Development of the PET breast imager optimized for close approach to the chest wall and biopsy guidance using compact SiPM-based modules

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Abstract

Objectives:
Benefiting from the recent availability of very compact PET detection modules based on SiPMs, design an improved dedicated breast PET imager that will address the limitations of the so far built systems (with different degrees of deficiency, depending on the particular system) (1) low efficiency, (2) poor approach to the chest wall and the bases of the breast (posing barriers in that region), and (3) lack of biopsy guidance. Also integrate the imager with the specially designed patient bed facilitating this improved operation.

Methods:
We used commercially available, SensL, and Hamamatsu SiPM arrays, and LYSO scintillation arrays from Proteus. Special compact tapered light guides from Agile Technologies were used to reduce cracks and dead edge regions between individual modules. Only minimal front-end electronics was permitted to be on board the modules to minimize their size. 4th charge division and end-on-column readouts were favored for their spatial and energy resolution performances. Three groups of 4x4 or 5x5 LYSO blocks were used to digitize the outputs from the energy position circuitry. We have also considered novel patient bed designs incorporating and enhancing the increased functionality of the new scatter designs.

Results:
We have developed two basic types of practical solutions for the breast PET imager using: (1) the SensL ArraySL-4P9 SiPM modules and (2) Hamamatsu 25 MPPC (5x5) array modules. Hamamatsu variant permits 1° or 2° (using 2x2 array of 1° modules) basic module size, while the SensL option is ~2° in size. 1.5-2 mm spatial resolution can be attained @511 keV in both 2° variants using 4-ch readout at room temperatures. Based on the obtained module sizes we have then designed several breast PET imager modules comprised of 2-3 rings of the individual modules.

Conclusions:
Availability of the very compact and robust, and now also economical, SiPM-based high performing PET imaging technology permits construction of breast PET imagers that can deal much better with the issues of detection of b vexas at the base of the breast, and of the biopsy guidance in the whole breast.

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Results

Assembly of the PET module based on the compact SensL-Array SL-4P9 SiPMs and 4-ch current division readout. Photopeak LYSO 230,2323 keV with 20mm thick and 30mm long piece. (Top left) 1.59mm LYSO array. Center and Right: 2.0mm LYSO array. Bottom: timing curve, start – fast PMT/LYSO, stop: sum signal in Option B detector. Operation at 73 °C.

Conclusions

- The cost of the system is no more a barrier against constructing breast PET imagers. The current LYSO and SiPM modules can be considered as a low cost and compact alternative to TOF PET systems that are not MRI compatible.
- The ring-shaped breast imager based on the compact SiPM modules can closely follow the shape of the human body and therefore image the base of the breast.
- The LYSO and SiPM-based PET breast imagers are highly insensitive to temperature changes, however, their noise is much lower at lower temperatures, i.e., cooling offers advantages.

Acknowledgements

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Note: The SiPM based PET module was constructed in-house. The Hamamatsu detectors and the Hamamatsu electronics for the coincidence matrix were interfaced with the SensL electronics using a 16-channel multiplexing board with one scanner tower module of ArraySL-4P9 modules and two scanner towers to form one super module = 36 circumferential position signals – 16x12 outputs = 192 16 sums for energy and trigger signals (for coincidence matrix).

Debian version of the PET module based on the compact SensL-Array SL-4P9 SiPMs and 4-ch current division readout. Phot peak LYSO 230,2323 keV with 20mm thick and 30mm long piece. (Top left) 1.59mm LYSO array. Center and Right: 2.0mm LYSO array. Bottom: timing curve, start – fast PMT/LYSO, stop: sum signal in Option B detector. Operation at 73 °C.

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