Small Field of view HpXe hybrid detector for scintigraphy

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Abstract - **The potential of the Portuguese idea, the MicroHole and Strip Plate (MHSP) for medical imaging is discussed. Three major developments are in course: a low cost high energy and spatial resolution sensitive gamma detector based on a CsI- MHSP structure operating in high pressure xenon environment envisaging planar scintigraphy of small organs and tumours, and of small animals; an x-ray imaging detector also based on an MHSP operating in charge mode for single photon imaging; and a position sensitive visible gas photomultiplier (GPM) using the MHSP as part of the multiplication stage and also contributing for a strong reduction of the ion back flow to the photocathode, needed for GPMs. The latter can be combined with a solid scintillator, allowing several applications in nuclear medical imaging.**

I. INTRODUCTION

The increasing importance of the medical diagnostic and research using nuclear medical imaging in the last two decades triggered the development of gamma detectors for this application. The very low sensitivity of scintigraphy for organs of small animals and tumours under 1cm in diameter, with current nuclear medicine cameras, is the major limitation of this modality for such screening and studies. A detector with high energy and spatial resolution will improve nuclear medicine imaging with respect to scatter and random coincidence reduction, and reduction of cross-talk in multiple isotope imaging.

Solid state detectors have been the natural choice for nuclear medicine imaging applications due to its superior detection efficiency, although they poor energy and position resolution. At present, the need for high position and energy resolution for scintigraphy purposes pushed the development of new systems that fulfil part of the requirements. Although small areas devices present very good intrinsic position resolutions from 1 to 2 mm (deteriorating for larger areas), the energy resolution is still poor [e,g.1,2] and the photosensors used (PMTs, LAPDs, etc) are the main contributors for the system cost, namely when large areas are considered. Recent developments in high pressure xenon gas detectors based on microstructures operating in avalanche mode triggered the possibility of a fair detection of hard x-rays and gamma rays [e.g. 3,4,5,6]. Also, advances on VUV photosensors operating within the xenon medium allow the efficient detection of the VUV photons from xenon scintillation [5, 7, 8]

A low cost high energy and spatial resolution sensitive gamma detector based on the MHSP microstructure operating at high pressure xenon environment is under investigation envisaging planar and dynamic scintigraphy, SPECT of small organs and tumours, and of small animals. The goal is to “stress” the development to achieve intrinsic position resolution of about 1.5 mm and an energy resolution of about 5%, for 140 keV. Detectors with a field of view varying from 3x3 cm2 to 10x10 cm2 will be developed envisaging applications from scintigraphy of small animals (mice and rats) to scintimammography.

II. THE MICROHOLE & STRIP PLATE

The MicroHole and Strip Plate (MHSP), a microstructure developed in Portugal [9] led to applications such as soft to hard x-ray detection [6], VUV detection [7], neutron detection [10], ion suppression for TPCs and visible gas photosensor [e.g. 8,11,12,13], and x-ray imaging detection in single photon counting [14,15]. The MHSP together with other features have an intrinsic capability for position detection [15]. It is conceived as a combination of a Gas Electron Multiplier (GEM)[16] and a Micro Strip Gas Chamber [17] in a single, double sided element, with two successive independent stages of charge amplification. Like the GEM, the MHSP is manufactured with printed circuit board technology from a 50-μm Kapton film, metallised with 5-μm-thick copper-layers on both sides. The MHSP achieve gains in excess of 10^4 at 1 bar xenon atmosphere, and a ratio between top and anode signals of about 0.35, allowing measuring the charge signal produced on both sides with good efficiency. For position detection, a special MHSP was designed with independent anodes and structuring the top side with strips orthogonal to the anodes direction to measure x-ray interaction position. Resistive layers were placed, by serigraphy, connecting all the anodes and all the top strips allowing 2D detection. The signals produced by the radiation were collected from both ends of this resistance in the anodes and in the top structure. The method of resistive charge division is the most simple and inexpensive for this type of microstructures. Combining the position sensitive MHSP with a CsI photocathode deposited on the top side of the MHSP, VUV detection from xenon scintillation with good efficiency was shown [7].

