Picosecond imaging at high spatial resolution using TOFPET2 AISC v2d and Microchannel plate detectors

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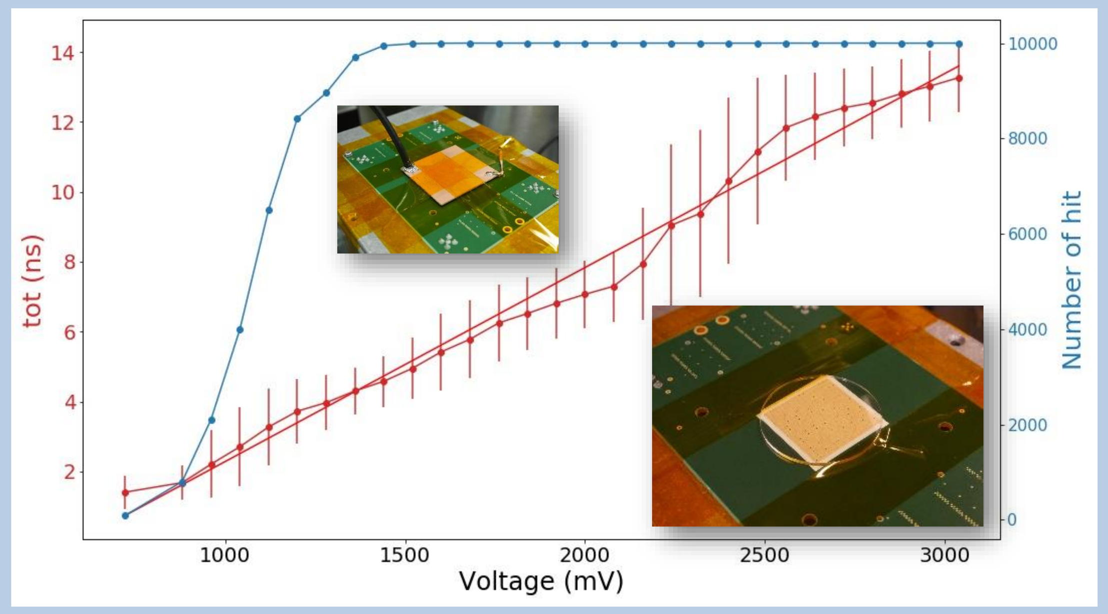
Abstract Microchannel plate-based detectors provide advantages over their solid-state counterparts for applications where a combination of virtually zero noise photon-counting, large format, short wavelength sensitivity with high resolution timing and imaging are required. Solar-blind applications, Cherenkov detectors for high energy physics, and UV astronomy are such fields. The application to Cherenkov detection is particularly demanding, requiring time resolution below 100 picoseconds combined with imaging and high throughput. This requires the readout to combine high spatial and temporal event resolution at high rates necessitating a parallel readout approach. We describe a readout design comprising a pixellated readout array instrumented using multi-channel fast timing electronics and incorporating charge centroiding to achieve sub-pixel spatial resolution. We present experimental results of the relationship between time over threshold and signal amplitude, the centroiding image obtained with an MCP detector using a pixellated readout geometry. The readout was optimised for a fast electronics implementation based on the TOFPET system, a multi-channel all in-one ASIC originally designed for time-of-flight PET using silicon photomultipliers.

