aPeak — *Innovation in Single-Photon Detection*

64-Pixel GPD Array for WLS Fiber Readouts

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OBJECTIVE AND INTRODUCTION

OBJECTIVE

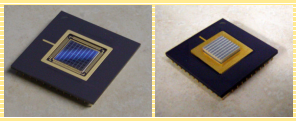
Develop, in high-volume manufacturing CMOS, 64 pixel Geiger Photodiode (GPD) arrays capable of reading out 64 x 1mm core diameter wavelength shifting fibers (WLS) with tracking and calorimetric output.

INTRODUCTION

Low cost, large arrays of GPDs with performance similar to multi anode PMTs (MAPMT) would provide High-Energy and Nuclear Physics experiments with new compact solid-state detectors capable of withstanding high magnetic fields.

RESULTS

In 2005, aPeak Inc. has extended the design of its single-pixel GPD to 64-pixel GPD arrays arranged in a two-dimensional matrix of 8x8 pixels with 1.25 mm center-to-center distance. This layout allows to read simultaneously 64 x 1mm diameter core fibers with up to 1.2 mm core + clad diameter and maximum 0.05 mm fiber outer diameter tolerance. Pixel segmentation, consisting of multiplexed small area GPDs with on-chip quenching circuits, allows extracting low-resolution calorimetric information from the output signal amplitude.



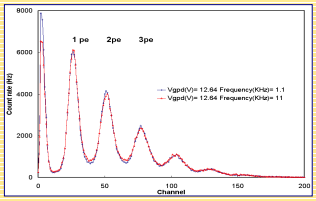
- the 64 pixel array is packaged in an open cavity PGA108 lead ceramic package with 64 GPD outputs and additional pins used for in-line process control monitors (left photo).
- it allows monitoring on-chip temperature, with accuracy better than 0.1°C,
- the detection surface is protected with a fiber optic window with numerical aperture NA=1 that allows safe coupling of 64 fibers to the GPD array. Large NA allows very low insertion losses when used with today's WLS and scintillating fibers with NA ≤ 0.72 (right photo).

1 Calorimetric performance

Each pixel contains 16 sub-pixels and on-chip passive quenching. This configuration allows acquiring either tracking or limited-bit calorimetric information.

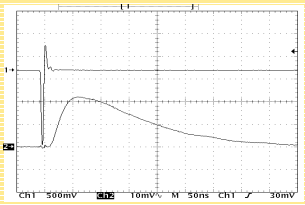
Calorimetric results

Pixel layout



Single photoelectron discrimination is achieved below –20 °C. These spectra were acquired at –60 °C for 1.1, 11 kHz event rate.

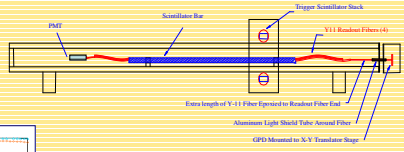
2 Pulse Output

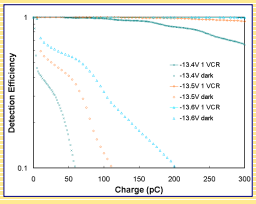


GPD pixel response to a green, pulsed LED.
- LED driver pulses (approximately 5ns) are shown on Ch1.
- Ch2 shows the GPD pixel output.

3 Detection Efficiency and Noise

MINOS style setup





- Scintillator bars were illuminated by blue LEDs to produce photon signals in selected fibers.
- GPD arrays were tested at photons intensity/pulse equivalent with photons generated and collected in a WLS fiber embedded into a MINOS type scintillator bar, crossed by muons.
- Photon intensity is defined as 1VCR≈220 photons/(mm^2 x pulse).

4 Breakdown Voltage vs. T and Uniformity

Breakdown voltage = 13.5V
Breakdown voltage STDEV / array of 64 pixels = 0.02V
Variation of the breakdown voltage with temperature = 12 mV/°C
Breakdown voltage run-to-run repeatability = 0.03V

5 Reliability

Single GPDs processed in the same technology used for 64-pixel array fabrication were previously tested for reliability using:
- Standard room temperature 1,000 hour test (LTOL) open cavity package
- Accelerated high temperature test (HTOL) open cavity package
- 26,000 hours room temperature extended test (LTLL) open cavity package

RESULTS
LTOL – no degradation @ 95% confidence level;
HTOL – 25% increase of the dark count rate for an equivalent of 1 year moisture - induced contamination and 7 years of ion - induced contamination;
LTLL – 25% increase of the dark count rate after 26,000hours (3 years) of continuous operation.

Paper on the radiation hardness of this GPD technology to be presented in the companion paper N09-7

CONCLUSIONS

- A monolithic 64 pixel GPD array was fabricated to allow both tracking and limited calorimetric detection.
- The GPD array has a low-loss optical interface with NA=1, capable of interfacing to most high-collection efficiency WLS and scintillating fibers.
- The array was tested for operation down to –60 °C
- Its low breakdown voltage (13V) allows easy interfacing with newest logic standards (LVCMOS, GTL, HSTL, etc.)
- GPD pixels are capable of single-photoelectron discrimination
- They achieve 100% detection efficiency at typical photon intensity generated in WLS fibers

1 Advantages of Using High-Volume Manufacturing

GPD Array Fabrication
Advantages of aPeak's technology

- High-volume manufacturing GPD –CMOS / proprietary layout library
- Die fabrication is certified ISO 9002 (you get all these goodies i.e. QC, process reliability, repeatability, SPICE files)
- Five-year technology lifetime
- 8-10 week guaranteed die fabrication
- Typical 1-month design turnaround
- 4-month GPD array custom design, fabrication and burn-in for qualified configurations

2 Potential Applications

- 3D imaging
- Single molecule detection
- Tracking with scintillating fibers
- Limited calorimetry
- Cargo radioactive materials imaging using crisscrossed scintillating fiber arrays
- Neutron imaging in CW or pulsed mode

ACKNOWLEDGEMENTS

This work was supported by grant DE-FG02-03ER83607 from the U.S. Department of Energy.
The authors thank Robert Wilson (CSU) for his valuable feedback on array evaluation and experiment design; Joshua Rau (aPeak Inc.) and Qinglin Zheng (CSU) for performing calorimetric and detection efficiency measurements

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