Evaluation of Matrix9 for Small-Animal PET

Junwei Du[1], Jeffrey Schmall[1], Yongfeng Yang[1], Kun Di[1], Emilie Roncali[1], Nikolai Pavlov[2], Steve Buckley[2], Carl Jackson[2] and Simon R. Cherry[1]
[1]Department of Biomedical Engineering, University of California, Davis
[2]SensL Technologies Ltd., 6800 Airport Business Park, Cork, Ireland

Introduction

SensL's Matrix9 is a large-area modular silicon photomultiplier (SPM) detector, including the detector head and readout electronics. The detector head consists of a 3 × 3 matrix of SPM arrays, each with 4 × 4 pixels[1]. The total area of this device is 47.8 × 46.3 mm^2, and each SPM pixel measures 3.16 × 3.16 mm^2. A "scrambled crosswire readout" technique is used to read out the 144 detector pixels using just 25 electronic channels [1]. The purpose of this study was to assess the performance of the Matrix9 detector when using scintillator array dimensions consistent with small-animal PET applications that require light sharing across SPM elements.

To find the best working conditions in terms, the noise, signal, signal-to-noise ratio (SNR)[2], energy resolution, flood histogram and timing resolution were measured and compared at five different temperatures, ranging from 5 ^oC to 25 ^oC, in 5 ^oC intervals. At each temperature, measurements were obtained at different bias voltages, from ~28.0 V to 32.5 V, in 0.5 V intervals.

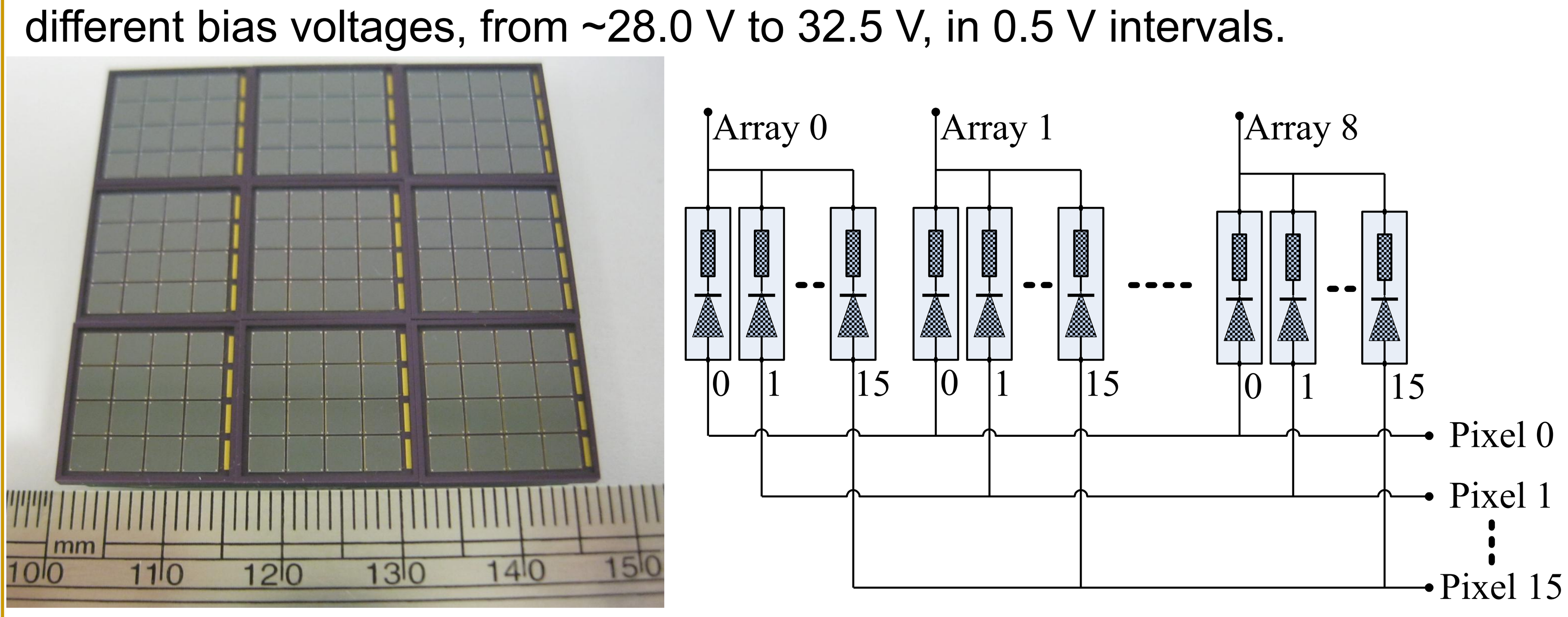

Fig. 1: (Left) Picture of Matrix9 and (right) schematic of the crosswire readout.