Introduction

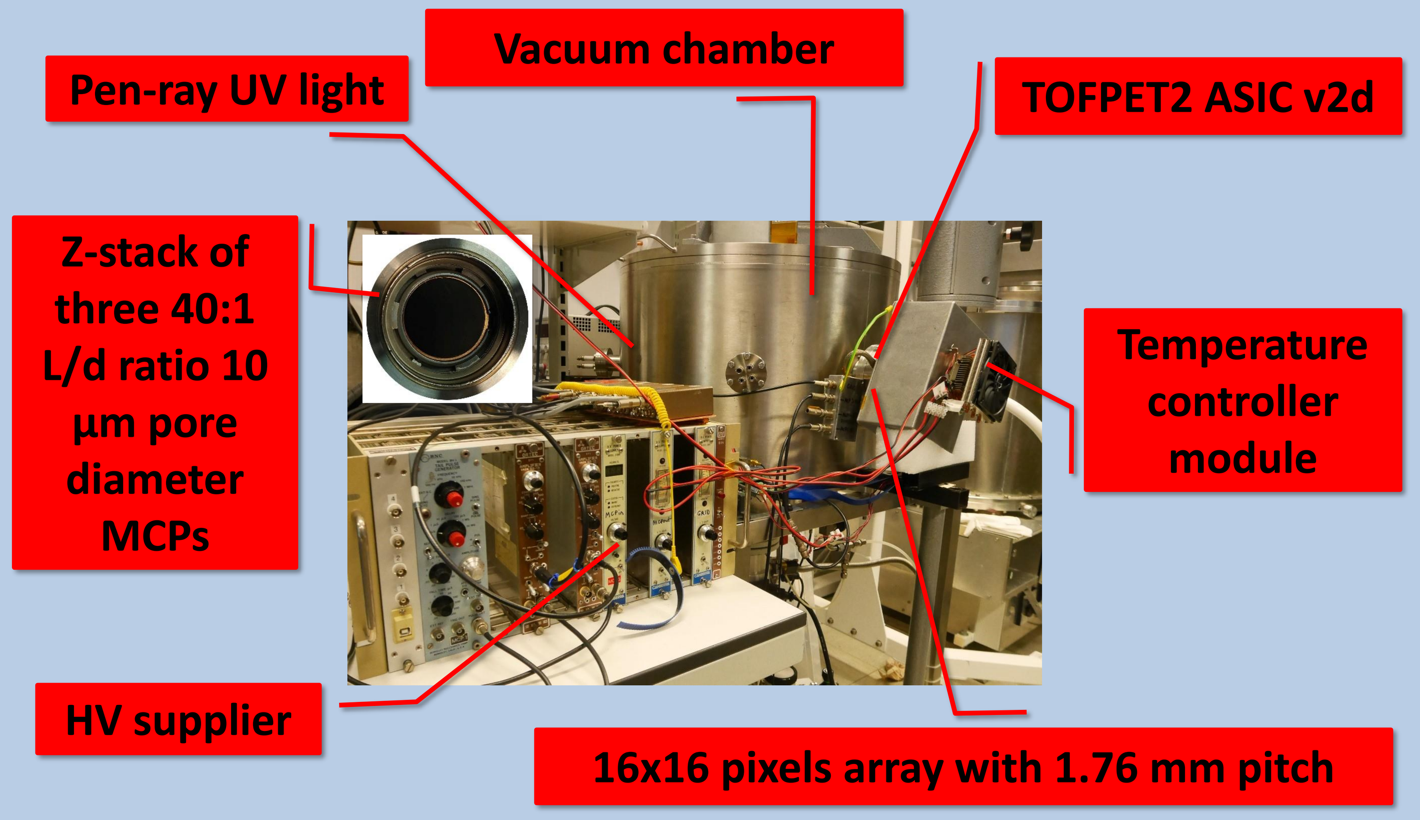
- TOFPET2 ASIC v2d in negative mode with using 2 different microchannel plate detectors.
- Using time over threshold measurement to measure signal amplitude for centroiding.
- Image charge measurement by using capacitive charge collection [1].
- Timing selecting and filtering algorithm.
- High time resolution in picoseconds which is up to 150 ps FWHM [2].
- Using 3 different signal sources and 2 centroiding techniques.

