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A Neutron Sensitive Detector using 3D-Printed Materials

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In this presentation, we will outline the development of a neutron-sensitive scintillator produced through 3D printing and its integration into a detector using a high-speed optical camera. The scintillator was produced using the Fused-Deposition Modelling (FDM) method of 3D-printing, whereby a thin plastic filament is heated and extruded to create layers of an object. Two methods for creating scintillating filaments are explored. The first used an organic scintillator based on polystyrene. The polystyrene was doped with PTP and POPOP to give visible scintillation, biphenyl to give appropriate mechanical properties for FDM printing and 6LiF for neutron sensitivity. The quantities of these additives were tested, with the greatest light emission found at 2% PTP, 0.05% POPOP and 0.1% 6Li by weight. The second method to be explored will use perovskite crystals in an inert plastic binder, either Polylactic Acid (PLA) or Polyethylene Terephthalate (PETG), both polymers commonly used for 3D-printing. Crystals of (PEA)2PbBr4:Li and CsPbBr3 are to be synthesised and combined with the PLA to produce a filament, along with 6Li to enhance neutron sensitivity. Each of these filament types was used to 3-D print scintillators, the design of which was optimised using MCMC simulations with Geant4. These were used to test the response of the material to neutron emission in a variety of configurations, allowing for the selection of designs with the highest light yield. These simulations were also used to calibrate the detector, determining the expected neutron spectrum. The final 3D-printed scintillators were imaged with a TimePix3-based camera, offering high spatial (16 μm) and temporal (1.56 ns) resolution. This was combined with an image intensifier, offering single-photon capability. This setup enabled the development of a neutron-discrimination algorithm that leverages the capabilities of the TimePix3 camera's capabilities. Finally, the detector was tested by exposing the scintillators to electrons, gamma-rays and thermal neutrons, with the results being compared to Geant4 simulations, allowing for a determination of the most effective filament. The ability to distinguish neutrons from gamma rays was demonstrated. This work supports the construction of a cheap, easily customisable radiation detector that can be tailored to suit any required application, offering significant promise for flexible, cost-effective radiation sensing.

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