The Micro-Hole and Strip Plate as an imaging detector

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***Abstract* – The Micro-Hole and Strip Plate (MHSP) is a hybrid microstructure that combines within the same Kapton™ substrate the capabilities of a Gas Electron Multiplier (GEM) and a Micro-strip Gas Detector (MSGD). Due to its two multiplication stages it is able to achieve better gains than eather the GEM or the MSGD alone. In this work, the 2D imaging capabilities of such a microstructure are being studied, and some very encouraging results have already been achieved, with spatial resolutions of less than 300 µm for one of the dimensions.**

I. INTRODUCTION

The standard MHSP [1] is a double-sided microstructure, where a Kapton™ foil is covered with a copper layer on each side. On one side, the perforated pattern of a GEM [2] is produced through a photolithographic process. On the other side, the Micro-strip pattern is drawn with the same process, making the holes coincide with the cathodes of the MSGD[3]. It has been shown that this detector principle has very good characteristics in terms of gain in charge and energy resolution [4, 5].

To use the MHSP as a 2D imaging detector some small changes have to be introduced. For one of the dimensions, the anodes of the Micro-strip side are made all independent and connected through a resistive layer. Between each anode there is a resistance of about 100 Ω. The charge is then collected from both ends of this resistive layer, and from the difference of amplitude of both signals it is possible to determine the centre of mass of the electron avalanche. The following formula is applied:

$$X = k \frac{X_L}{X_L + X_R}, \qquad (1)$$

where X_L and X_R are the amplitudes of the charge signals coming from the left and right edges of the resistive line and k is a calibration constant.

For the second dimension, the GEM side is also structured in several independent strips perpendicular to the strips on the other side and the same principle of resistive charge division is applied.

II. EXPERIMENTAL SETUP

The MHSP used in this work has an active area of 28*28 mm^2, with 100 µm wide cathodes and 30 µm anodes, with a pitch of 200 µm. The holes have an outer diameter of 60 µm, and have a distance of 140 µm between their centres in the direction of the cathodes.

The X-ray detector consists of a stainless steel vessel filled with xenon at 1 bar with a 25 µm thick aluminized Mylar™ window, and the MHSP placed 5 mm away. The induction gap has 3 mm.

The window was equipped with a 3 mm thick aluminium stainless steel collimator matrix of 5*5-2 mm diameter holes, separated by 6 mm between their centres. The gas was purified using SAES getters.

For the readout electronics Canberra 2006 charge pre-amplifiers were used to integrate the charge signals, and the shaping was made by Tenelec TC243 amplifiers, with 0.5 µs shaping time. After this stage, both signals were processed by an electronic circuit which included the analog divider AD754 to execute equation (1), returning a signal amplitude directly related to the 1D position of the X-ray interaction over the MHSP.

The X-ray energy used for this study was the Mn K_α line (5.89 keV) from a ^{55}Fe X-ray source. It was placed about 30 cm away from the detector window, in order to have a well collimated X-ray beam. It has been noticed that the position resolution is strongly dependent on the signal-to-noise ratio, which means that, the higher the detector gain, the better the position resolution. This implies that the polarization voltages have to be the highest possible that allow a stable operation of the detector.

The imaging capabilities of this system were studied independently for each dimension, therefore, it was only possible to have 1D projections of the imaged objects due to electronic readout limitations.

III. RESULTS

Figure 1 (a and b) show two of the most impressive results obtained with the present system. Figure 1a is the 1D projection of the collimator shown. Each circular hole

