LAPPD Recent Results

M. Popecki
map@incomusa.com
Incom
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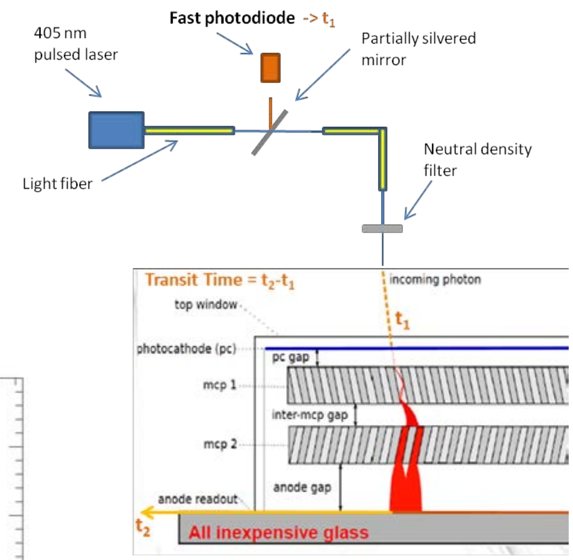
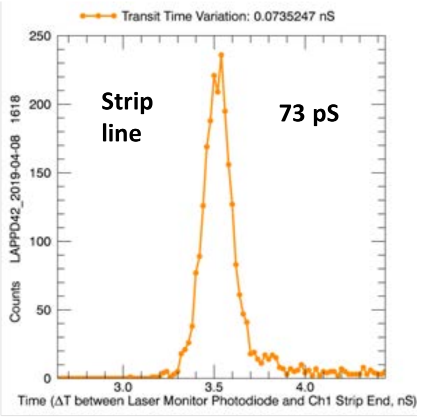
LAPPD: Recent Results

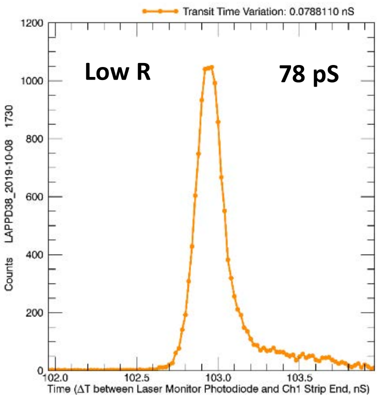
- LAPPD Transit Time
- Rate Response
- Position Measurement with capacitively-coupled pixels

LAPPD Transit Time

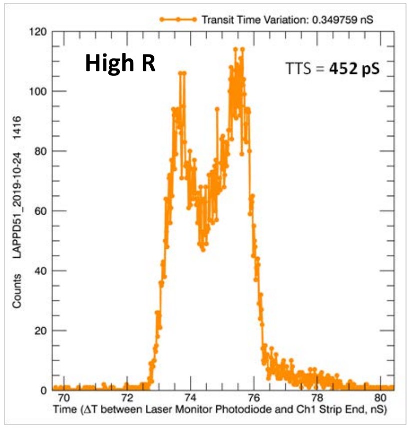
- Transit time variation has been measured with internal stripline and capacitively-coupled LAPPDs.
- Internal stripline results tend to be in the 50-80 pS (sigma) range)
- Capacitively-coupled LAPPDs:
  - Low resistance anode, similar to internal stripline
  - High resistance anode – much wider TTS



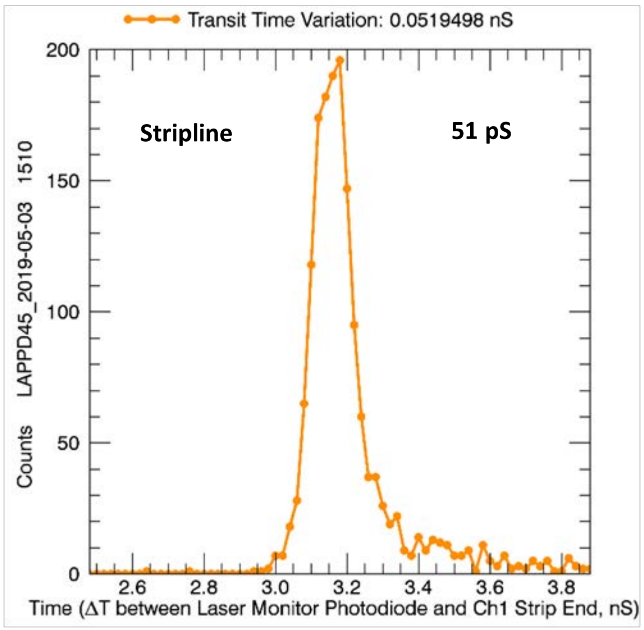


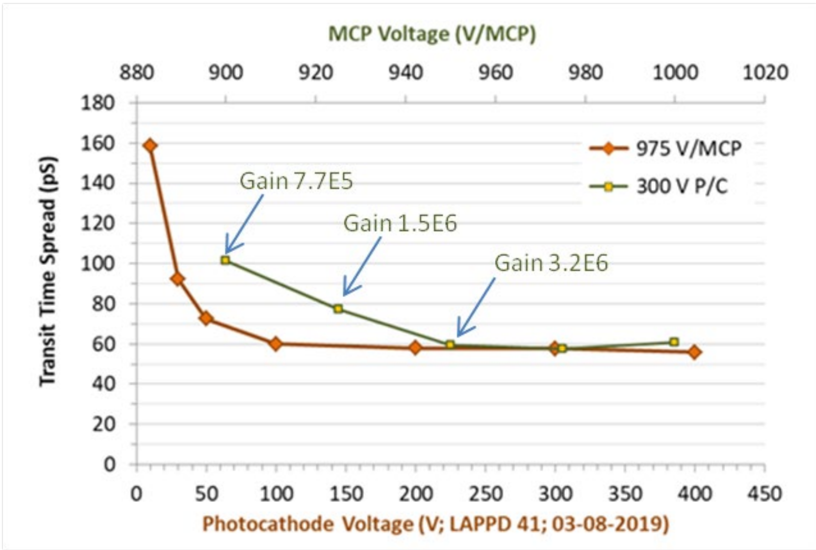


Capacitively-coupled



Transit Time Spread: Effects of MCP and Photocathode V



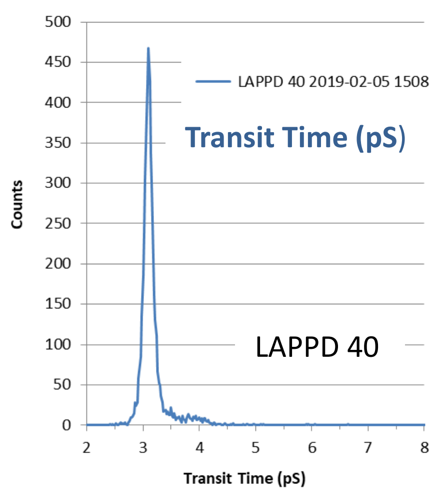


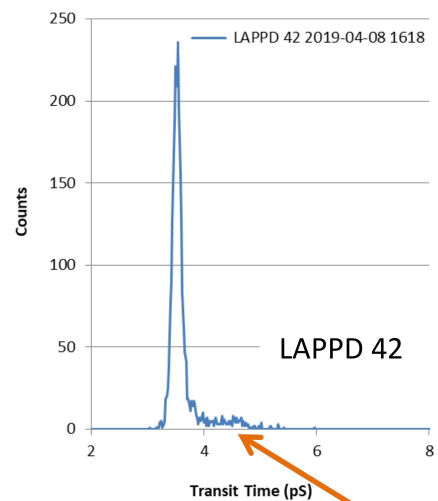
- Transit time spread is a function of MCP and photocathode voltage.
- A photocathode voltage of 100 volts, across a 2 mm gap between photocathode and MCP, provides a low transit time spread, with diminishing gains at higher photocathode voltages.
- A gain of 3.2E6 provides the best TTS, with diminishing returns at higher gains.
- A **TTS** of **51 pS σ** has been measured at Incom for single photoelectrons.
- Measured Transit Time Spread includes laser pulse width, which is then removed by quadrature:
  - $\sigma_{Meas}^2 = \sigma_{LAPPD}^2 + \sigma_{LaserWidth}^2$
- Higher MCP voltage produces a larger pulse – better signal/noise ratio for timing.
- Higher photocathode voltage produces high speed photoelectrons – less time variation among electrons striking the MCP at different depths.
- Higher incident energy electrons produce more secondary electrons, better gain, larger MCP pulses.

