APD-based PET for combined MR-PET imaging

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Abstract: We propose a MR-compatible PET detector using avalanche photodiodes (APDs) in a light-sharing readout scheme. A prototype APD-based PET detector block has been designed, built and tested for PET performance inside and outside a magnetic field. The block design consists of an 8 x 8 array of 2 mm x 2 mm x 20 mm LSO crystals coupled to a lightguide and read out by a 2 x 2 array of APDs. The APDs used are manufactured by Hamamatsu Corp. (Model # S8664-55). The average pixel energy and timing resolution (measured against plastic/PMT) were 16-18% and 1.8-2.0 ns, respectively. The detector block has been tested in a 0.4 Tesla static magnetic field with no degradation of position resolution or energy resolution. These results are promising and are comparable to other APD-based PET designs. For the full paper, we will show results from a prototype detector operating in a whole body MR scanner.

Introduction: Recently, there has been exciting work in combined MR-PET imaging [1,2] though the idea has been around for quite sometime [3,4]. Historically, there has been two main ideas on how to achieve a PET image within an MR bore: 1) using optical fibers to transport the light from scintillators to magnetically-sensitive photomultiplier tubes (PMTs) and 2) using magnetically insensitive photosensors, such as APDs, coupled to scintillators inside the MR bore. We believe the latter option will be more cost-effective while still producing better results.

Preliminary Results: An APD-based block detector has been built consisting of an 8 x 8 array of 2 mm x 2 mm x 20 mm LSO crystals. This array was coupled to a lightguide and read out by a 2 x 2 array of APDs as shown in Figure 1. The APDs used in these measurements were manufactured by Hamamatsu Corp. (model # S8664-55) and have an active area of 5 mm x 5 mm with an overall package size of 9.0 mm x 10.6 mm. The average pixel energy and timing resolution (measured against a plastic scintillator on a PMT) were 16-18% and 1.8-2.0 ns, respectively. This block design was chosen for these measurements based on previous work by [5].

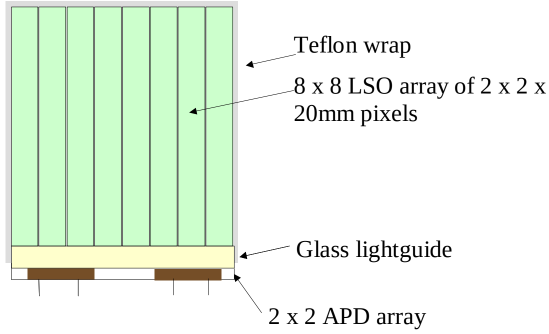

Figure 1. Drawing of an 8 x 8 LSO array coupled to a glass lightguide and read out by a 2 x 2 APD array. The entire array is wrapped with a few layers of Teflon.

This block was also tested in a magnetic field to determine the effect of a magnetic field on APD performance. The block was tested inside the bore of a permanent magnet that has a field strength of approximately 0.4 Tesla. The experimental setup is shown in Figure 2. The detector block, as described above, was placed inside the bore of the magnet with the electronics displaced far enough away so as not to be disturbed by the magnetic field. These measurements were made inside a light-tight box that is temperature controlled and set to 21° C. Measurements were made with and without the APD block inside the bore of the magnet. The position profiles, identifying the 8 x 8 array of crystals, are shown in Figure 3. The position profile is a 2D image that represents the crystals in the array that are being irradiated by a 511 keV flood source. The position profile on the left is the block outside of the magnetic field and the position profile on the right is the block inside the magnet bore. There is no qualitative difference between these two position profiles. Energy resolutions and 511 keV photopeak positions were recorded for each crystal in the array. The average energy resolution and 511 keV photopeak position for the array outside the magnetic field were 17.0% and 536 channel compared to 17.0% and 540 channel for the array inside the magnetic field. These results show there is no degradation in light collection performance of the APDs. Timing resolution measurements were not performed due to the sensitivity PMTs have within a magnetic field, but since there was no light loss we can safely assume the timing resolution of the block in the magnetic field would be identical to previous measurements.

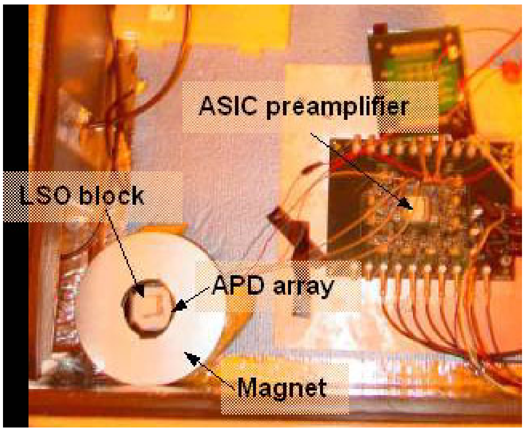

Figure 2. Photograph showing experimental setup of measurements with the APD detector in a permanent magnet.

Future Work: Detector prototypes will be built consisting of multiple blocks in one package. This module will be tested for PET performance in a benchtop setting and then tested within a whole body MR scanner. Data will be presented from measurements showing the effects the different magnetic fields (B_0, Gradients and RF) have on the PET detector, as well as, any effects the PET detector has on the magnetic fields and subsequent MR images. We will also evaluate possible RF shielding options for mutual compatibility. These results will be reported and compared to previous MR-PET prototypes.

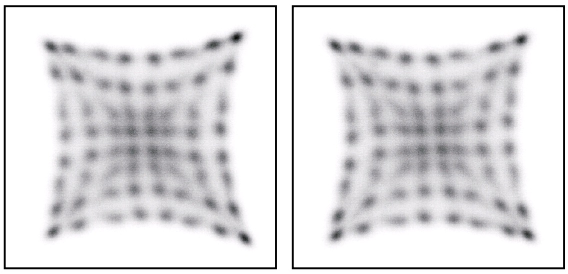

Figure 3. Position profile of an 8 x 8 LSO array outside of the magnetic field (left) along with a position profile of the same array inside the magnetic field (right).

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[3] Engineering Considerations for a MR-PET Scanner, B. E. Hammer, 1995.

[4] Development of a PET Detector System Compatible with MRI/NMR Systems, Y. Shao, et al., 1997.

[5] APD performance in light sharing PET applications, R. Grazioso, et al., 2003.