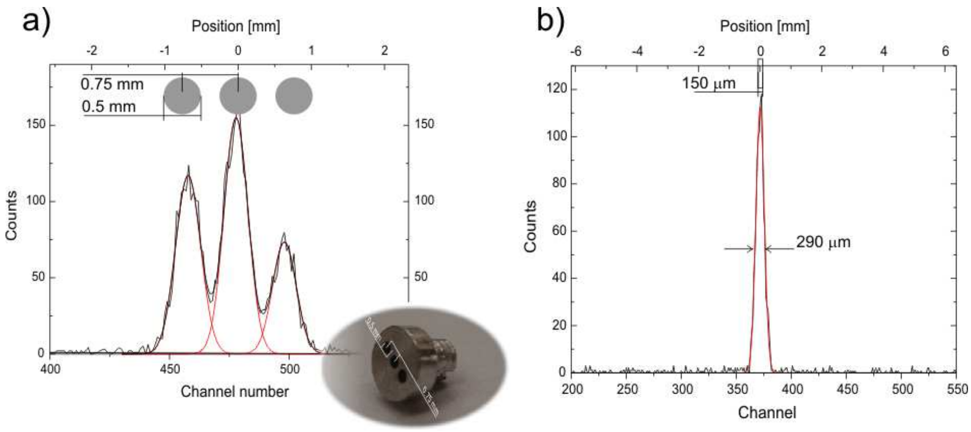

Fig. 1 – a) Al collimator with three 0.5 mm holes with a pitch of 0.75 mm. b) projection of a 0.15 mm slit. The signals are collected from the anodes of the MS-side, the 'best' dimension.

has 0.5 mm diameter and the holes are separated by 0.25 mm. It can be seen that the peaks corresponding to the holes are clearly distinguished. Figure 1b is the image of a 150 μm slit. The low background of this spectrum is remarkable, taking into account that no coincidence circuitry was used, and that such a distribution was collected during about one hour. The width of this distribution is 290 μm.

Both results in the figure were obtained by collecting the signals from the Micro-strip side, where the signal-to-noise ratio was about 30.

IV. DISCUSSION AND CURRENT WORK

The signals collected from the top side of the MHSP are the charge induced by the Micro-strip anodes through the Kapton^{TM} substrate. This means that this signals are much smaller in amplitude. In fact, their amplitude is typically 35% of the amplitude of those collected from the anodes. As a consequence, the signal-to-noise ratio is also smaller. This degrades the position resolution for this second dimension. The best results achieved so far were 1.2 mm, in contrast with the 290 μm of the micro-strip side.

Studies are being made to simplify the electronics even further and a 4 channel ADC TNT card was already purchased. This card was developed in the Institut Pluridisciplinaire Hubert Curien, and distributed by CAEN and has fully programmable FPGAs to process the signals coming from the pre-amplifiers. Each ADC has a 14 bit resolution and can be logically related with all the other channels. This will save the need of shaping amplifiers in the circuit and a simple PC processing software can be developed to solve equation 1 and return images in a very little time. Other more sophisticated solution can also be programming the FPGAs to solve equation 1 in real time, making the card return three coordinates: *x*-position, *y*-position and energy.

To solve the problem of the low signal-to-noise ratio for signals collected from the top electrodes of the MHSP, might be not a simple task. The quality of manufacturing of the MHSP has increased drastically over the past years, however, it is still difficult to achieve the perfection that allows exploiting the maximum gain at a stable operation. The lowering of the noise has to do with a correct choice of high-voltage supplies, filtering capacitors, good quality grounding, low mechanical vibrations and others. All these variables are to be optimized before starting the measurements, however, the result might still not be satisfactory. One possibility to consider might be to apply a GEM as a pre-amplifier stage. This would increase the overall gain by a few tens, while allowing decreasing the operating voltages of the MHSP.

V. CONCLUSION

The results already obtained with the MHSP show a very competitive ability for imaging in several fields of science. It has been shown that these can still be improved, using more sophisticated solutions, but due to its simplicity and bulkiness, the MHSP by itself can be used as imaging device in medicine, X-ray diffraction experiments and in neutron beam monitoring, if used in a $CF_4/^3He$ atmosphere. The use of the resistive charge division has proven to be simpler and several orders of magnitude less expensive than the solution of high density electronics for individual anode readout.

It is expected that in the near future a real inexpensive imaging detector with submilimeter resolution capabilities will be at hand, thanks to the use of the Micro-Hole and Strip Plate.

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