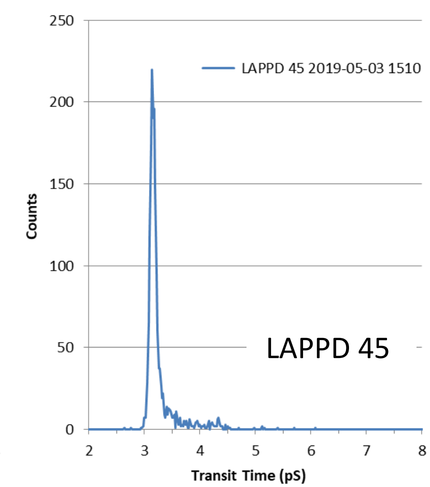
LAPPD TTS

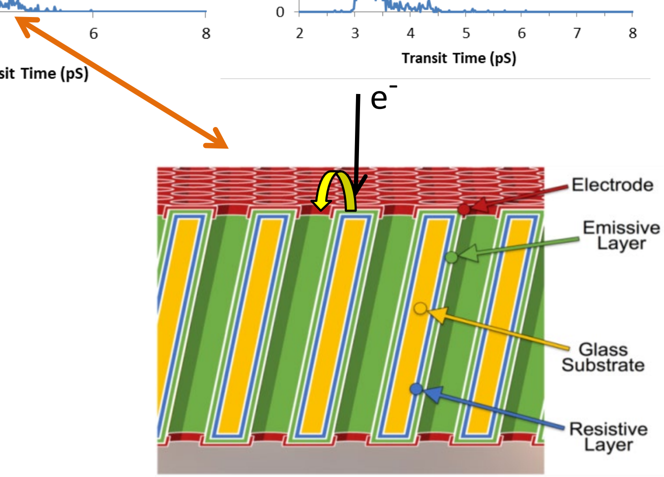
LAPPD	Standard Dev Including Tail (pS)	Sigma (Gaussian fit to peak)	Standard Dev less Laser Pulse Width (pS)
40	74	74	69
42	83	74	79
45	82	52	79

- Transit Time distributions for three LAPPDs
- Distributions feature a primary peak and a tail
- Tail may be from electrons bouncing from interstitial spaces on entry MCP, then re-entering microchannels late.
- The primary peak may be fit with a gaussian, and sigma reported.
- Standard deviation may be calculated for the entire distribution, including the tail.
- Incom MCPs have an open area ratio of ~74%, reducing the probability of bounce electrons.





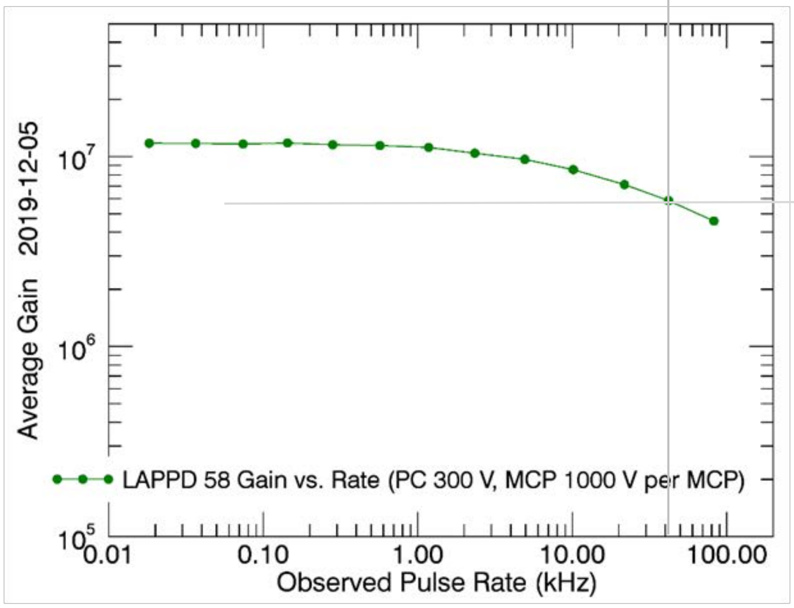


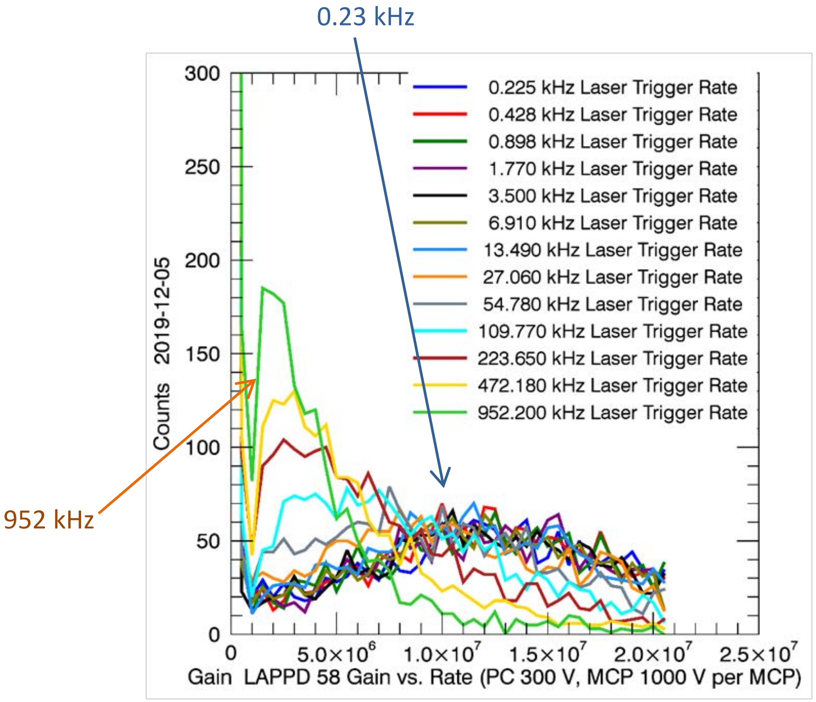


Rate Response

Gain vs Repetition Rate

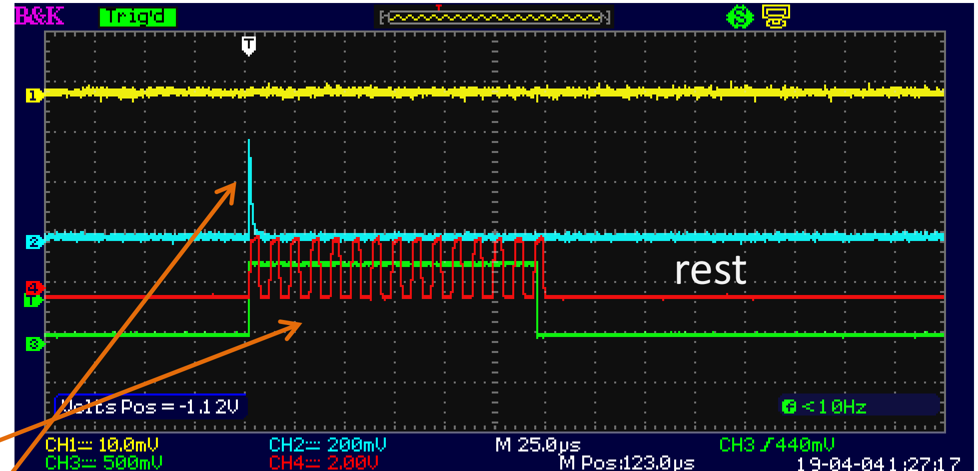
- Gain is shown for single photoelectrons, vs. laser pulse rate.
- 405 nm pulsed laser
- Spot size: 1 mm diameter
- Operation in the single photoelectron regime: only ~11% of laser pulses produce an LAPPD response.
- Gain decreases by a **factor of two** as the observed trigger rate increases from 0.02 kHz to ~42 kHz/0.8 mm^2
  - **0.03 kHz/ mm^2 to ~54 kHz/mm^2 (observed)**
- Gain is ~5.5x10^6 at ~54 kHz/mm^2 (observed)
- Pulse height distributions move leftward toward the threshold as the rate increases.