Materials and Methods

Two 8 × 8 polished LSO arrays (pitch 1.5 mm and length 6 mm, enhanced specular reflector) were used for all measurements. Each LSO array was coupled to the center of one SPM array via BC-630 optical grease, whilst the other eight SPM arrays were covered by black paper. A 100 μCi ^{68}Ge point source, placed 20 mm above the front of the LSO array was used to irradiate the crystals except the timing resolution measurements. For the timing resolution measurements, the source was located at the center of two LSO arrays and Matrix9 detectors with a center-to-center distance of 80 mm.

Results

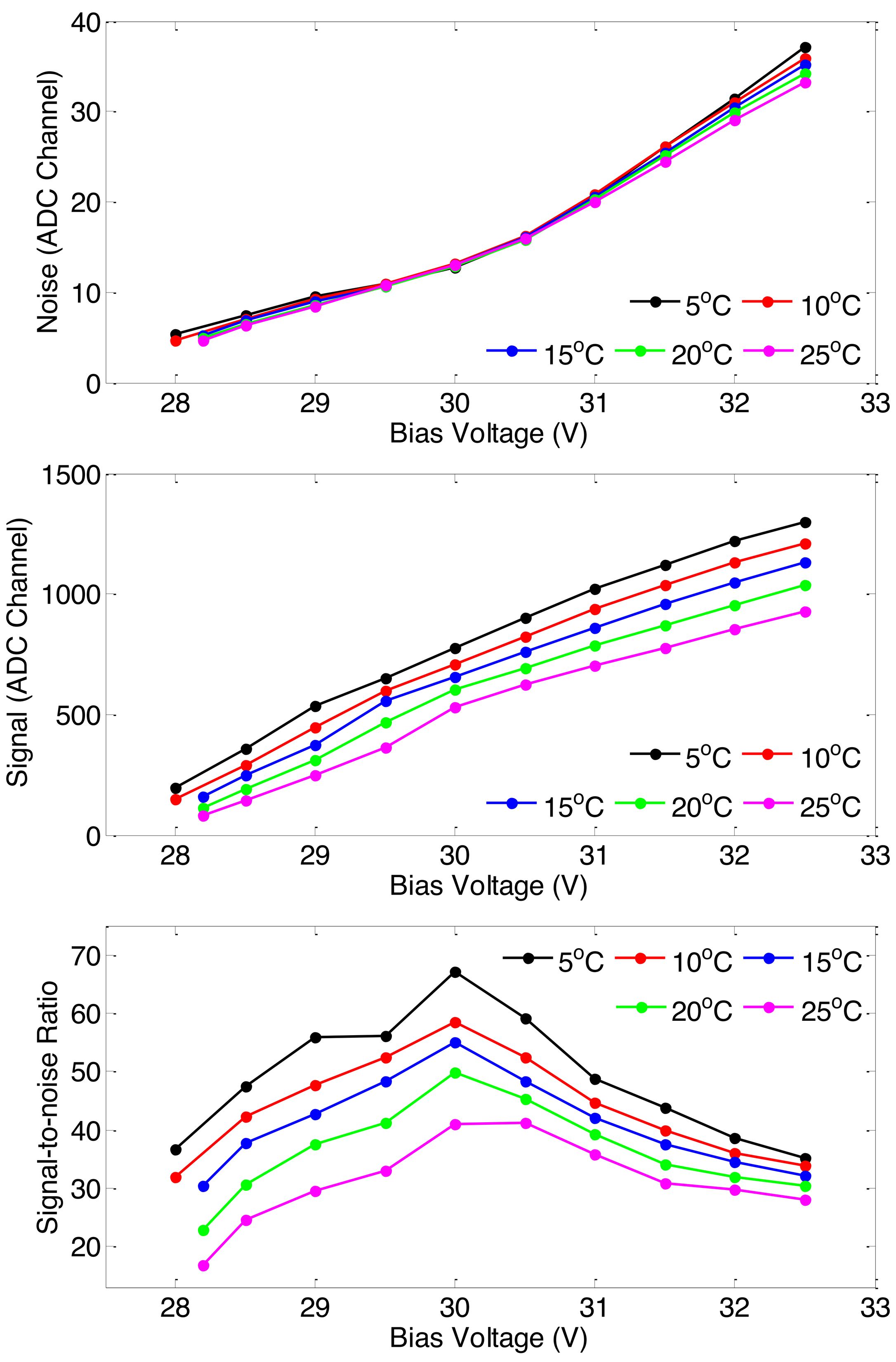

Fig. 2: (Top) Signal, (middle) Noise and (bottom) SNR.

Figure 2 shows the signal, noise and SNR at different bias voltages and temperatures. The signal is the amplitude of the photopeak position of the 511 keV photons. This signal amplitude was corrected by subtracting the channel offsets. The average FWHM of the noise distribution of the 16 pixels was treated as the detector noise and the SNR was the ratio of the 511 keV photons amplitude to the detector noise[2]. The best SNR was obtained at a bias voltage of 30.0 V except at 25 ^oC, where the optimum occurred at 30.5 V. This is because the SPM breakdown voltage goes up with increasing temperature (~20 mV/^oC).

