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Initial results of a prototype brain PET system using a time-based digitizer and an FPGA-based real-time coincidence processor

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Our group is developing a brain-dedicated PET insert that will be combined with an ultra-high field (7T) MRI system. Herein, we present a prototype brain PET scanner with a diameter of 254 mm and an axial length of 26 mm consisting of two time-based digitizers and FPGA-based DAQ systems.
The scanner was based on dual-layer depth-of-interaction (DOI) detectors with a relative offset by half a crystal pitch in x- and y-directions. Each detector block consisted of a 14×14 array of 1.78×1.78×12 mm3 and 13×13 array of 1.78×1.78×8 mm3 LSO crystals coupled with a 2×2 array of 4×4 silicon photomultipliers. A time-based digitizer had 132 energy channels and 33 timing channels, which can support up to 33 detector blocks. The position-encoding signals were digitized using charge-to-time converters and binary counters and the timing information was acquired using a time-to-digital converter implemented in an FPGA. Single event data were sent to the master FPGA from which coincidence pairs were generated. A two-dimensional Hoffman brain phantom was scanned and the reconstructed image was evaluated by comparing with those acquired using a clinical whole-body PET/CT scanner.
The average energy resolutions were 10.7±0.6% and 11.1±1.5% for the upper and lower layer crystals, respectively. The reconstructed phantom image showed better spatial resolution and contrast recovery compared to that of a clinical whole-body scanner. The detailed structures can be observed with less edge artifacts from the image acquired using the developed brain PET scanner. The next milestone will be to incorporate PSF and TOF information in the reconstruction.

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