Development of MR-Compatible SPECT System: A Feasibility Study

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Introduction: MRI and single photon emission tomography (SPECT) offer complementary but distinct information. Integration of these modalities into a single device would offer unique opportunities by providing high resolution anatomic and dynamic information from MRI combined with fully co-registered both in space and time metabolic information from SPECT. However, the development of a SPECT detector that is compatible with high magnetic field and would not interfere with the image quality of MRI poses a great challenge. The current work is a feasibility study of a combined MRI-SPECT system using CdZnTe (or CZT) detectors coupled with the availability of high-density low noise ASIC electronics to read out the semiconductor detectors. The preliminary results given here indicate that CZT detectors are compatible with static magnetic fields up to 3-4T and do not interfere with the images obtained simultaneously by MRI while the detector is inside the magnet bore.

Methods: A single module of CZT, 2.54 x 2.54 cm^2 and 16x16 pixels in a square array (Fig. 1), was prepared. The module is read out by low noise, low power consumption, multi-channel integrated circuit (ASIC), which is self-triggered, data driven and sparsifying. The ASICs are produced in 0.8 micron N-well CMOS technology. Upon signal detection above the adjustable threshold, the circuit responds with sending out the energy and position information of the hit channel. Up to 65536 channels (512 chips) can be daisy chained on a common shared bus. The module was placed on detector carrier board and enclosed in Al box of size 25cm x 10 cm. The signals and HV were carried by ~3 m long cables to detector interface board (DIB) and then to the computer. Detector and DIB units were located in the magnet room while the computer and acquisition systems were placed in the control room (Fig. 2). MR system used in the experiments was a Philips 3T Achieva system. The detector array was tested in the static field alone as well as while MR images were being collected simultaneously.

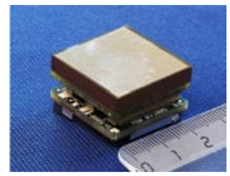

Fig. 1: CZT detector module.

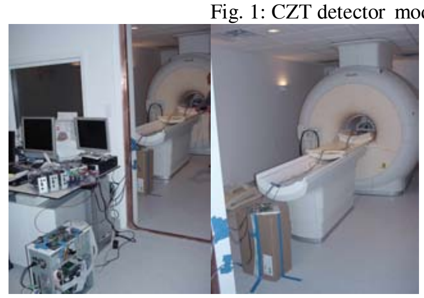

Fig. 2: Photograph of the single-module CZT setup that was used in the 3 T imaging experiments

Results: A single module of CZT, 2.54 x 2.54 cm^2 and 16x16 pixels in a square array (Fig. 1), was tested in earth's magnetic field, in an 800 G permanent magnet, and at 0.5 T, 1.0 T, 2.0 T, and 3.0 T. Measurements of spectral and imaging performance were made at two orientations: electron drift perpendicular and parallel to the magnetic field. Results showed that there was no significant change in the energy spectra of Co-57 (Fig. 3) and little change in the 15-minute flood acquisition images (Fig. 4). Furthermore, simultaneous imaging with the 3.0 T MRI of an MR quality phantom showed no changes or artifacts in the CZT images. Axial MR images of a spherical phantom using the CZT detector with and without a lead collimator are shown in Fig. 5. The images clearly show that the CZT detector using a Pb collimator on the CZT detector did not result in any artifacts in the MR images.

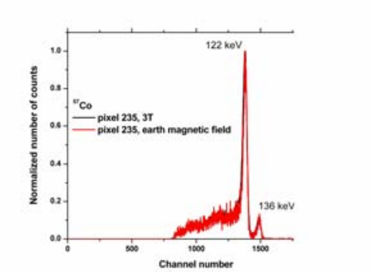

Fig. 3: Spectral response at earth field (0.5 G) and 3 T.

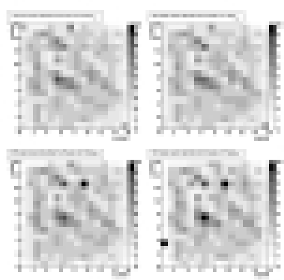

Fig. 4: Uncalibrated 16x16 images at various field strengths. The imaging module functioned at up to 3 T

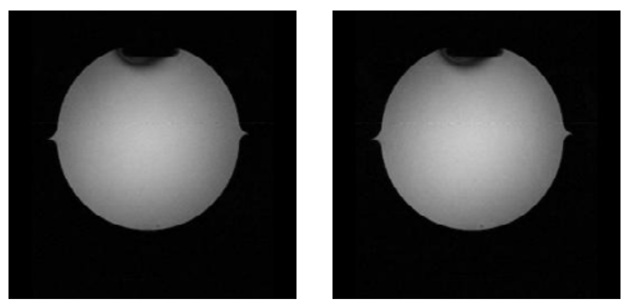

Fig. 5: Axial MRI of a phantom a) without collimator, and b) with collimator.

Our very recent results indicate that the GMI CZT module continues to operate spectroscopically at 7 T.

Discussion: The preliminary studies presented here support the feasibility of development of a SPECT system that would operate inside an MR system for simultaneous multi-modality data acquisition. Further work is in progress to extend the current studies to higher fields up to 9.4T as a basis for a small animal MR-SPECT system. Extension of the small animal system to a human system could be achieved by scaling up various system components. It is believed that such true multi-modality imaging systems will provide a new direction in molecular imaging.

Reference: "Development of MR-Compatible Nuclear Medicine Imaging Detectors" (Wagenaar DJ, Nalcioglu O, Muftuler LT, Szawlowski M, Kapusta M, Pawlov N, Maehlum G, Patt BE) Proc. IEEE NPSS Medical Imaging Conf. San Diego 2006.