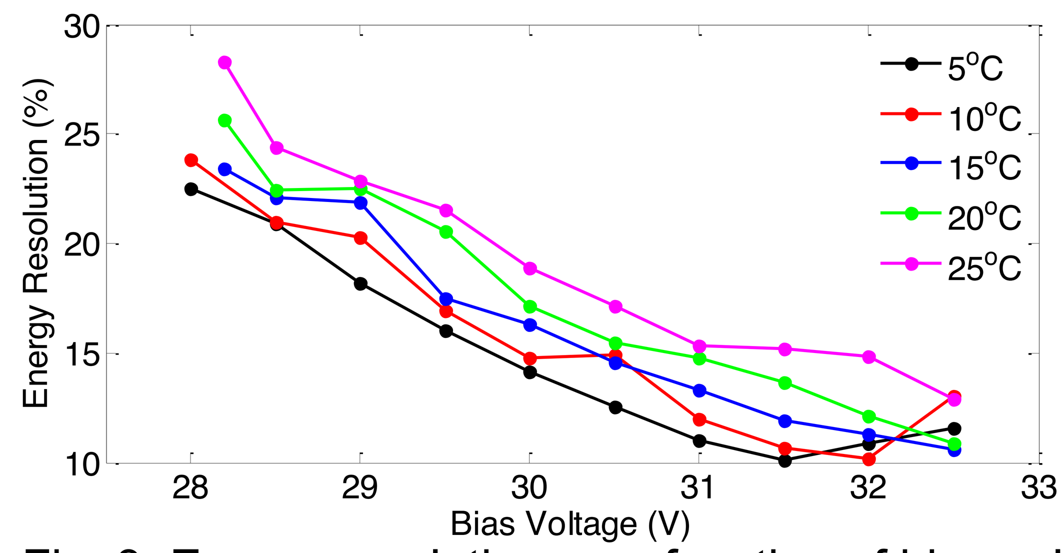

Fig. 3: Energy resolution as a function of bias voltage and temperature.

Figure 3 illustrates the energy resolution obtained at different bias voltages and temperatures. At higher bias voltage, the detector is partly saturated, hence the energy resolution becomes artificially good.

The gamma photon interaction position was calculated using four different methods: M1) all energies method[1], M2) all energies with offset calibration method, M3) region of interest (ROI) method[1], M4) ROI with offset calibration method. The "ROI method" uses the pixel with the maximum signal and its eight surrounding pixels. "Offset calibration" means that the signal offset was first subtracted from the signal (if the subtracted signal was smaller than half the FWHM of the noise distribution for that pixel, the signal was set to be 0). Figure 5 (left) shows the flood histograms and figure 5 (right top) shows the flood histogram quality using the four methods. Figure 5 (right bottom) shows the flood histogram quality using the "ROI with offset calibration" method. The flood histogram quality is calculated by comparing the width of the crystal spot and the distance of the two adjacent crystals in the flood histogram[2]. A smaller value implies better flood histogram quality.