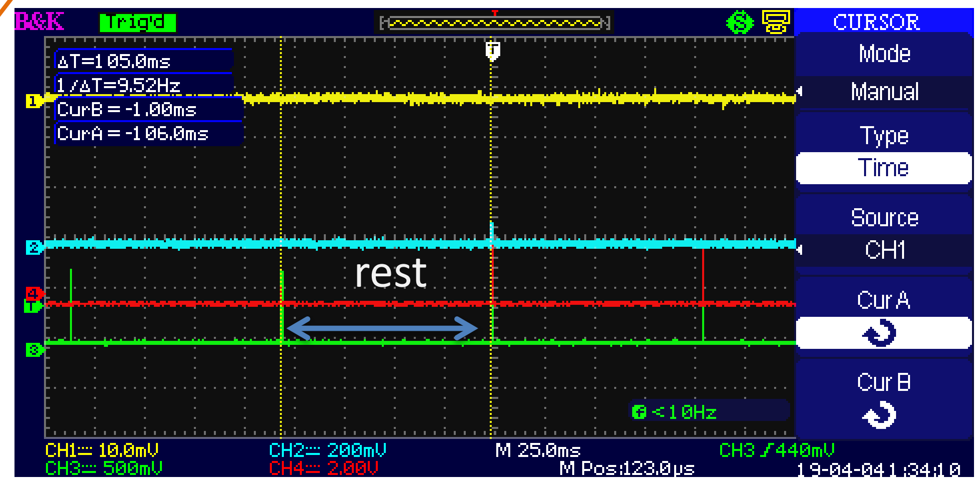


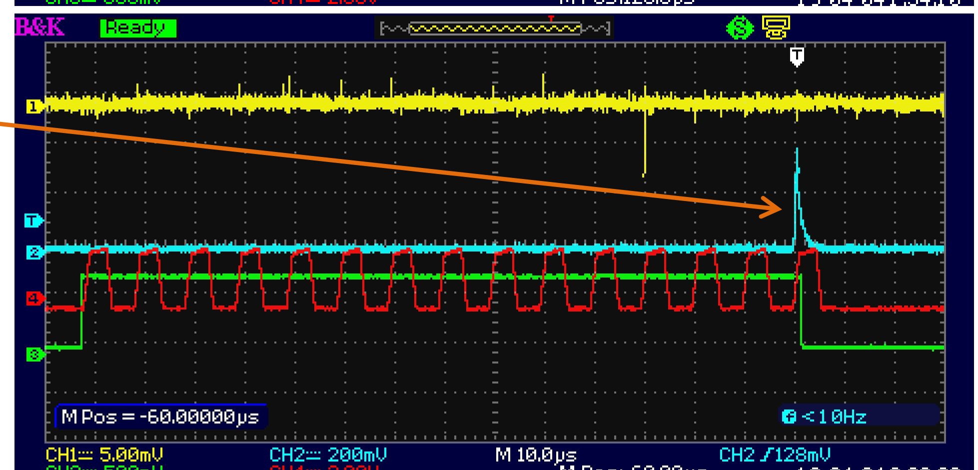


Gain Recovery

- How quickly does the LAPPD gain recover after a period of high rate operation?
- Trigger laser 15 times, every 10 uS. Allow a recovery time between laser pulse groups (red trace)
- Acquire an LAPPD response at the beginning of the next pulse group, after a **rest** period (blue trace).
- Observe gain as a function of rest period.
- One sample – observe pulse amplitude at the end of a pulse train.







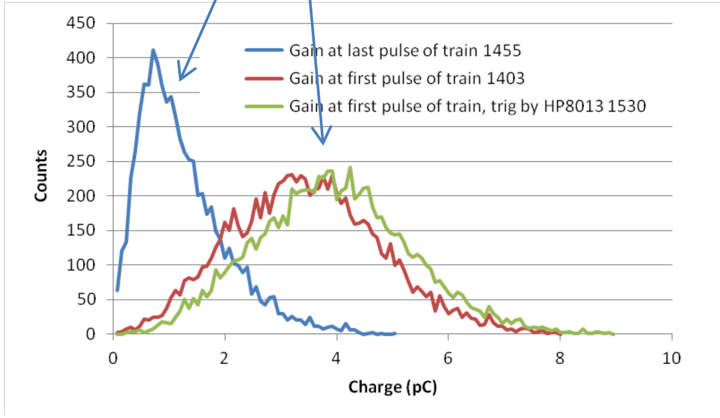
Gain Recovery

- Pulse height distributions as a function of recovery period.
- Gain is low at the end of a series of 10 uS laser pulses.
- Gain is measured at the beginning of the next series of laser pulses, after a rest period.
  - Short duration rest period – low gain at the start of the next series of laser pulses.
  - Long duration rest period – high gain at the start of the next series of laser pulses.

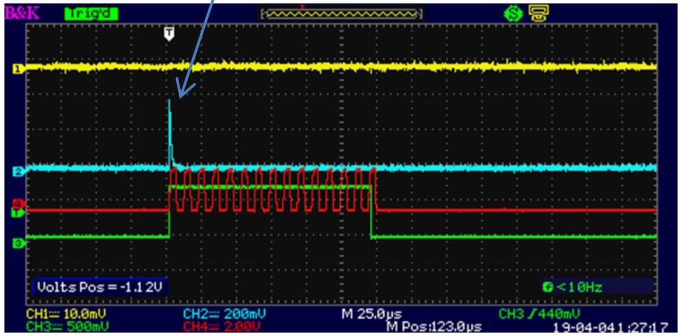
Gain decreases as a result of repeated laser pulses in the pulse train.

