High Rate Picosecond Photodetector (HRPPD) Program

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Program Overview

Incom is using a 3-phase approach to address the needs of the nuclear physics community.

1. Through the current Phase IIA SBIR program, fully characterize and optimize the Gen-II LAPPD readout.
   - Maximize coupling to the external readout board my minimizing the anode thickness while maintain mechanical stability
   - Optimize the internal resistive anode by exploring materials, patterns, and resistivity
   - Design and test the limits of a pixelated readout board
2. Use a 10 cm × 10 cm version of the Gen-II LAPPD to further optimize detector design,
   - Taking advantage of the 10 µm pore MCPs
   - Reduced gap spacing for improved timing resolution and B-Field tolerance
   - An unobstructed FOV (no window support)
3. Development of a novel anode to advance the LAPPD performance beyond what is capable in the current designs
   - Decouple the electrical and mechanical properties of the anode so each can be independently optimized.
   - Phase I DOE SBIR Program (funding period Feb-Nov 2020)

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Motivation

- The 20 cm × 20 cm Gen-II LAPPD program has successfully demonstrated capacitively coupled readout
  - Current focus is on demonstrating capacitive coupling using 25 mm, 12 mm, 6 mm, & 3 mm, pixelated anodes, evaluating signal quality and the degree of undesirable cross coupling of signals.
- Gen-II plans:
  - Optimize readout for high rate experiments
    - Signals seen over whole area for each event due to charge dissipation in internal resistive anode
      - Direct readout (leak prone)
      - Pixelated resistive anode (resistive pads with low resistance grid, need high fidelity metallization)
  - Coupling through full anode thickness is inefficient, resulting in small signals
    - J-Lab testing has shown that large signals are needed for high radiation environments to account for the signal amplitude loss over long cable runs.
    - Need much better coupling to achieve required signal strength by reducing anode thickness without compromising mechanical rigidity.
  - B-field tolerance
    - B-Field tolerant optimizations have not been implemented in a full LAPPD
      - Small pore MCPs, Small gap spacing, non-magnetic materials, etc.
- A 10 cm device (HRPPD) will provide a testbed for anode and photocathode development and optimization.
  - Lower cost and faster development time.

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Detector Features

Feature	Large Area Picosecond Photodetector (LAPPD™)	High Rate Picosecond Photodetector (HRPPD)
Application	Picosecond Time of Flight	PET, TOF, UV Imaging
Detector Size	20 cm × 20 cm	10 cm × 10 cm
UHV Package Design	X-Spacers window support -> creates dead zones	X-Spacer free -> large effective area
Window	Fused Silica, B33 Glass	UV Fused Silica, MgF_2
λ Sensitivity	200 (300 for B33) - 600 nm	115 - 400 nm
Photocathode	Bialkali	UV optimized Bialkali
MCP Pore Size	20 µm & 10 µm	10 µm
MCP Stack	Not yet optimized	Minimized Gap Spacing
Anode	Direct readout of thick film strips or capacitive readout with application specific patterned anode	High density pixelated anode with direct or capacitive readout
Lower Tile Assembly	Walls hermetically sealed to anode	Walls hermetically sealed to anode
Connections	Through Frit Seal -> 2 side abuttable	Through anode -> 4 side abuttable with minimum dead space