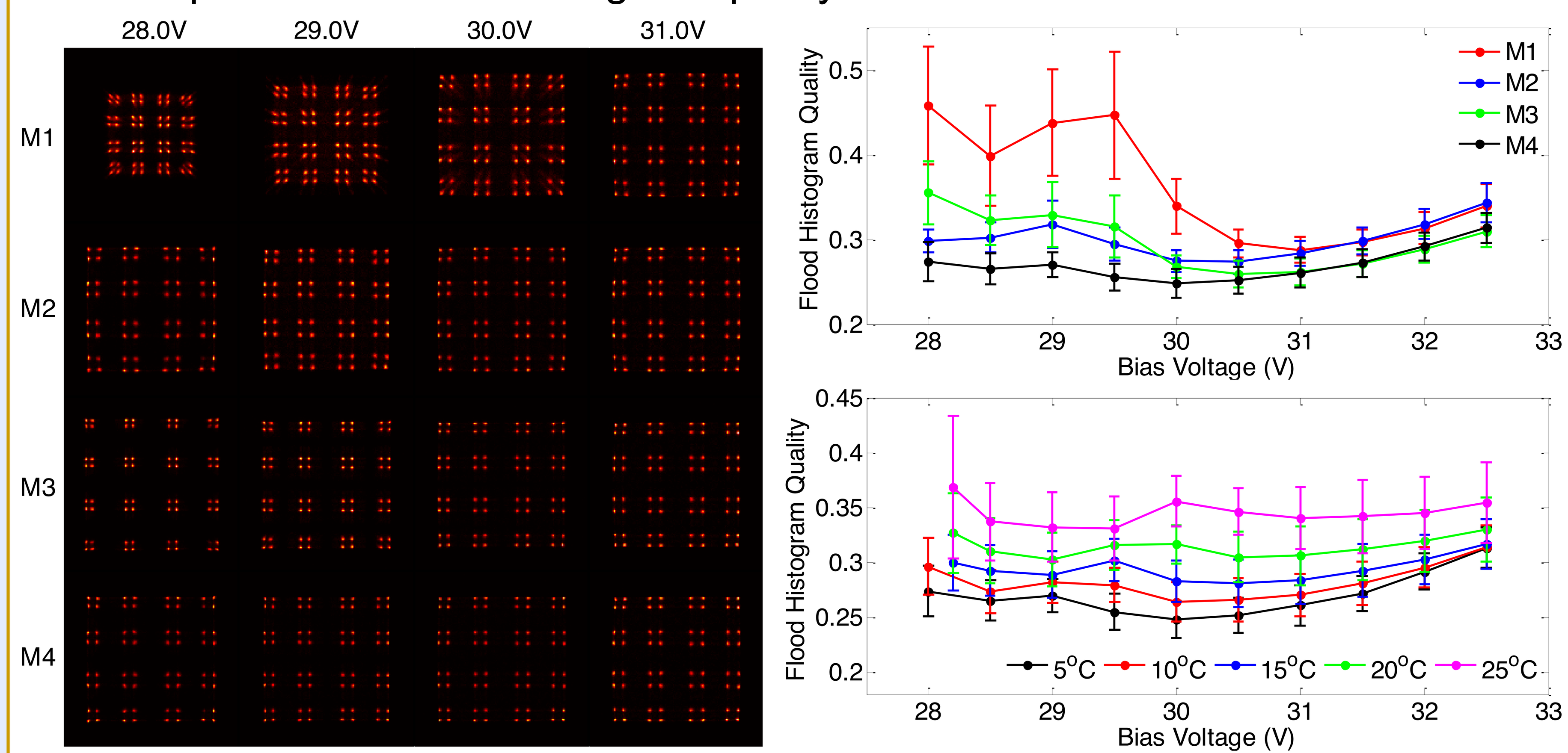

Fig. 4: (Left) Flood histograms and (right) flood histogram quality.

Figure 5 illustrates the timing spectra and timing resolution. The bias voltages were (29.7+0.02*T) V. The red, blue and green curves indicate the results from the raw data (leading edge discrimination (LED)), "LED time walk calibration" and "LED time walk and crystal timing shift calibration", respectively[3]. The solid and dashed curves in figure 5 (right) indicate the timing resolution for each method with a wide-open energy window and a 400-650 keV energy window respectively.