Last pulse of train

First pulse of train

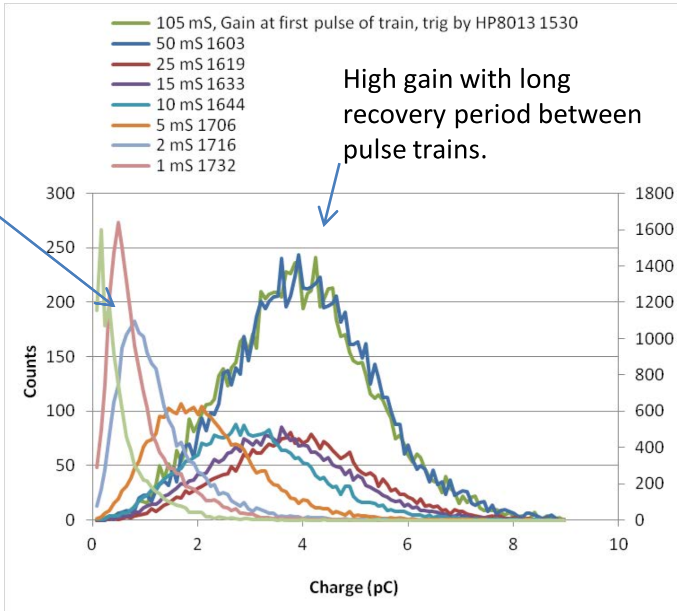


Measure gain here



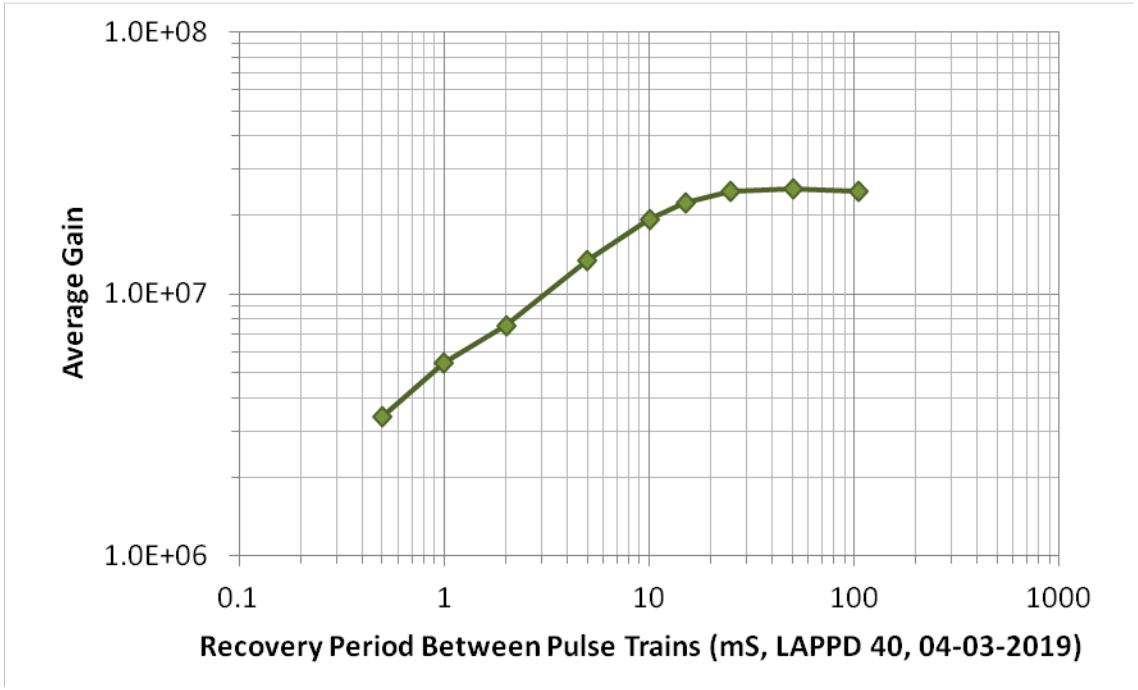
Low gain with short recovery period between pulse trains.

High gain with long recovery period between pulse trains.



Gain Recovery

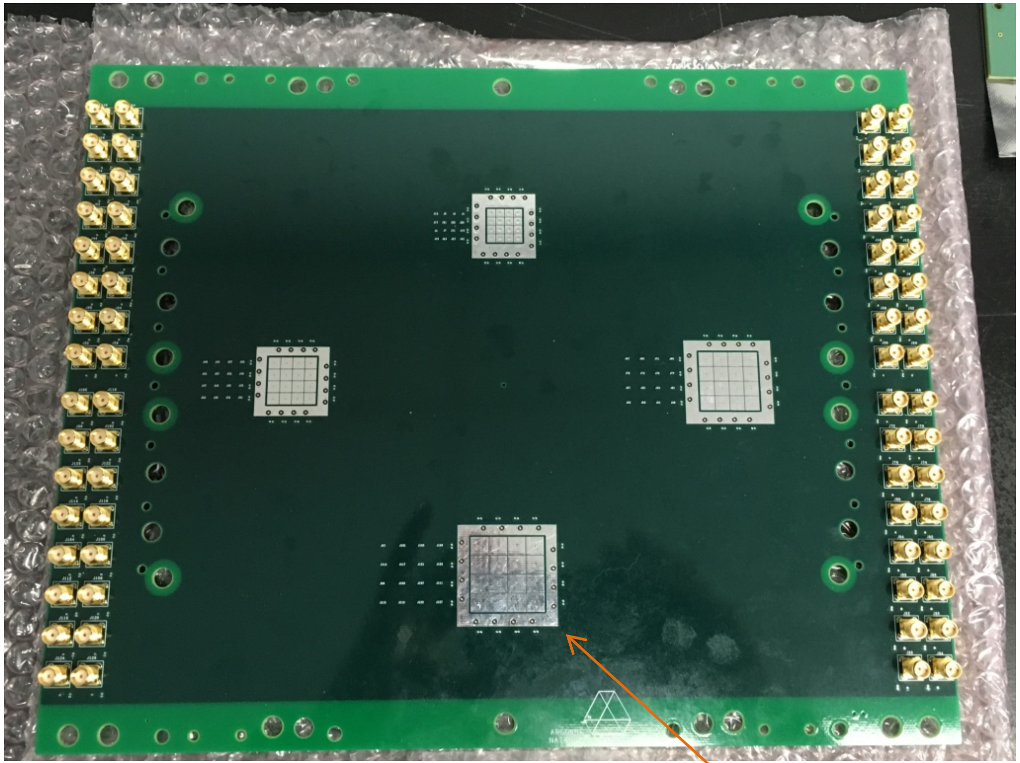
- Gain is plotted as a function of recovery period between laser pulse trains.
- The gain recovered to its initial value with a **15 mS** recovery time, and half the initial value with a **5 mS** recovery time.



Pixellated, Capacitively-Coupled Anodes

4x4 Pixel Capacitively-Coupled Signal Board

- Argonne National Lab fabricated a signal board for the LAPPD with four 4x4 arrays of pixels.
- The board was installed under the LAPPD 38 ceramic anode.
- Pixel sizes:
  - 3 mm
  - 4 mm
  - 5 mm
  - 6 mm
- Transit scans and gain measurements were performed in each group
- Observe:
  - Adjacent pixel signal size
  - Unwanted crosstalk elsewhere on the board



6 mm pixels

3 mm Pixel Pulse Example

- Laser on leftmost 3 mm pixels 1&2.
- Some signal on adjacent pixels
- No unwanted crosstalk to the 6 mm group ~ 6” away (DRS4_2)

