Development of CsLiI:Tl single crystal scintillators for thermal neutron detection

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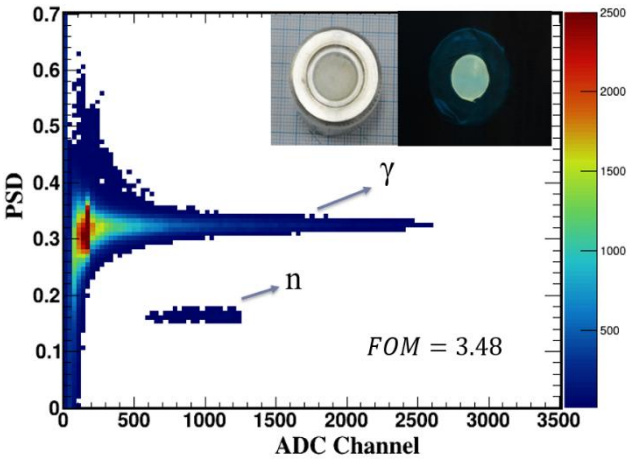
Neutron detection is essential to various applications such as radiation monitoring, homeland security and environmental safety. The worldwide shortage of ^{3}He gas has made ^{3}He proportional counter very expensive, leading to the development of alternate neutron detectors. The ^{6}LiI:Eu is sensitive to thermal neutrons but is limited by high hygroscopicity and lack of n/γ pulse shape discrimination (PSD) [1]. The low cost and scalability of alkali haldie scintillators make them attractive candidates for neutron detection through ^{6}Li incorporation. NaI:Tl, Li has recently shown good n/γ PSD with Figure of Merit (FOM) as high as 4 [2]. For compact neutron detection system, CsI:Tl is a promising scintillator because of its compatibility with photodiodes and SiPM. In this work, we present the crystal growth and scintillation characteristics of CsI:Tl scintillator engineered for neutron detection through co-doping with ^{6}Li and Sr.



PSD performance of CsI:Tl, 2% ^{6}Li, 2%Sr irradiated at thermal neutron beamline of Dhruva Reactor, BARC, INDIA. Insert is the hermetically sealed crystal under daylight and UV light

Four CsI:Tl single crystals doped with 2% ^{6}Li, without and with Sr co-doping (1%, 2% and 5%), and three CsI:Tl single crystals doped with 5% ^{6}Li, without and with Sr co-doping (2% and 5%), were grown using a vertical Bridgman furnace at a growth rate of 0.5mm/h. The $10\ mm \times 10\ mm$ crystals were cut, polished and hermetically sealed for scintillation measurements. The Radioluminescence (RL) spectra of the grown crystals exhibits a broad peak at 540 nm due to Tl^{+} luminescence, along with a weak peak at 410 nm attributed to CsI host lattice, whose intensity increase with Sr concentration in 2% ^{6}Li doped crystals. The ^{137}Cs gamma ray response of the grown crystals was measured using a 5-inch Hamamatsu PMT, with a hemispherical spectralon dome used to direct the scintillation photons toward PMT. The light output of the grown crystals is observed to decrease with increasing Sr concentration. The α/γ ratio of CsI:Tl with 2% ^{6}Li, without and with Sr co-doping (2% and 5%), as well as CsI:Tl with 5% ^{6}Li, was found to be approximately 0.5, as measured using ^{241}Am alpha and ^{137}Cs gamma sources. The PSD performance of the crystals was evaluated by irradiating them at the thermal neutron beamline of Dhruva Reactor, BARC. The n/γ PSD figure of merit (FOM) for CsI:Tl co-doped with 2% ^{6}Li and 2% Sr was found to be 3.48. A reduction in the afterglow was also observed in CsI:Tl co-doped with 2% ^{6}Li and Sr (2% and 5%). Detailed thermoluminescence (TL) and ICP-MS studies, along with the afterglow and n/γ PSD measurements will be presented.

1. Pietropaolo et al., "Neutron detection techniques from μeV to GeV," *Physics reports*, **1**, 875 (2020).
2. Yang et al., "Li co-doped NaI:Tl (NaIL) – A large volume neutron-gamma scintillator with exceptional pulse shape discrimination," *IEEE Transactions on Nuclear Science*, **8**, 64 (2017).