Electronic stim signal measurement

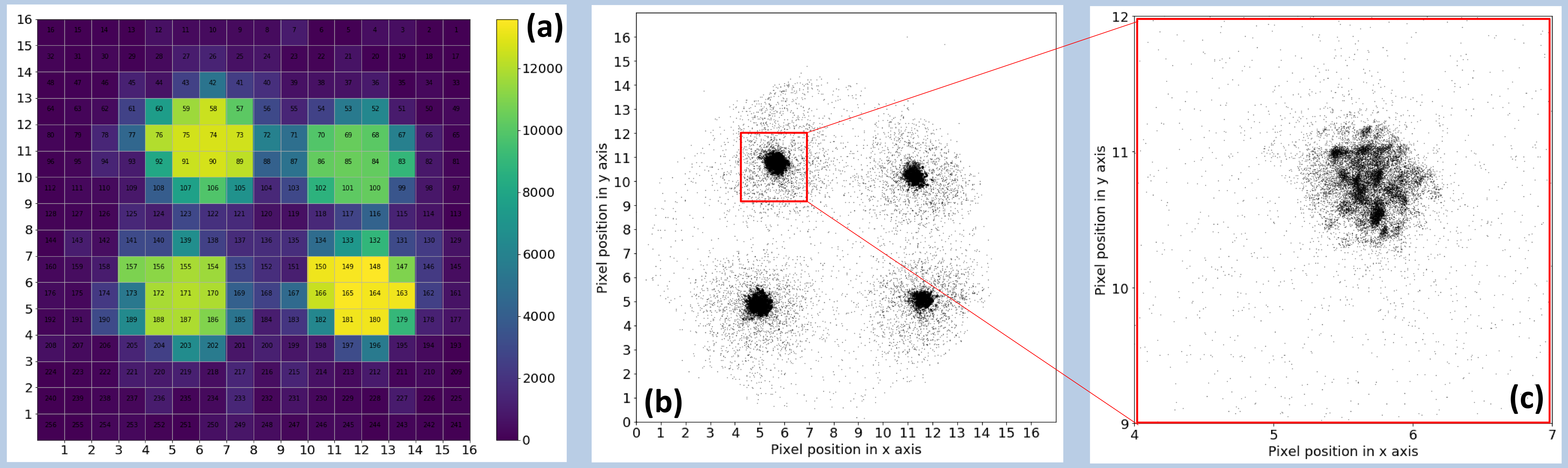
The TOFPET2 [3][4][5] electronic system evaluated here is well-matched to a pixellated readout geometry. The function generator BNC-575 was used to stim different negative signal directly to the dielectric layer via the PCB board to generate the electric charge direct to the 256 discrete anode. The TOT increases proportionally to the signal amplitude. The number of hit counts climbs dramatically then remains stable after around 1500 mV which corresponds to the signal level from the BNC-575. The measurement shows a linear relationship between TOT and signal amplitude.



