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#4-153 Development of a High-Resolution Neutron Detector for the SAM Instrument at ILL Using 6Li Scintillator Glass and SiPM Technology

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Small Angle Neutron Scattering (SANS) is an essential analytical technique in material science, enabling the study of structural and dynamic properties at the nanoscale.

The SAM instrument at the Institut Laue-Langevin (ILL) in Grenoble, France, is a pinhole geometry instrument for SANS experiments, aiming at the determination of the structure of large-scale objects (1 –100 nm) in various systems of physical interest. These span the fields of biophysics, magnetism, material science, soft matter & superconductivity.

This paper presents the development of a neutron detector of 50 x 50 mm2 using a lithium-6 (6Li) scintillator glass (Epic Crystals) coupled with silicon photomultiplier (SiPM) arrays technology (ONSEMI), alongside with a high-performance readout system specifically designed for the readout of SiPM based on Weeroc's Radioroc 2 ASIC.

The detector configuration focus on the properties of the 6Li scintillator glass SG101 doped with Ce3+/Ce4+. The control of the ratio between 6Li and Ce is critical to achieving the correct light emission, optical decay, and optical transmission characteristics. The 6Li glass is chosen for its high sensitivity to thermal neutrons due to the interaction of 6Li with neutrons, producing ionization and in result, the emission of photons. The scintillation light is then collected by four silicon SiPMs ARRAYJ–30035–64P provided by ONSEMI, which are optimized for high photon detection efficiency, compactness, and fast response times.

The performance goal of the SAM's SiPM based neutron detector is achieving a spatial resolution of 1 mm and a timing resolution of 100 ns. The spatial resolution is enhanced by carefully optimizing the thickness and composition of the 6Li scintillator glass to maximize light output while minimizing light scattering, ensuring precise location tracking of neutron interactions. Each SiPM array offers reliable, high photon detection efficiency, low noise, and a pixel pitch of 3.36 mm. To achieve the targeted spatial resolution of 1 mm with the SiPM array pixel pitch, a centroid algorithm is applied to interpolate neutron event positions and improve spatial accuracy. This technique enables precise neutron localization, ensuring that SAM achieves the spatial resolution necessary for detailed structural studies.

The timing resolution is another critical requirement, with the detector design. This is facilitated by the integration of Weeroc's Radioroc 2 front–end ASIC, a dedicated application-specific integrated circuit developed for high-speed readout in photon-detection applications. Radioroc 2 is engineered for high-speed operation with low noise and a large dynamic range, supporting accurate and efficient processing of scintillation signals generated by each neutron interaction.

The detector will be placed in the direct neutron beam path after the sample, where a flux of approximately 10000 neutrons per second per cm^2 is expected. Given this exposure, radiation damage of the detector components, especially the sensitive SiPMs and ASIC, is of significant concern.

The electronics are positioned outside the direct beam path to minimize radiation damage, preserving long-term performance and reliability. In addition to the performance metrics, we discuss considerations regarding the thermal stability, radiation tolerance, and scalability of the detector components, which are essential for reliable, long-term operation of the SAM beamline.

The detector prototype has been tested under laboratory conditions to evaluate its spatial and timing resolution, efficiency, and neutron-gamma discrimination capabilities. Preliminary results demonstrate that the

6Li scintillator and SiPM-based configuration provides spatial precision down to 1 mm, achieving the critical resolution needed for detailed neutron scattering analysis on the SAM instrument. Timing resolution tests also show promising performance, approaching the 100 ns target, with further optimizations planned to reach this target under operational conditions at ILL.

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