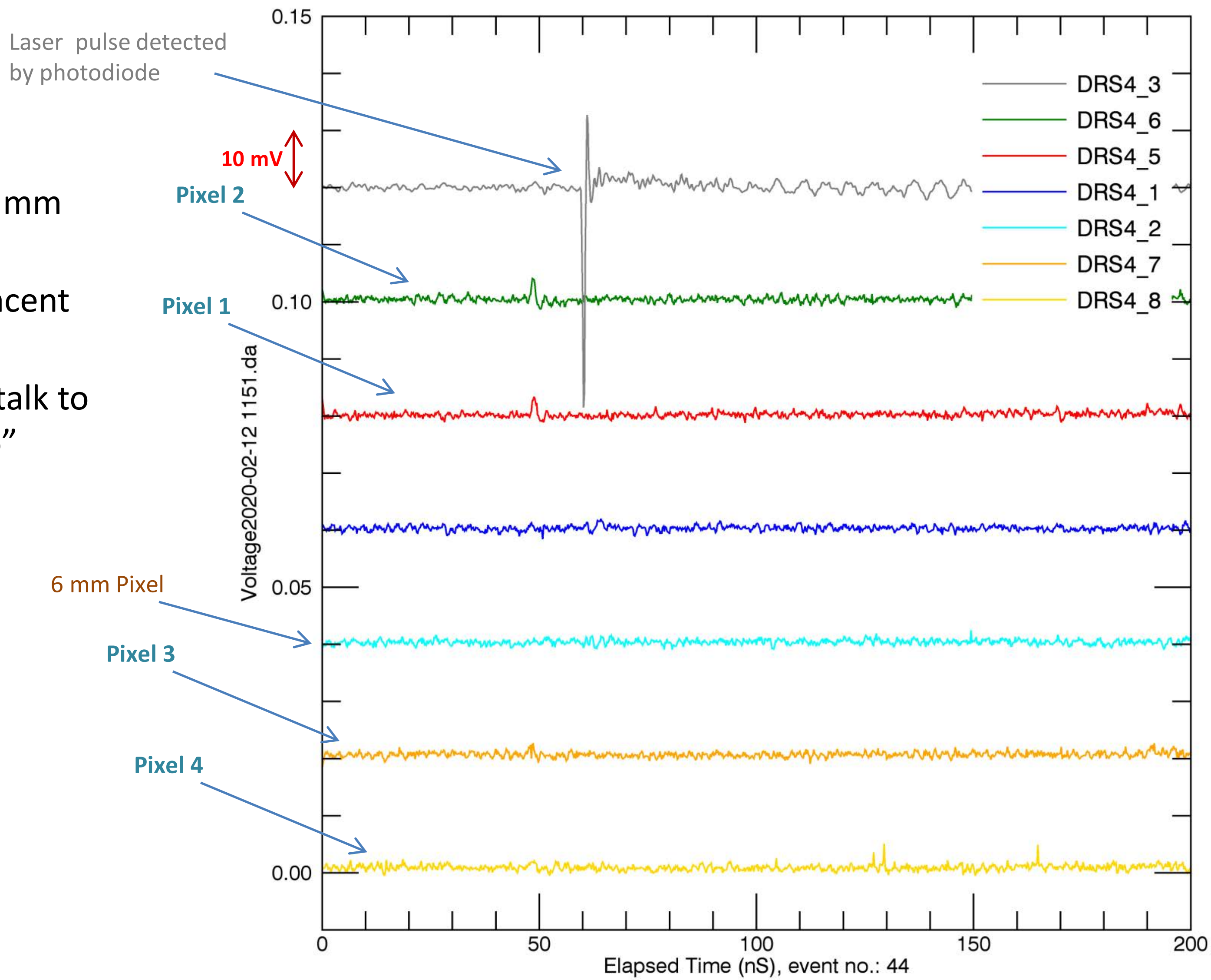
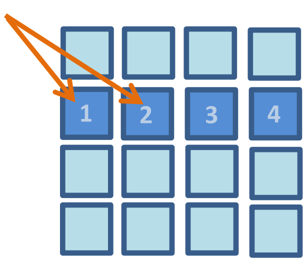
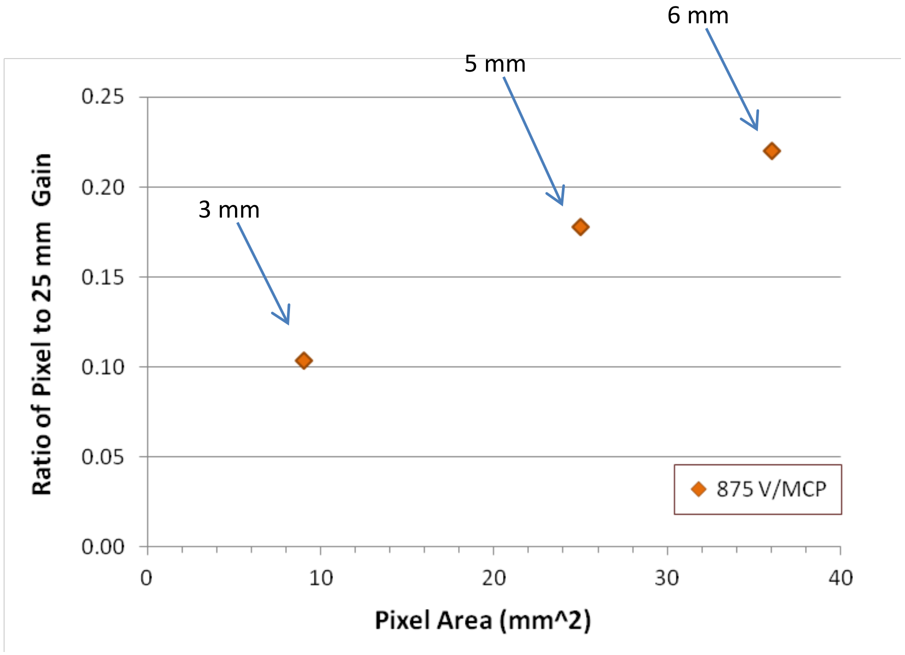


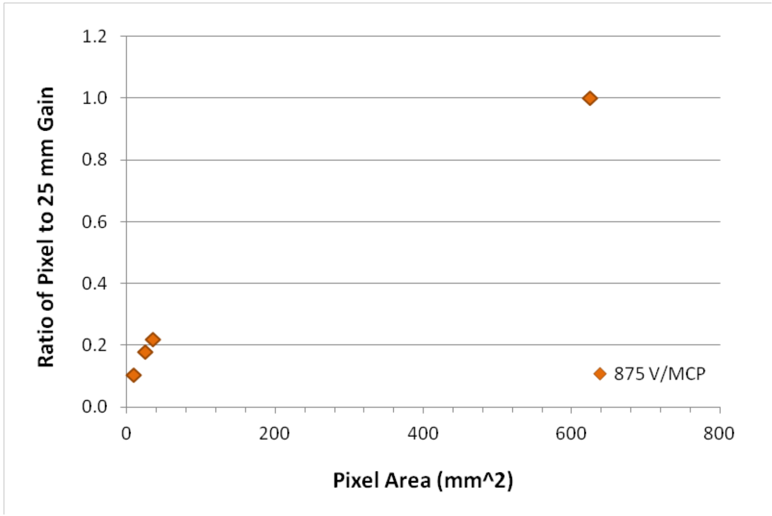
Photo of 4x4 board

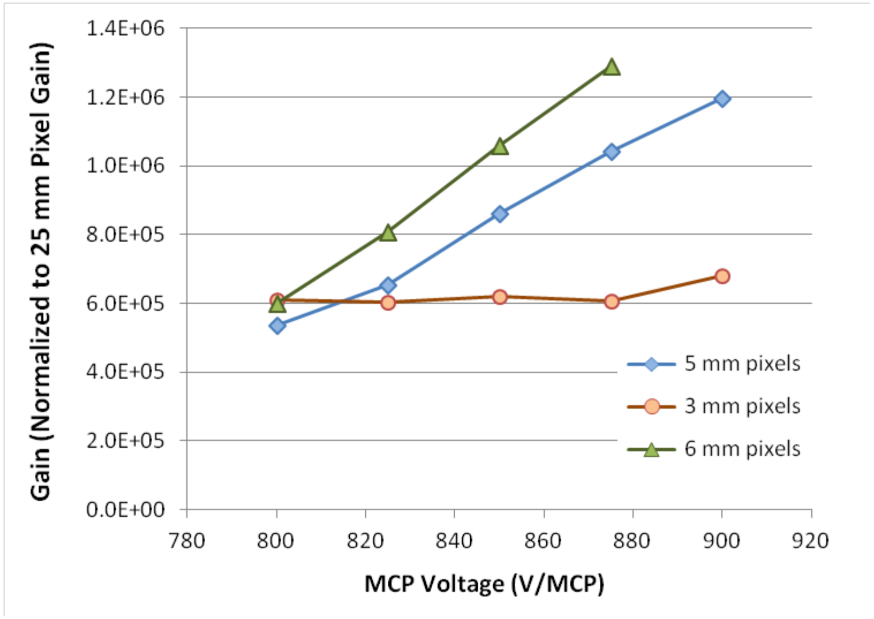


Gain vs. Pixel Size

- Gain was measured on three sizes of capacitively-coupled pixels
  - 3 mm
  - 5 mm
  - 6 mm
- Gain was highest on the 6 mm pixels.
- Gain was relatively low on the 3 mm pixels, and spread over adjacent pixels.
- Gain decreased with smaller pixel size: non-linearly with pixel area.