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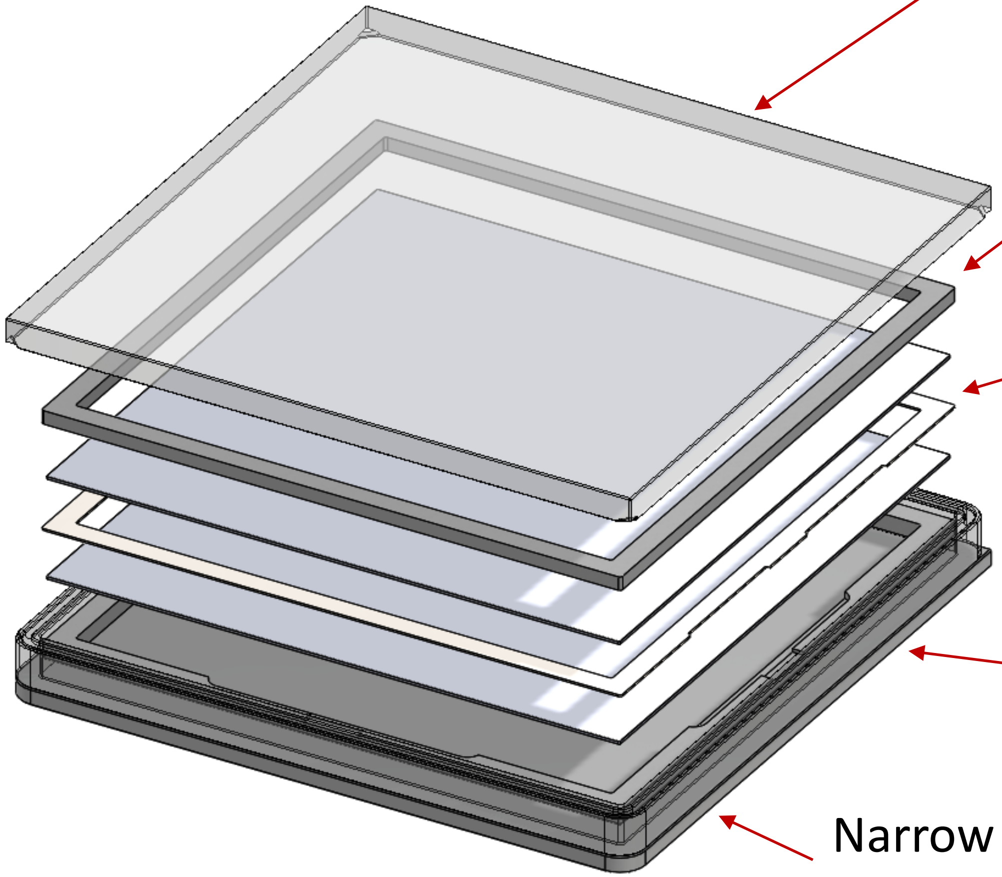
Prototype Design



Fused Silica, B33, or MgF_2 (115 nm cutoff) window

Unsupported window with no obstruction 10 cm × 10 cm field of view

Reduced gap spacing and small pore MCPs (10 µm) for B-field tolerance

Innovative, new process anode for direct or capacitive coupling readout

HV and anode connections on bottom (4-side abuttable)

Narrow Sidewall and spacers for reduced deadspace 0.35” [8.89 mm]

Novel Anode Concept

- Using a new process to produce multi-layer, monolithic, microelectronic devices where the entire ceramic support structure and any conductive, resistive, and dielectric materials are processed together to achieve the following;
  - Decouple the electrical and mechanical properties of the anode so each can be independently optimized.
  - Excellent high frequency properties
  - Embedded passive components
  - High electrical conductivity of metal patterns
  - Very high fidelity features
  - Leak-free thru vias
- Risk
  - The process we are proposing to use has been established for small electronic packaging for many years.
    - However, unclear whether the required tolerances (TIR <0.002”) can be maintained over a 10 cm anode during tube processing and anode manufacturing.
  - Expensive in small quantities

Development Timeline

Phase I	Specific Aim	Months								
		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Task 0	Program Management	■	■	■	■	■	■	■	■	■
Task 1	CC Anode Design	■	■	■	■	■	■	■		
Task 2	CC Anode Testing				■	■	■	■	■	■
Task 3	10 cm Detector Design	■	■	■	■					
Task 4	10 cm Detector Assembly			■	■	■	■	■	■	■
Task 5	Measurement & Testing						■	■	■	■
Task 6	Commercialization & Planning						■	■	■	■

