MRC-SPECT: A Sub-500 um Resolution MR-Compatible SPECT System for Simultaneous Dual-Modality Study of Small Lab Animals

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Motivations and challenges
- How to allow simultaneous SPECT and MR imaging without sacrificing the strength of both modalities?
- SPECT and MR images at matching spatial resolutions (~500/250 um)?

Development of an Energy-Resolved Photon Counting CdTe/CZT Detectors
A generic and flexible detector architecture
- Excellent energy resolution (3-4 keV @ 140 keV) and adequate sensitivity.
- Operation in strong magnetic fields (3T, 9.4T or higher).
- Adequate timing and DOI resolutions and count-rate capabilities for PET applications.
Development of ERPC Detectors

- Detector hybrids
- Wire-bonding to the readout PCBFPGA for controlling the readout sequence
- Copper substrate for supporting the hybrids

Current Detector for the SPECT-MRI System

- Current Detector for the SPECT-MRI System
- CdTe Detectors, 2.3 cm x 4.5 cm x 2 mm
- Four 2048-channel readout ASICs
- Copper Heat sink
- Rapid prototyping supporting board

- 2.3 cm x 4.5 cm x 2 mm thickness
- Relatively compact packaging
- Customer designed copper heat sink

Current Detector for the SPECT-MRI System

- Connector for receiving external trigger signal
- High spatial (350um) and energy (ER: 3~4kev at 140kev) resolution
- Good MR compatibility
- Nylon-based rapid prototyping supporting frame with air cooling channel

An MR-Compatible Emission Microscope System

- Key Features:
  - 300-500um spatial resolution.
  - Simultaneous SPECT and MRI.
  - Also work as "low-cost" desktop ultrahigh resolution SPECT system.
  - Coincidence measurements...

- Detector ring: 10 detectors (each 4.5 cm x 2.25 cm), distance between opposite detectors: 15.6 cm
- Aperture ring: 6cm diam., total of 40 pinholes, Pinhole sizes: 300-500 um diam.
An MR-Compatible Emission Microscope System

Key Features:

- Two rings can be put together
- More sufficient angular sampling
- FOV ~ 4cm x 4cm
- 80 pinholes with sensitivity up to ~ 0.15%

Collimation Aperture Design

- Lead aperture with 60mm inner diameter and 16mm thickness
- 40 platinum (90%) die-cast pinhole inserts with 300/500μm diameter
- Apertures of different inner diameter (40/60mm) are designed for different imaging applications

Collimation Aperture Design

- Maximize the use of detection area, FOV~ axial 2.5cm x transversal 2.2cm
- Specific aperture structure designed to prevent severe projections overlap, projection through each pinhole locates on two adjacent detector hybrids

Aperture Pinhole Fabrication

- Platinum (90%) die-cast pinhole inserts with 300/500μm diameter, pinholes with 50 degree open angle and 6mm height
- Novel micro-ring aperture with 50-100μm gap will be experimentally investigated
A Stationary MR-Compatible SPECT System

- Slots for heat disperse
- Rapid-prototyping housing
- Individual detector module
- A low-profile support used to mount on bench top or MR scanner

MR-Compatible SPECT Components

- Up to 12 channel LV/HV/DAQ board
- Rear cover with hollow buried in center to provide compressed air cooling
- Cable through
- HV/LV power supply
- 10 4-pin LEMO connector for communication
- Slots for heat disperse

MR-Compatible SPECT Front/Back View

- D=6cm for animal/phantom bed
- HV/LV power supply
- 10 4-pin LEMO connector for communication
- Slots for heat disperse

SPECT Phantom Images Outside the MR Scanner

- Regular-triangular shape Co-57 point source phantom generated by precise motor control, 16 angles
- Point source of 250μm diameter active area, 500μm and 350μm between neighboring point source locations (d)
- Pinhole aperture: cast platinum-iridium inserts, 300 μm diam.
- 350μm spatial resolution can be achieved, room to be improved

Φ ≈ 250μm point source
Φ ≈ 350μm point source

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MRC SPECT System Conclusion

System Highlights:
- Fully customized for operation in MR scanners
- 20 CdTe detectors in 2 rings, each detector is 2.2 cm x 4.5 cm in size.
- Detector ring diameter: 15.6 cm, and aperture diameter: 4 cm and 6 cm
- Up to a total of 80 pinholes, pinhole sizes: 300 and 500 um
- Imaging resolution: sub-500 um

MRC-SPECT inside 3T Siemens MR scanner

Thanks and any questions?