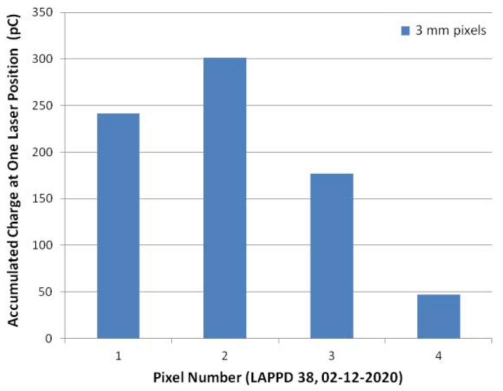


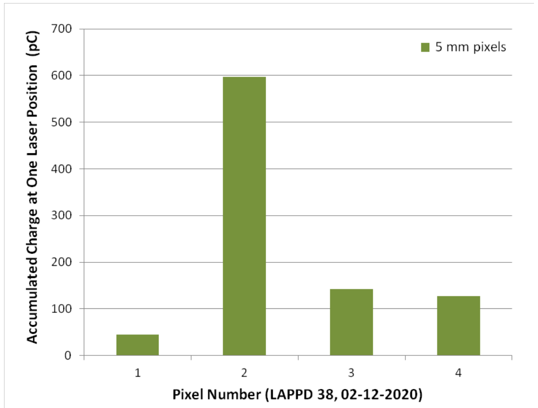


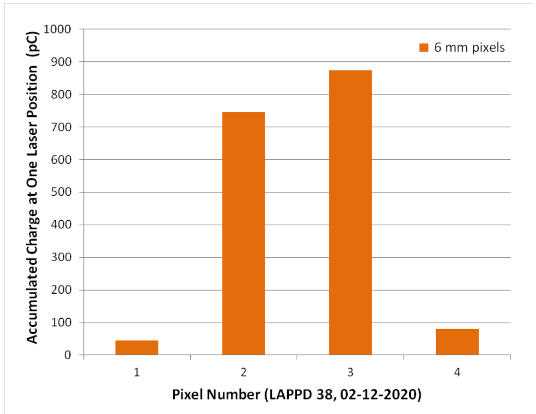


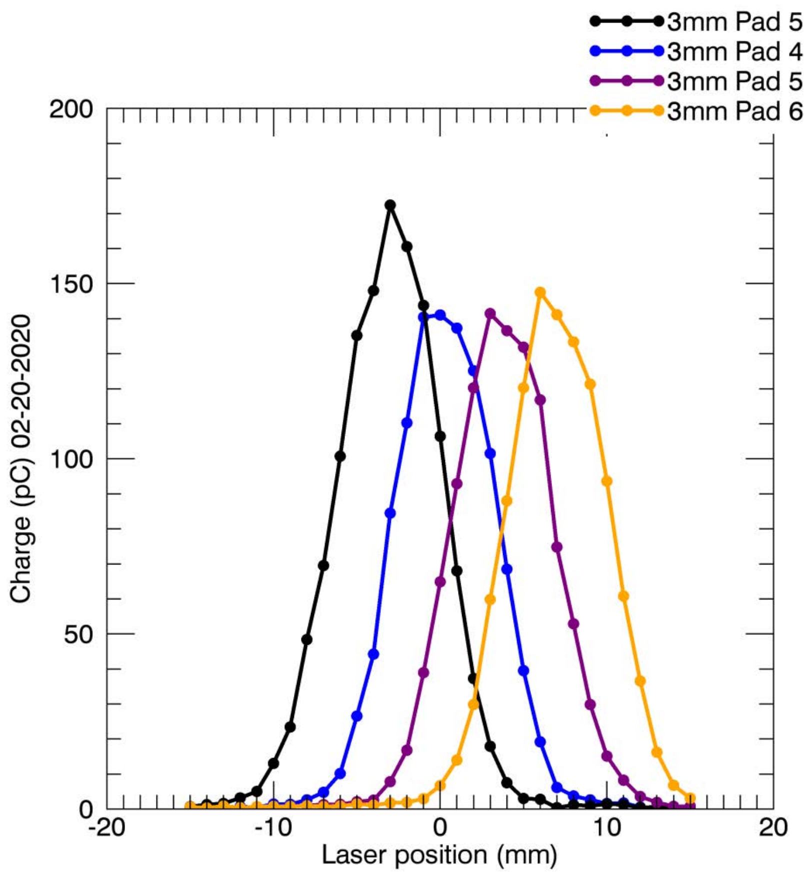
Adjacent Pixel Response

- Adjacent pixels detect MCP pulse charge by capacitively-coupling to:
  - the charge directly above and
  - more weakly to nearby charge
- Response of Adjacent Pixels is shown for 3, 5 an 6 mm pixels.
- 6 mm pixels have the most digital response with the present LAPPD configuration

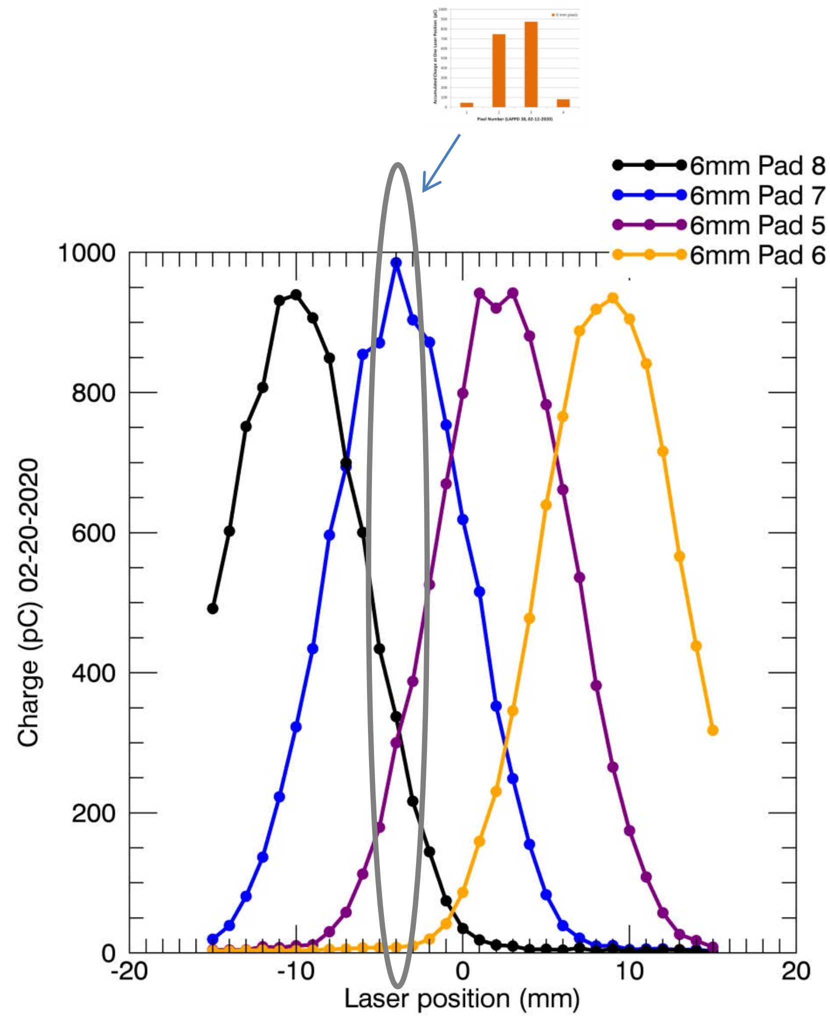








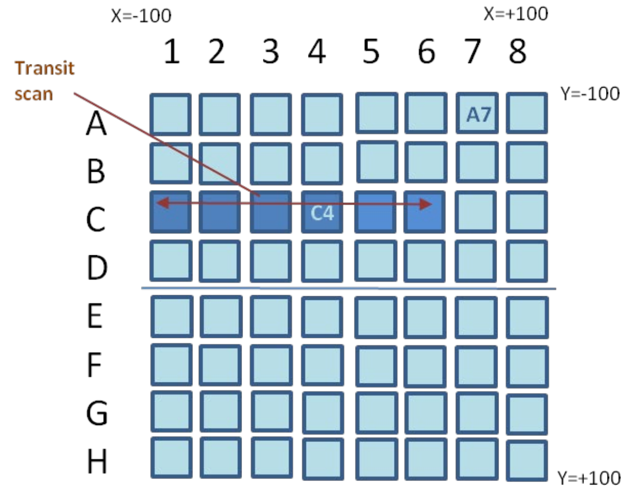
3 mm pixels, 600 v MCP to anode; L38



6 mm pixels, 600 v MCP to anode; L38

Spatial Response: 25 mm Pixels

- A position scan was performed by moving a laser spot of ~1 mm dia. across the window.
- The 25 mm ANL pixelated board was used.
  - SMA connectors faced away from the LAPPD side.
- Deviations from linearity are ~2.7 mm.
- The response of a 25 mm pixel is essentially discrete when the laser is in the center of a pixel.