Milestone	Requirement for Success	Expected Completion
• **Leak tight seal of SiO_2 window to body wall**	• Leak rate <10-9 Torr L/s	Month 5
• **Leak tight seal of standard Al_2O_3 anode to sidewall**	• Leak rate <10-9 Torr L/s	Month 5
• **Leak tight seal of CC anode to sidewall**	• Leak rate <10-9 Torr L/s	Month 8
• **Fully functional open face 10 cm detector with CC anode**	• No change in MCP gain, uniformity, background • No voltage contacts shorted	Month 9
• **Fully functional 10 cm tube sealing with resistive anode and MCPs (Na_2KSb photocathode/SiO_2 window)**	• Functioning in room environment • No voltage contacts shorted • No change in MCP performance • QE of > 15% at 365 nm	Month 9
• **Fully functional tube sealing with CC anode and MCPs (Na_2KSb photocathode/SiO_2 window)**	• Functioning in room environment • No voltage contacts shorted • No change in MCP performance • QE of > 15% at 365 nm	Stretch Goal

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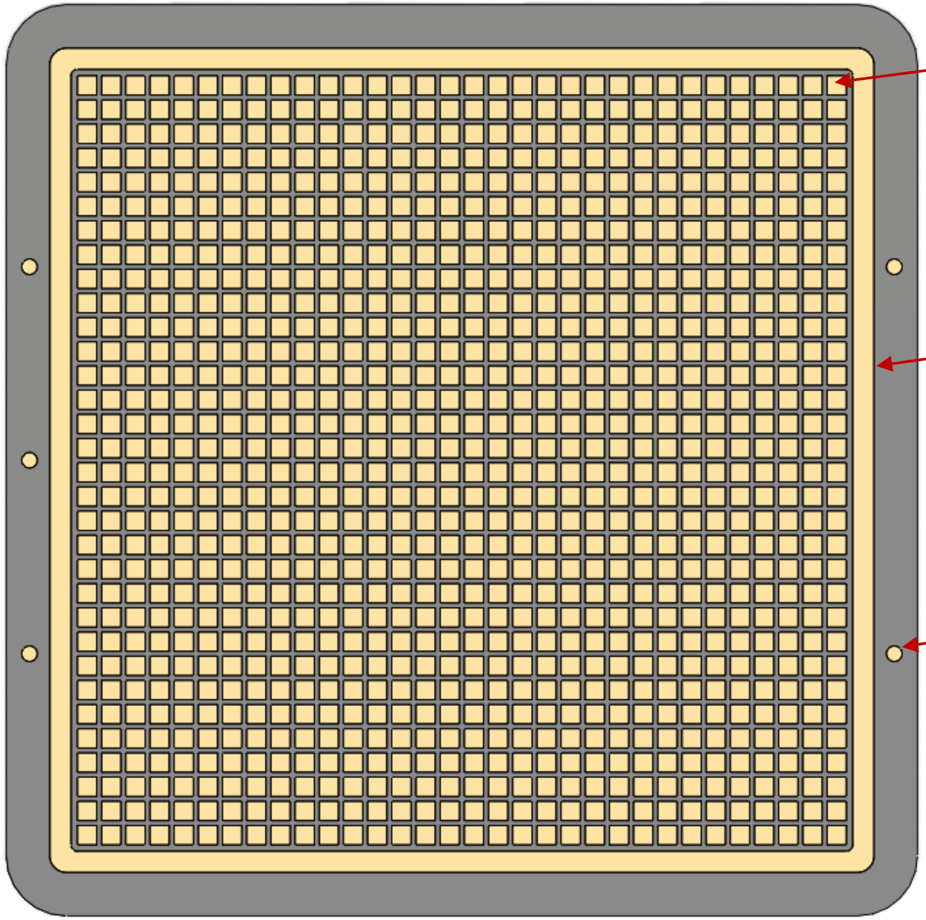
Anode Layout



32 × 32 array of pixels (0.100” on a 0.125” pitch)

- To be optimized for reduced crosstalk

Ground plane

High Voltage feedthroughs