Pen-ray UV light source measurement

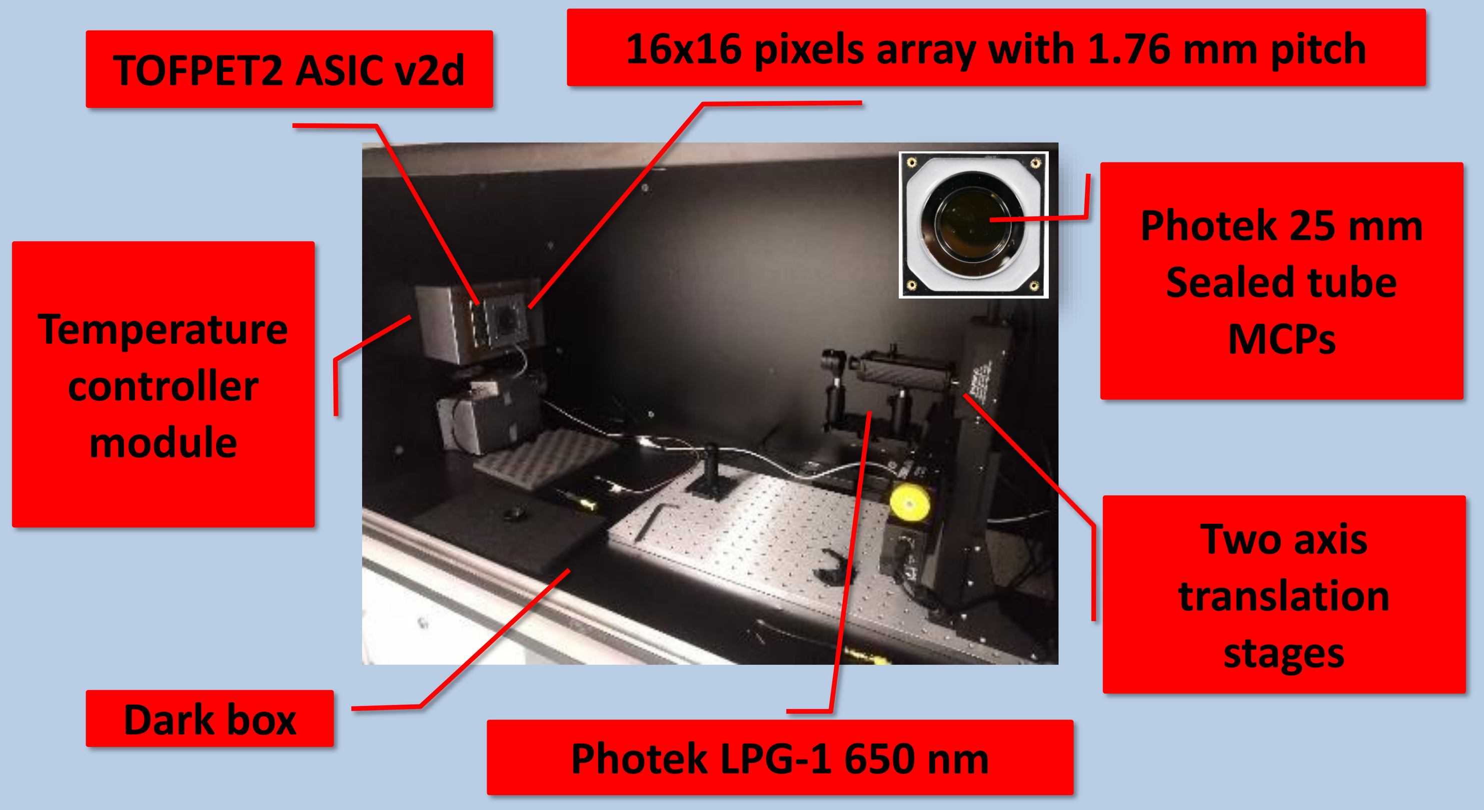


- We have Successfully demonstrated TOFPET2 ASIC v2d in negative mode of measurement.
- Using the dual threshold trigger t1 and t2 in negative mode measurement.
- The cumulative hit counts corresponding to the 4 pinhole positions (a).
- Time over threshold (TOT) mode of measurement.
- Using TOT to centroiding signal instead of signal amplitude or energy.
- Using timing and pixel position to filtering and selecting a real signal.
- Collecting charge cloud footprint and plotting the centroiding image (b).
- All-pixel Gaussian distribution centroiding [6] can be used with has artifact imaging pattern effect (c).