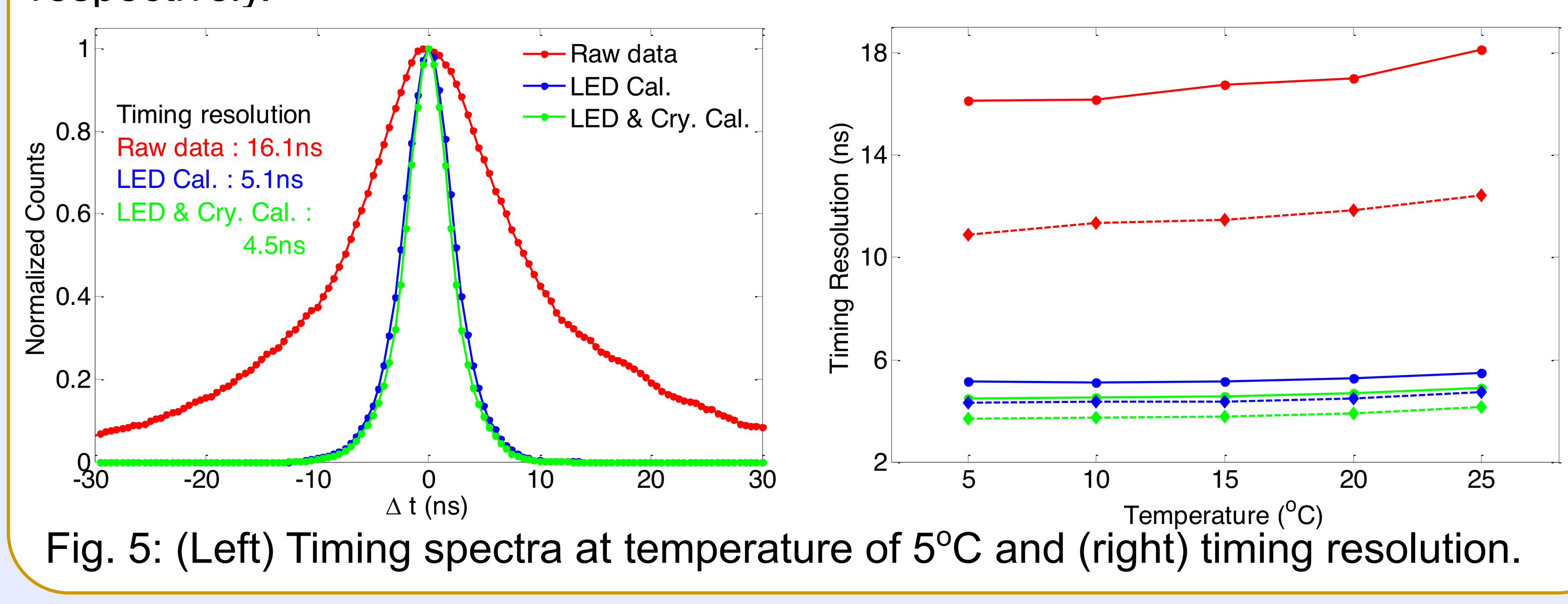

Fig. 5: (Left) Timing spectra at temperature of 5°C and (right) timing resolution.

Discussion and Future Work

The best working bias voltage for Matrix9 is around 30.0 V. The flood histograms show that LSO arrays with a pitch of 1.5 mm can be clearly resolved and indicates that smaller crystals (~1 mm pitch or smaller) might be resolved. A timing resolution of 3.7 ns can be achieved with proper time calibration. With these attractive features, high-resolution small-animal PET and PET/MRI scanners, or dedicated scanners for breast and brain imaging, could be based upon these large-area detectors.

References

[1] Matrix9 system user manual, http://sensl.com/matrix9software/.
[2] Y. Yang *et al.*, *Phys. Med. Biol.*, vol.56, pp. 6327-6336, 2011.
[3] Y. Wu *et al.*, *Phys. Med. Biol.*, vol.54, pp. 5155-5172, 2009.

Department of Biomedical Engineering
UCDAVIS
UNIVERSITY OF CALIFORNIA
center for molecular and genomic imaging
cmgi