III. SMALL FIELD OF VIEW GAMMA CAMERA

The proposed hybrid system combines an assisted scintillation in a high pressure xenon (HpXe) with two VUV photosensors based on microstructures operating face to face, having the xenon medium sandwiched between them. The gamma interaction produces a primary electron cloud in the HpXe medium; these electrons are accelerated with a suitable voltage applied in a multi-millimetric-size gap, producing VUV light along they path. This will allow a gain higher than 100 for scintillation production when compared to primary scintillation, increasing the statistic of the VUV photons resulting in an improvement of the energy and position resolution. This scintillation is then converted to a fast (about 100ns) electric signal by the two position sensitive photosensor devices based on a Micro-Hole and Strip Plate (MHSP) covered with a CsI reflective photocathode, operating inside the xenon medium. The gamma rays can be fairly stopped by the high pressure xenon medium and, the interaction position point resolved by reading the centroid from the VUV light burst distribution over the CsI photosensors area. The use of the face to face photosensors minimizes parallax errors due to solid angle effects when compared with the use of a single photosensor. Also, the use of the 2nd photosensor, allows determining the third coordinate and the correction of reading position and pulse amplitudes, resulting in an improvement of the overall position and energy resolution. Monte Carlo simulation study of the physical process involved in this concept (light production, spatial distribution and detection for different xenon pressures, electric fields and detector geometries; evaluation and correction methods of position and energy distribution, etc.) are being performed as guidelines for the detectors development [18]. Prototype detectors with active areas from 3x3cm^2 to 10x10cm^2 and filled with xenon at pressures up to 10 bar are being developed, build and tested. Preliminary experimental studies of light production as a function of gas pressure and the voltage applied in the electron drift gap, as well as of CsI-photosensor response as a function of gas pressure and MHSP electrodes voltages, were performed [19]. Some effort will be put in pulse processing, namely correction of the pulse amplitude and position interaction by weighting the several pulses produced by the detector collection electrodes.

IV. OTHER MEDICAL IMAGING APPLICATIONS WITH THE MHSP

An x-ray imaging detector based on a MHSP operating in charge mode for single photon imaging and using xenon as the detection medium is under investigation. A position resolution of about 300µm obtained for one dimension [15], as well as high count rate capability [20] opens good perspectives for low x-ray flux radiology.

Finally, a position sensitive visible gas photomultiplier (GPM) using the MHSP as part of the multiplication stage and also contributing for a strong reduction of the ion back flow to the photocathode, needed for GPMs, is in development[12, 13]. The use of a bialkali photocathode allows efficient detection in the visible range. This will allow the coupling to a solid scintillator for applications in nuclear medical imaging, namely for camera gammas and PET systems.

ACKNOWLEDGEMENT

This work was supported by Project POCI/FP/63903/2005 through FEDER and Fundação para a Ciência e a Tecnologia (Lisbon) programs.

REFERENCES

[1] R. Pani et al., “Recent advances and future perspectives of gamma imagers for Scintimammography”, Nuclear Instruments and Methods A569 (2006) 296,

[2] F. Scopinaro et al., “High-resolution mini gamma camera for diagnosis and radio-guided surgery in diabetic foot infection”, Nuclear Instruments and Methods A569 (2006) 269

[3] A. Buzulutskov, “Physics of multi-GEM structures”, Nuclear Instruments and Methods. A 494 (2002) 148,

[4] J.F.C.A. Veloso, F.D. Amaro, J.M.F. dos Santos, J.A. Mir, G.E. Derbyshire, R. Stephenson, N.J. Rhodes and E.M. Schooneveld, “Application of the microhole and strip plate detector for neutron detection”, IEEE Transactions on Nuclear Science 51 (2004) 2104.

