specification.

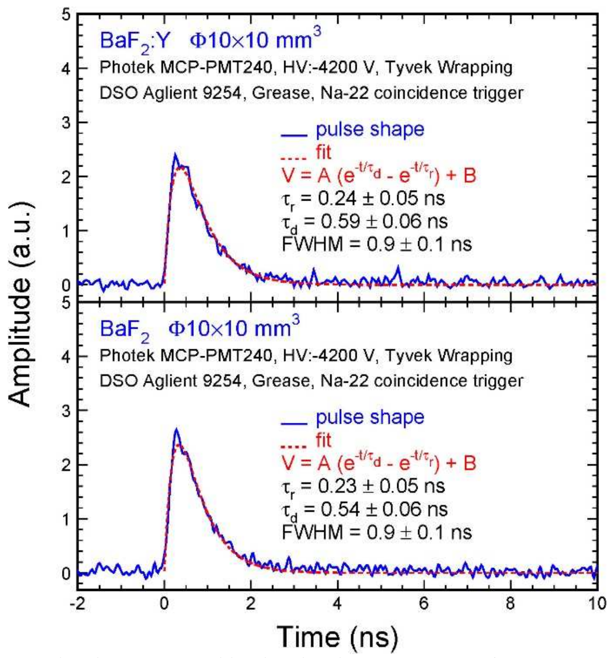

Fig. 3. Pulse shape measured by the Photek MCP-PMT240 for a BaF_2 sample of 30×30×30 mm^3.

Fig. 4 shows temporal response of a Lu_2O_3:Yb ceramic sample of Φ9×1 mm^3 responding to alpha-rays. The measured rise, decay and FWHM are 0.3, 1.1 and 1.5 ns respectively.

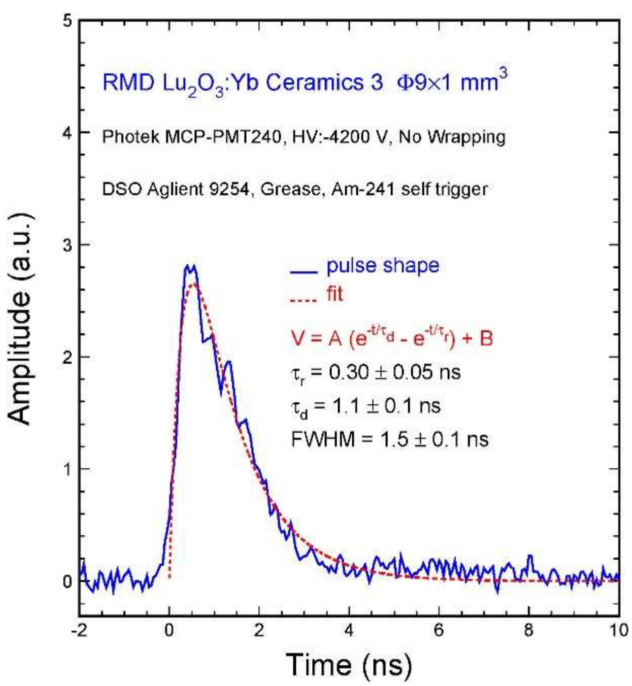

Fig. 4. Pulse shape measured by the Photek MCP-PMT240 for a Lu_2O_3:Yb ceramic sample of Φ9×1 mm^3 responding to alpha particles.

Fig. 5 shows a convolution fit for the temporal response. By taking out the IRF the intrinsic rise, decay and FWHM are 0.04, 0.63 and 1.6 ns respectively for the Lu_2O_3:Yb ceramic sample.

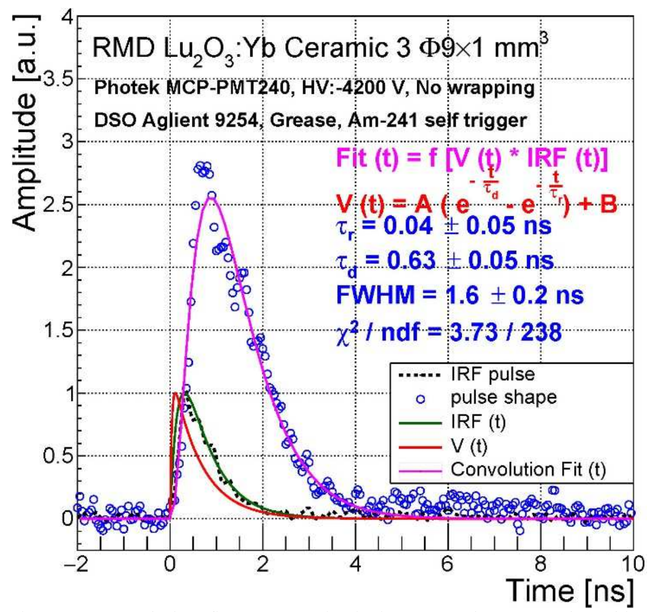

Fig. 5. A convolution fit to extract intrinsic temporal response by taking out the IRF for the Lu_2O_3:Yb ceramic sample.

IV. Summary

Ultrafast scintillators are required for future HEP experiments at the energy and intensity frontiers. An MCP-PMT and DSO based test bench was built to measured temporal response for various ultrafast inorganic scintillators at Caltech Crystal Lab. While BaF_2 and BaF_2:Y crystals show sub-ns decay time of 0.5 ns, Lu_2O_3:Yb ceramic shows a decay time of 1.1 ns. The 0.5 decay time of BaF_2 crystals can be compared to 1.2 ns measured at APS, where 15 m long cable was used. Result of temporary response of other ultrafast inorganic scintillators, such as ZnO:Ga, Ga_2O_3, YAP:Yb, YAG:Yb and Cs_2ZnCl_4 etc. are also be reported in TNS paper. With high density (9.4 g/cm^3) and ultrafast decay time Lu_2O_3:Yb ceramics are promising for future HEP TOF system.

Acknowledgements

Samples used in this investigation are provided by BGRI, Dungjun, RMD, SIC, SYSU and Tongji university.

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