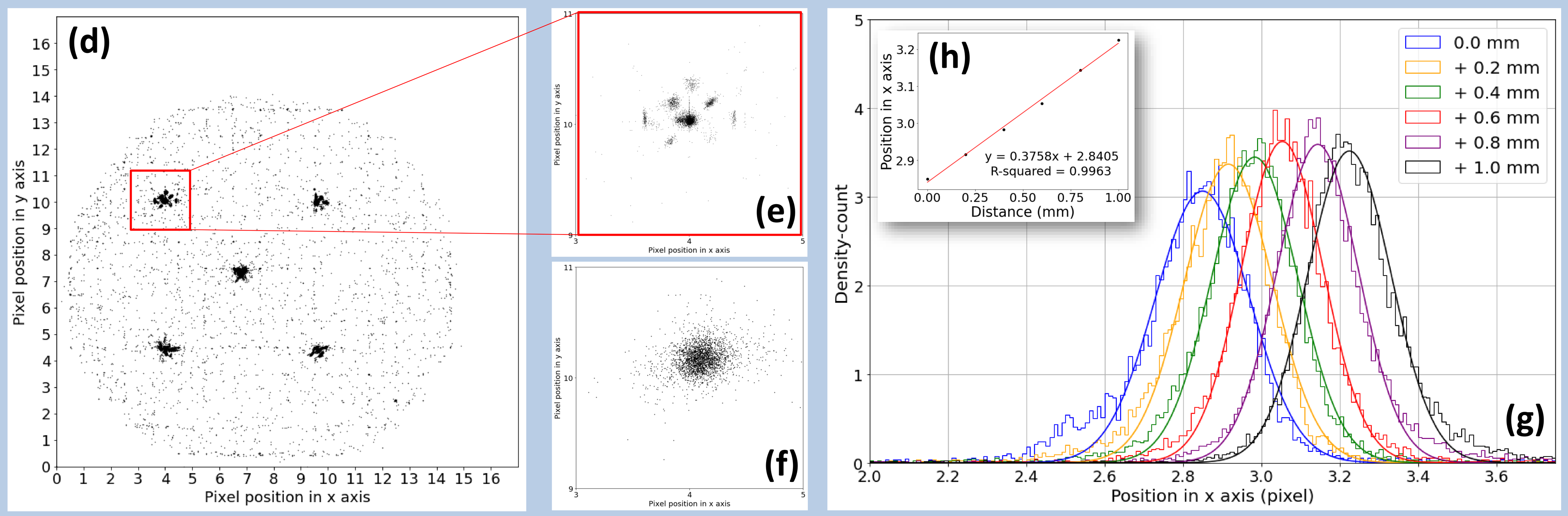


(a) The cumulative hit counts of the signal, (b) the 4 pinholes image which using time-over-threshold centroiding technique of the negative signal data were collected by the TOFPET2 ASIC v2d, and (c) the close-up plotting of the one pinhole image at the upper left of (b).

Laser 650 nm light source measurement



- Using the dual threshold trigger t1 and t2 in negative mode measurement.
- Using both of all-pixel Gaussian distribution centroiding and 3 cross pixel [7] Gaussian fit centroiding [8].
- Asymmetry charge cloud footprint affects the laser point source image with has artifact imaging dot pattern (e).
- Gaussian fit centroiding provides the image without any image pattern (f).
- The σx and σy of the centre position was 0.2133 and 0.1920 mm respectively with corresponding to the size of laser pointer source.
- The histogram plot of 5 centroiding images from different 5 laser positions along the x axis (g).
- A good linear relationship between centroiding position and the laser position.
- The r-squared of the plot (h) is 0.9963.



(d) A x-y scatter plot of the five laser positional coordinates obtained using an all-pixel Gaussian fit, (e) the close-up plotting of the one laser position image at the upper left of (a), and (f) the x-y scatter plot of (e) when using a symmetry 3 cross pixels Gaussian fit, (g) the histogram plot of centroiding 5 laser position along the x axis ,(h) the x-y scatter plot of centre position in x axis and distance of 5 laser position sources.

Conclusions

We are investigating the feasibility of utilizing TOFPET2 ASIC v2d to achieve single photon-counting with fast timing and high spatial resolution in conjunction with a MCP detector with a pixellated readout array. Negative signal arrival time and time over-threshold can be measured simultaneously by TOFPET2 ASIC v2d. The results we have already obtained indicate the potential for TOFPET2 ASIC v2d devices to image and time single photons with excellent linear relationship between time-over-threshold and signal amplitude, and TOT centroiding technique can be used to imaging signal from MCP detector instead of their energy or signal amplitude. Further experimental work is being undertaken to use alternative centroiding techniques and machine learning to investigate and explore the spatial resolution performance for signal photon events. And improved electronics calibration in timing and time over threshold in between each ASIC are also being investigated to increase the electronics readout device performance and image resolution.

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