[5] L.C.C. Coelho, J. F. C. A. Veloso, D.S. Covita, L.F. Requicha Ferreira and J. M. F. dos Santos, “High-pressure operation of a xenon GPSC/MSGC hybrid detector for hard x-ray spectrometry”, Nuclear Instruments and Methods 569(2007)796.

[6]- F. Amaro, J. F. C. A. Veloso, A. Breskin, R. Chechik, J. M. F. dos Santos,“Operation of MHSP multipliers in high pressure pure noble-gas” Journal of Instrumentation 1(2006)P04003

[7]- E.D.C. Freitas, J.F.C.A. Veloso, J.M. Maia, A. Breskin, R. Chechik, J.M.F. dos Santos, ”MicroHole & Strip Plate Based Photosensor” accepted for publication in Nuclear Instruments and Methods A (2006)

[8] J.F.C.A. Veloso, F.D. Amaro, J.M.F. dos Santos, A. Breskin, A. Lyashenko and R. Chechik, “The Photon-Assisted Cascaded Electron Multiplier: a Concept for Potential Avalanche-Ion Blocking”, Journal of Instrumentation 1(2006)08003

[9] J.F.C.A. Veloso, J.M.F. dos Santos and C.A.N. Conde, “A proposed new microstructure for gas radiation detectors: The microhole and strip plate”, Review of Scientific Instruments. 71 (2000) 2371.

[10] JFCA Veloso, F Amaro, JMF Dos Santos, JA Mir, G.E. Derbyshire, R. Stephenson, N.J. Rodes, E.M. Schooneveld, “Application of the Micro-hole & strip plate detector for neutron detection”, IEEE Transactions on Nuclear Science NS-51 (2004)2104-2109.

[11] S. Roth, “Charge transfer of GEM structures in high magnetic fields”, Nuclear Instruments and Methods A 535 (2004) 330.

[12] A. Breskin, D. Mörmann, A. Lyashenko, R. Chechik F.D. Amaro, J.M.Maia, J.F.C.A. Veloso and J.M.F. dos Santos, “Ion-induced effects in GEM & GEM/MHSP gaseous photomultipliers for the UV and the visible spectral range”, Nuclear Instruments and Methods A 553(2005)46-52.

[13] J.F.C.A. Veloso, F. Amaro, J.M. Maia, A.V. Lyashenko,A Breskin, R. Chechik, JMF dos Santos, O. Bouianov, M. Bouianov, “MHSP in reversed biased operation mode for ion blocking in gas-avalanche multipliers”, Nuclear Instruments and Methods A548 (2005)375-382.

[14]- H. Natal da Luz, J.F.C.A. Veloso, N.F.C. Mendes, J.M.F. dos Santos, J. A. Mir, “MHSP with position detection capability”, Nuclear Instruments and Methods A 573(2006), 191.

[15] H. Natal da Luz, J.F.C.A. Veloso, J.M.F. dos Santos, J. A. Mir, “A simple position detection system based on a MHSP”, Nuclear Instruments and Methods A (2006), in press.

[16] F. Sauli, “GEM: a new concept for electron amplification in gas detectors,” Nuclear Instruments and Methods, A 386(1997) 531–534.

[17] A. Oed, “A position sensitive detector with microstrip anode for electron multiplication with gases”, Nuclear Instruments and Methods A263(1988)351–359.

[18] CAB Oliveira, A.L. Ferreira, CDR Azevedo and JFCA Veloso, “Simulation Method for Position and Energy Corrections in Scintillation Detectors”, Proceedings of this workshop

[19] CDR Azevedo, CAB Oliveira, JMF dos Santos and JFCA Veloso, “Photoelectron collection efficiency at high pressure for a gamma detector envisaging medical imaging”, Proceedings of this workshop.

[20] J.F.C.A. Veloso, C.C. Caldas, C.D.R. Azevedo, J.M.F. dos Santos, A. Breskin and R. Chechik ,”High rate operation of the Micro-Hole and Strip Plate gas detector”, Nuclear Instruments and Methods A (2006), in press.