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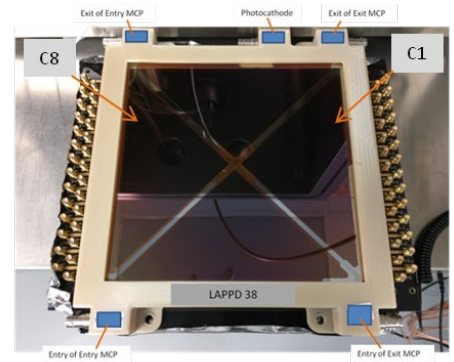
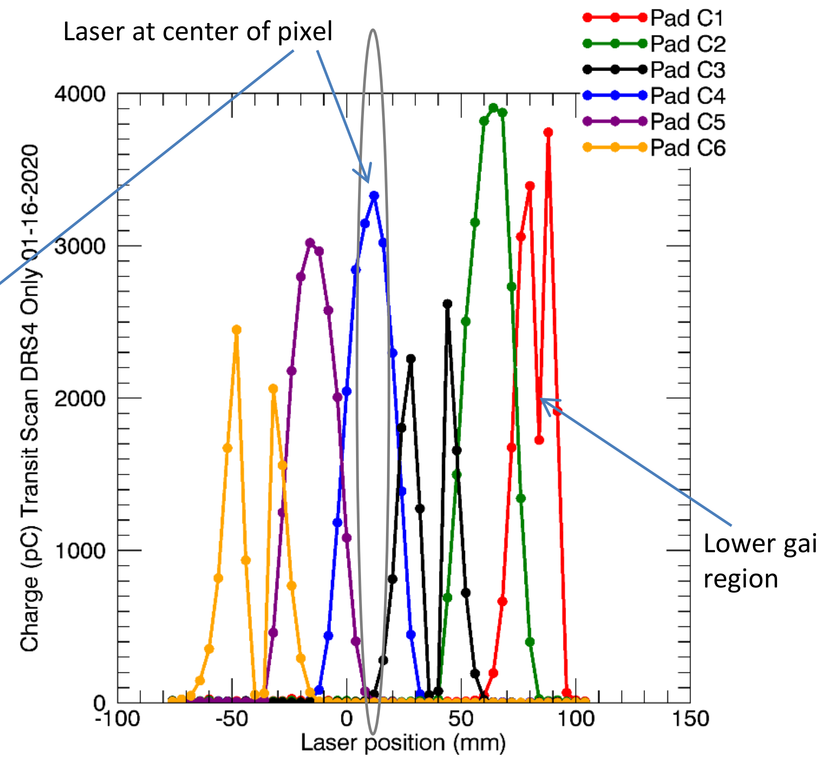
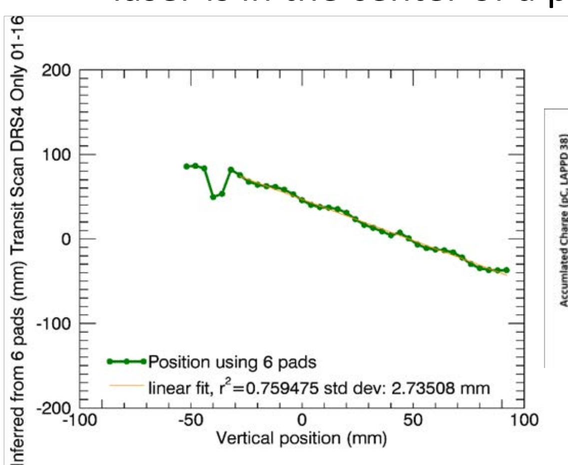
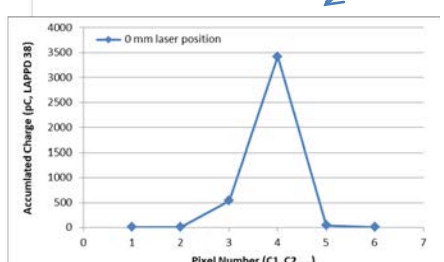
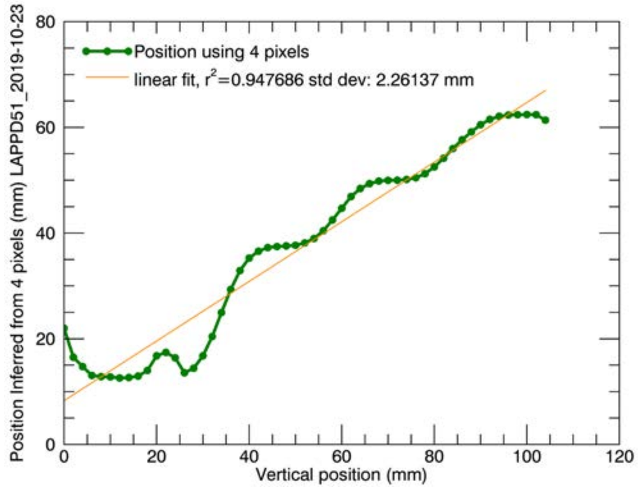




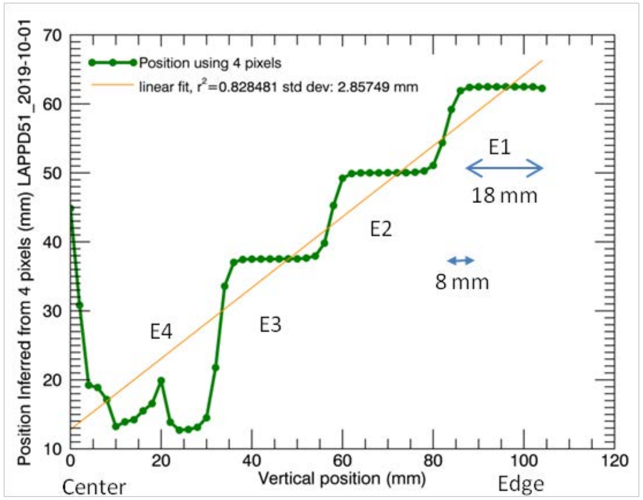




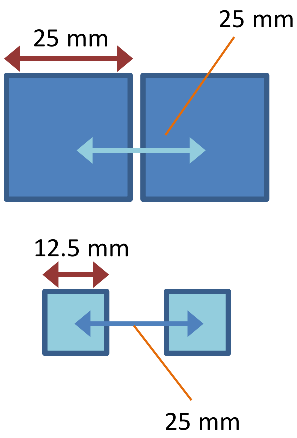
- Apparent width of MCP pulse footprint is 18 mm.
- Capacitive coupling is not exclusively vertical, above a pixel.
- Gaps between pixels:
- Provide a digital-like response
- Reduce electronics channel count.

