A Depth-Encoding Detector Module for an MR-compatible PET Insert

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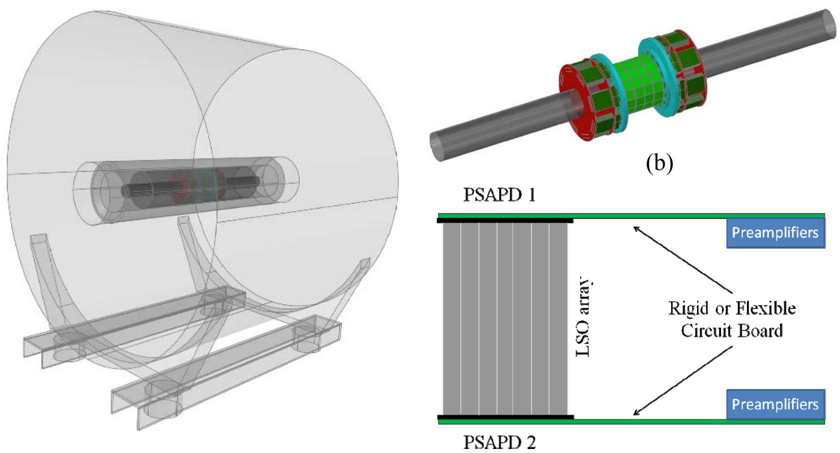
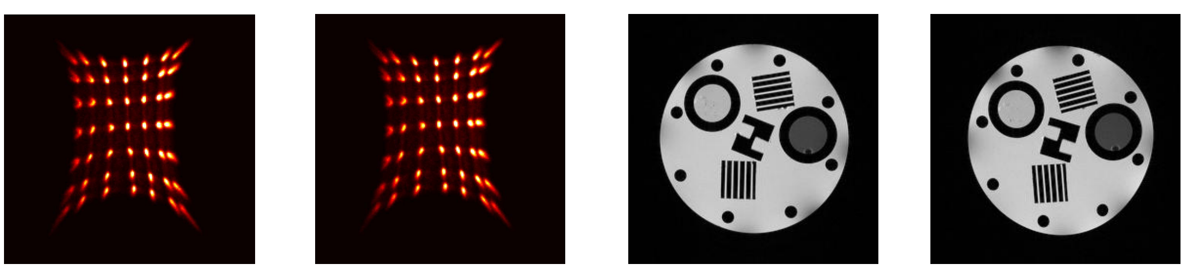
An MR-compatible PET insert has been built in our laboratory for small-animal imaging (1). We are developing the next generation PET insert with better performance, including improved spatial resolution, much higher sensitivity and a larger axial field of view. To achieve these goals, a new detector design, electronics and data acquisition system are under construction. Four rings of detector modules are used to increase the axial field of view and sensitivity (Figs. 1a and 1b) in addition much thicker (20 mm) scintillator elements are used to further improve sensitivity. However, with such thick detectors, spatial resolution degrades rapidly when moving transaxially away from the center of field of view, because of the parallax error. To overcome this effect, a detector module with that can measure the depth of interaction (DOI) of an event is proposed system as shown in Fig. 1c.



(a) (b) (c)

Fig 1. Proposed PET system (a) inside MRI and (b) PET insert only with outer shielding stripped off. (c) Proposed DOI detector module.

There are several approaches to design a detector module with DOI encoding. In the proposed system a dual-ended readout scheme (2) is used. Two position-sensitive avalanche photodiodes (PSAPDs) are used to read out the scintillation light from opposing ends of an array of scintillator crystals (Fig. 1c with rigid circuit board). The module was constructed using two 8x8 mm^2 PSAPDs to readout a 7x7 array of unpolished lutetium oxyorthosilicate (LSO) scintillator crystals with each element measuring 0.92x0.92x20 mm^3 on a pitch of 1 mm. The module is wrapped with 35 µm thick copper tape. The detector map measured with a ^{68}Ge source from this detector module acquired inside the magnet with the PSAPD parallel to B_0 field and no MR sequence running is shown in Fig. 2b. No obvious difference was observed when running typical RARE or FLASH sequences and no rotation was observed compared to the detector map acquired outside the magnet (Fig. 2a). A small gain reduction (<10%) was observed, possibly due to temperature changes and/or the magnetic field. The average energy resolution of a single crystal element was measured to be 14% both outside and inside the MR scanner. Images of the structured MR phantom acquired (RARE, TE = 14 ms, TR = 1000 ms) without and with PET detector present are shown in Figs. 2c and 2d respectively and no obvious artifact was observed. Due to the limited space available for the PET insert inside the MR scanner, the module needs to be redesigned as shown in Fig. 1c to fit into the MRI scanner. The PCB board needs to be redesigned to be thin enough to reduce the space in the front of and between detector modules. A long flexible circuit board is proposed to introduce high voltage (HV) to the PSAPDs and route the signals out to preamplifiers. To further improve the sensitivity, a tapered scintillator array design may be used to reduce the wedge-shaped gaps between modules. Testing on the new module will evaluate the use of larger area PSAPDs (increased capacitance), any additional noise introduced by the long flexible PCB board because of increased capacitance, and further studies will be conducted to ensure no interference between the PET and MR due to the new geometry and the use of shielding materials.



(a) (b) (c) (d)

Fig 2. DOI detector maps acquired (a) outside and (b) inside MR scanner. MR phantom images acquired (c) without and (d) with PET detector.

References

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2. Yang YF, Wu YB, Qi JY, James SS, Du HN, Dokhale PA, Shah KS, Farrell R, Cherry SR. A prototype PET scanner with DOI-encoding detectors. Journal of Nuclear Medicine 2008;49(7):1132-1140.