Description and Preliminary Results of an MR-Compatible PET System for Molecular Imaging Studies

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Introduction and Background

We have constructed an MR compatible PET system for acquiring dynamic PET and MR images of the rat and mouse brain, and the mouse body. It has been designed for use with a range of different MR scanner configurations and can acquire truly simultaneous MR and PET data. It uses long optical fibres to transport scintillation light from LSO detector crystals located at the centre of the MR scanner to multichannel photomultiplier tubes (MC-PMTs) situated in a low field region where they function with no degradation in performance. The key components and how the PET scanner is incorporated into the MR system are outlined in fig 1.

System description

The PET system consists of a single slice of four concentric rings of 104 2×3×5mm LSO crystals each individually coupled to 15cm long optical fibres which are then coupled to eight 3.25m long optical fibre bundles. The crystal arrangement, shown in fig 2, provides comparable system sensitivity to other small animal PET systems, whilst keeping the resolution uniform throughout the field of view as the multi-ring structure provides additional positional information derived from the depth at which the gamma rays interact. The crystal dimensions have also been chosen to optimise scintillation light transfer to the optical fibres. The crystal ring housed in an MR compatible material 'Tufnol' is shown in fig 2 attached to the eight fibre bundles. These fibre bundles are read out using MC-PMTs, which can tolerate magnetic fields up to 15mT, housed in an RF shielded box shown on the MR scanner couch in fig 3.

Preliminary Results

The PET crystals demonstrate uniform response, as shown in one of the 8 2D flood position histograms (fig 2) where all 52 channels are easily identifiable. Each spot on the histogram represents the intensity of the light output from each fibre. An initial assessment of MR compatibility was performed with a Philips Achieva 1.5 T with the PET system positioned inside the foot-knee volume coil. The PET electronics were placed outside of the 0.5 mT fringe field (fig 3) but were contained within the Magnet Room and fed by a filtered electrical supply, to maintain the integrity of the faraday cage. SNR measurements (fig 4) were made from a series of Turbo Spin Echo images (TR=500ms, TE=17ms, echo train =3, FoV=100mm, matrix=256, slice thickness =5mm, 3 averages) of a 6 cm diameter bottle containing a $CuSO_4$ solution. Three conditions were assessed: (a) without the PET scanner, (b) inside the PET scanner with it's electronics switched off and (c) inside the PET scanner with it's electronics switched on. PET and MR (Turbo Spin Echo: TR=13512ms, TE=15ms, echo train=128, FoV=80mm, matrix=128, 5mm slice, 32 averages) images of two capillary tubes containing F18 in solution were acquired simultaneously and are shown in fig 5

Conclusion

The preliminary results of the MR compatible PET system are promising both in terms of PET system performance and it's overall MR compatibility. The small amount of RF interference created by the PET system can be reduced by appropriate shielding of the PET electronics. The imaging performance of the system and how it interacts with the MR scanner will be now be fully assessed. The system will then be used to investigate novel molecular imaging techniques.

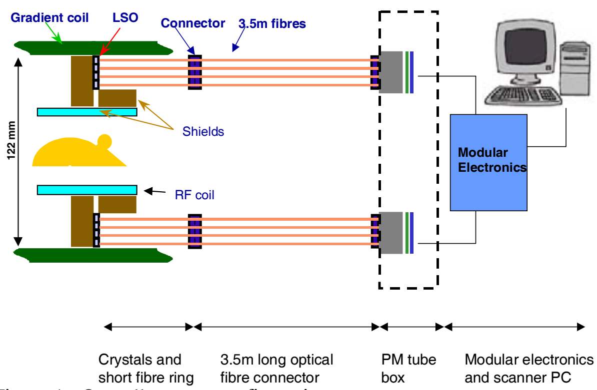

Figure 1 : Overall system configuration

Figure 3: PET scanner inside the Philips Achieva 1.5T MR scanner

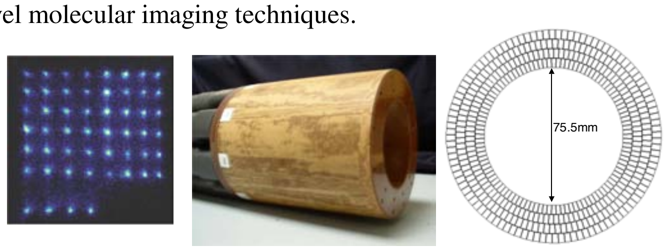

Figure 2: From left to right 2D coincidence flood position histogram, PET front end housed in Tufnol material, Crystal configuration side

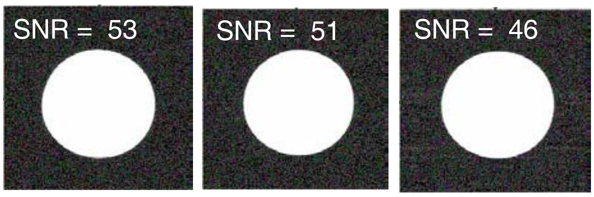

Figure 4: MR images of bottle in scanner left without PET scanner, centre with PET scanner , right with PET scanner electronics switched on

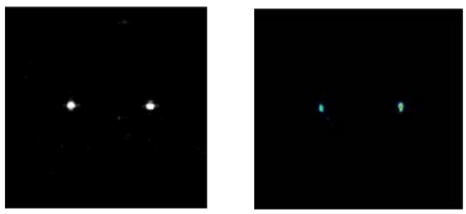

Figure 5: MR (left) and PET (right) images acquired simultaneously using F18 solution in two capillary tubes separated by 3cm