Combining PET and MRI - Challenges in Developing an MR Compatible PET insert

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Introduction

PET and MRI are two widely utilized imaging techniques that are largely complementary in the information they provide [1]. Integrating PET and MRI into a single system may benefit a range of existing studies where data from both modalities is required, and may also lead to new applications in molecular imaging. We are building a PET scanner insert for preclinical MRI systems by using field-insensitive position sensitive avalanche photodiode (PSAPD) detectors [2] coupled, via short lengths of optical fibers, to arrays of LSO scintillator crystals. The fibers are used to minimize radiofrequency interference between the RF and gradient coils, and the PET detector system. A drawing of the PET insert components around the RF coil is shown in Figure 1.

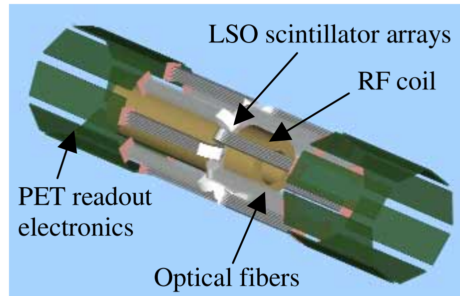

Figure 1. Drawing of the PET insert components and the 35 mm RF coil.

Methods

The prototype PET module consisted of an 8 x 8 LSO scintillator array (crystal size 1.5 x 1.5 x 10 mm^3), coupled through 10 cm long straight optical fiber bundles to a 14 x 14 mm^2 PSAPD. Charge sensitive preamplifiers (CR-110, Cremat, Inc.) were used to readout the PSAPD. Two similar modules were positioned 6 cm apart and timing and energy resolution measurements were performed using a Ge-68 point source.

To test the interference between the PET detector and the MR scanner, a 9 x 9 LSO array was directly coupled to a PSAPD. This detector and the associated electronics, enclosed in an aluminum box, were placed inside a 7 Tesla Bruker Biospec small animal MR scanner next to the 35 mm RF coil. In addition, we imaged a structured phantom with MRI to assess the effect of the PET modules on the MR data acquisition. The MRI sequences run were spin echo (TR=1000 ms, TE=11.6 ms) and gradient echo (TR=500 ms, TE=4.1 ms, flip angle=30º).

Results and Discussions

A coincidence timing resolution of 9.2 ns was determined for the prototype PET detectors. All 64 crystals were clearly identifiable in the resulting flood histograms and the average energy resolution was 25%.

The results of our studies suggest that the PSAPD-LSO detector operates with no major performance deterioration in the 7T scanner, both from the PET (Figure 2) and MRI perspective (Figure 3).

Based on the results of our experiments and the constraints imposed by the need to fit the PET detectors in the 2.9 cm space available between the RF coil and the standard gradient set of the 7 Tesla Bruker Biospec MR scanner, we built a PET module that consists of: 1) an 8 x 8 array of LSO crystals each measuring 1.43 x 1.43 x 6 mm^3, arranged with a pitch of 1.51 mm to allow space for the reflector; the crystals are polished on all faces except the entrance face which will be as cut; 2) an array of 6 x 6 double clad optical fibers each measuring 2 x 2 mm^2 (Saint Gobain Crystals); the radii of curvature for the 90º bended fibers measured to the center of the fiber range from 6-16 mm; the straight portion of the fiber bundle is 10 cm; 3) one 14 x 14 mm^2 PSAPDs (Radiation Monitoring Devices, Inc.); 4) five charge-sensitive preamplifiers (CR-110, Cremat, Inc.) mounted on printed circuit boards populated with non magnetic components (i.e. resistors, capacitors). A picture of the PET module is shown in figure 4 and the complete PET insert will consist of sixteen of these modules arranged as shown in figure 1. Nonmagnetic subminiature coaxial cables (Axon' Cable, Inc.) are used to connect the outputs of the preamplifiers to the signal processing electronics located at a safe distance.

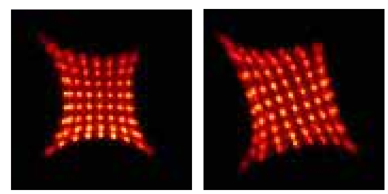

Figure 2. PET detector crystal histograms of the data acquired outside the magnet (left) and inside the magnet (right) while running a SE sequence.

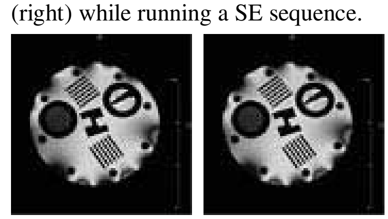

Figure 3. MR images of a structured phantom; data acquired with and without the PET detector next to the RF coil.

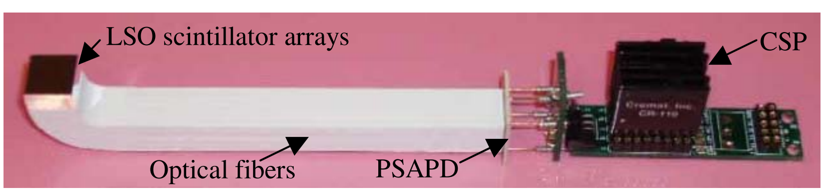

Figure 4. Picture of the PET module showing the LSO array, the optical fiber bundle, PSAPD, and charge sensitive preamplifiers (CSP) mounted on printed circuit boards populated with nonmagnetic components.

Prior to constructing a PET imaging insert using these modules we will build a shielding enclosure for a complete ring of detectors, which is necessary to avoid the potential MR image artifacts caused by the PET electronics or the generation of false PET events by the RF. This enclosure will likely consist of two copper cylinders placed outside the field of view of the magnet [3].

References

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