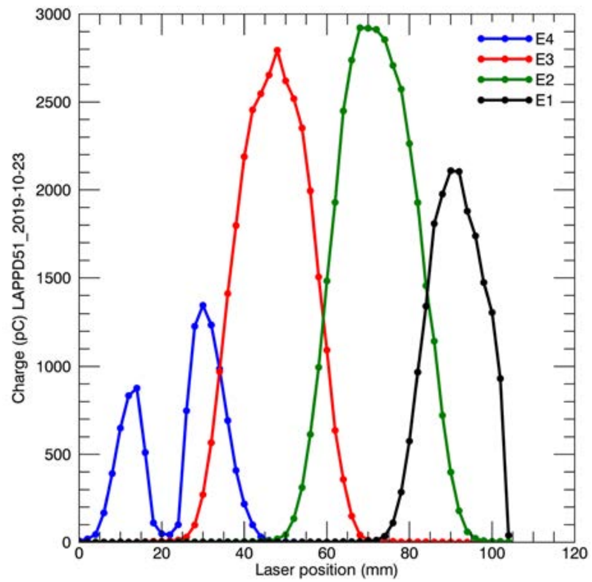


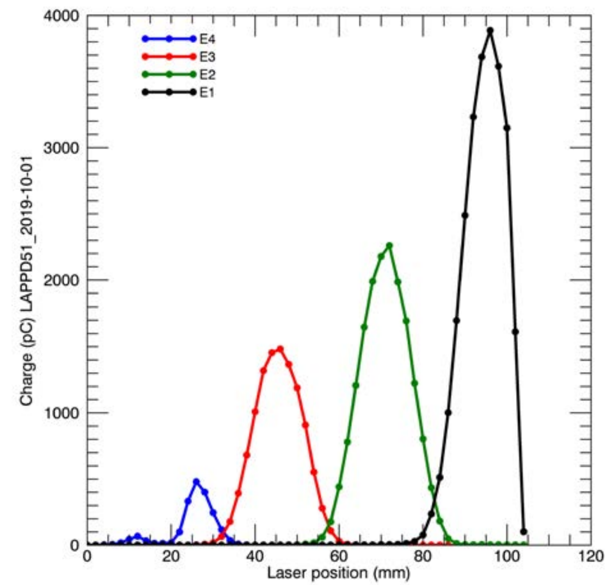
25 mm pixels, 25 mm pitch, ~no gaps between pixels



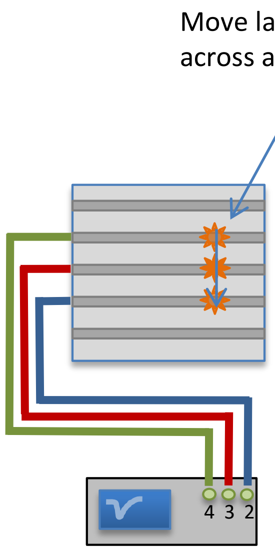
12.5 mm pixels, 25 mm pitch, gaps between pixels

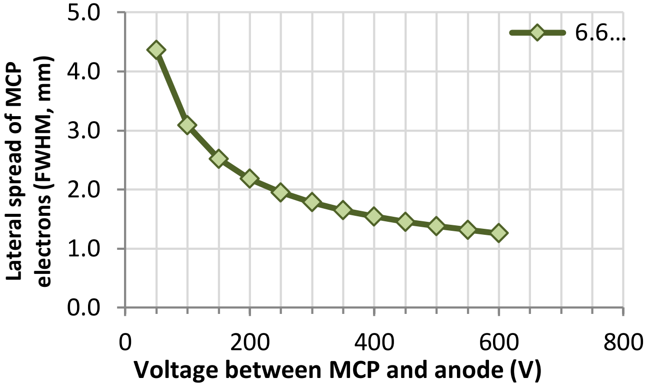


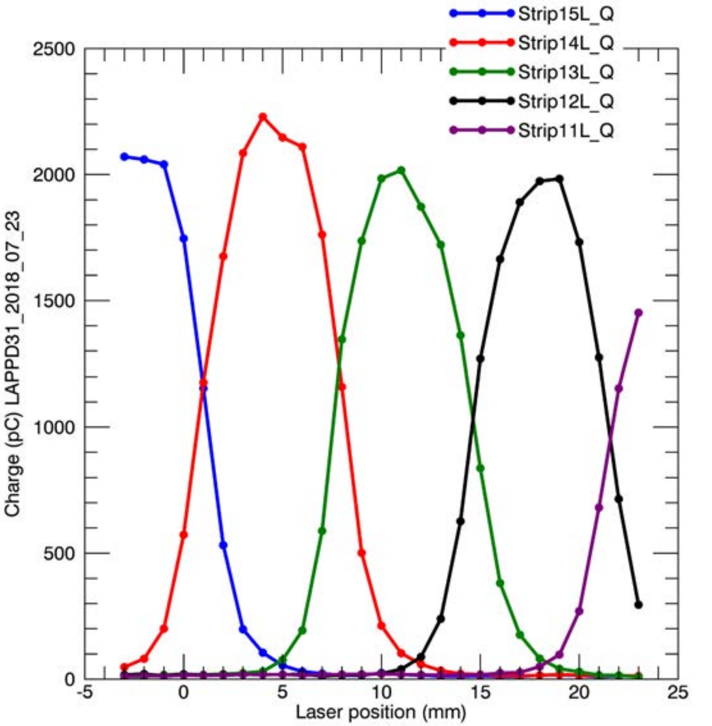


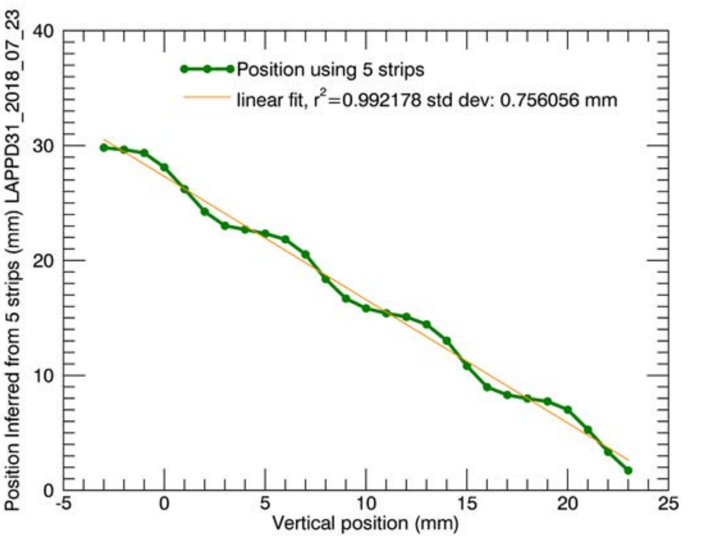


LAPPD31 Position Measurements: Transit across adjacent strips with an internal stripline LAPPD









- Position may be calculated at a higher resolution than the width of the strips using **centroiding**.
- The maximum amplitude here is strip-dependent, presumably from **spatial gain** variations
  - Spatial gain maps are important for LAPPD use.
- FWHM of the strip response is: **7.6 mm**
  - Strip width: ~5.2 mm, gap ~1.7 mm
  - Laser spot width: ~1 mm
  - Lateral spreading of electrons (~3 mm FWHM)

Narrowing the Pixellated Response

Narrow the MCP pulse itself:

1) Increase the voltage between the MCP and anode – minimal returns here
2) Increase the voltage between the MCPs – this might reduce the gain at high rates, because fewer microchannels are involved in the second MCP.
3) Decrease the gap between the MCP and anode – this is the best step, with no downside.

Decrease the lateral capacitive coupling on the pixel side of the anode:

1) Make the pixels as small as possible, limited by acceptable signal size.
2) Leave a gap between pixels, to reduce capacitive coupling of the neighbor pixel to the MCP charge pulse. This will degrade somewhat the active area of the signal board, but it will digitize the pixel response and moderate the electronics channel count.
3) Tentative – add a ground checkerboard on the interior anode
4) Tentative - add a ground trace between external pixels

The pad count for an LAPPD with no gaps between pixels:

Pixel size (mm)	Qty
25 mm	64
6 mm	1,111
5 mm	1,600
4 mm	2,500
3 mm	4,400

Summary

- Rate response and recovery after high rate operation are similar to MCP-PMTs with conventional MCPs.
- Transit time variations are in the 50-80 pS range, with in-house measurements.
- The 3 mm pixellated, capacitiviely-coupled signal board produced promising results on the LAPPD.
- Pixel digital response may be improved by narrowing the MCP pulse on the anode and modifying the signal board itself.