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Design and assembly of a fibre-type heterostructured scintillator for Time of Flight Positron Emission Tomography (in-person)

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Improving the performance of time of flight (ToF) positron emission tomography (PET) scintillators towards a coincidence time of 10 ps will enable real time imaging and a 16x increase in sensitivity [1], [2]. To achieve this both ultra-fast scintillation and short attenuation length are needed. Current monolithic inorganic scintillators are effective at capturing 511 keV gamma radiation but have decay times of 10s to 100's of nanoseconds, whilst plastic or nanoparticle loaded plastic scintillators have fast decay times but lack the attenuation length to be effective PET scintillators. To bypass these limitations a heterostructured scintillator has been proposed [3] which synergistically combines a dense single crystal matrix with a fast scintillator component. Gamma capture occurs primarily in the matrix and energy shared with the fast component through recoil electrons, leading to fast scintillation and effective gamma capture in one volume.
Here we present the fiber-based heterostructure detector: a single crystal matrix enclosing fast scintillator fibres. The scientific and engineering challenges involved are complex, ranging from the optimisation of scintillation properties to pixel manufacture. Simulations were used to map the available parameter space and thus guide pixel design and material choice. An initial layout was chosen and Bismuth germanate (BGO) selected as the matrix material. Machining this hard, brittle material is non-trivial, but could be optimised. We patterned BGO slices with channels, before assembling them into a matrix. This was then filled with a vinyltoluene based polymer scintillator to form a prototype fibre-type heterostructure. Preliminary scintillation performance of the pixel prototype will be presented.
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