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UV Detectors for POLLUX

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Outline

- Proposed detector technologies for POLLUX
- MCP UV Imager technologies
  - Photocathode choice and detector format
  - Large area MCP technology
  - ALD-MCP performance enhancement
  - Square format MCP detectors
- High speed readout techniques
  - Cross-strip
  - Centroiding Pixel Array

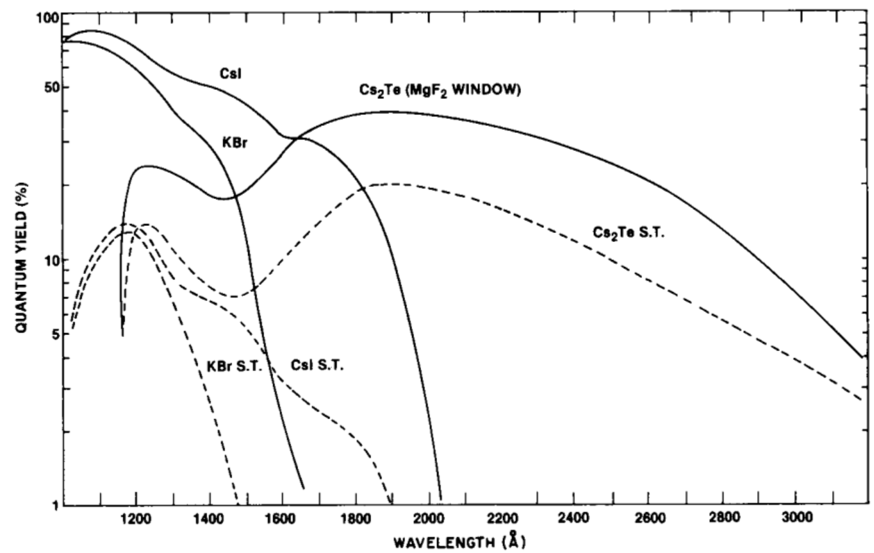
Proposed detector technologies for POLLUX

- FUV detector
  - 98-123 nm
  - Format (tbd) nominally 150 x 64.2 mm^2
  - Open-faced MCP coated with alkali halide photocathode
- MUV detector
  - 119-220 nm
  - Format (tbd) nominally 152 x 44.8 mm^2
  - Sealed tube MCP
  - Semi-transparent photocathode e.g .Cs_2Te – solar blind
- NUV detector
  - 210-390 nm
  - Format (tbd) nominally 90.5 x 44.9 mm^2
  - CCD or sCMOS 4k x 4k $pixel^2$ format, 13 µm pixel
  - Enhancement using graded AR coating, or scintillator coating?

MCP UV Imager technologies

FUV Photocathode & Detector

- Alkali halide deposited on MCP
  - Typically CsI or KBr
  - Much space heritage
  - Sensitive to incident angle
    - Choose MCP bias to match optical design
- Open tube configuration
  - Requires door mechanism
  - Higher mass, complexity, cost
  - Performance trade-off:
    - Repeller grid enhances QE at expense of spatial resolution

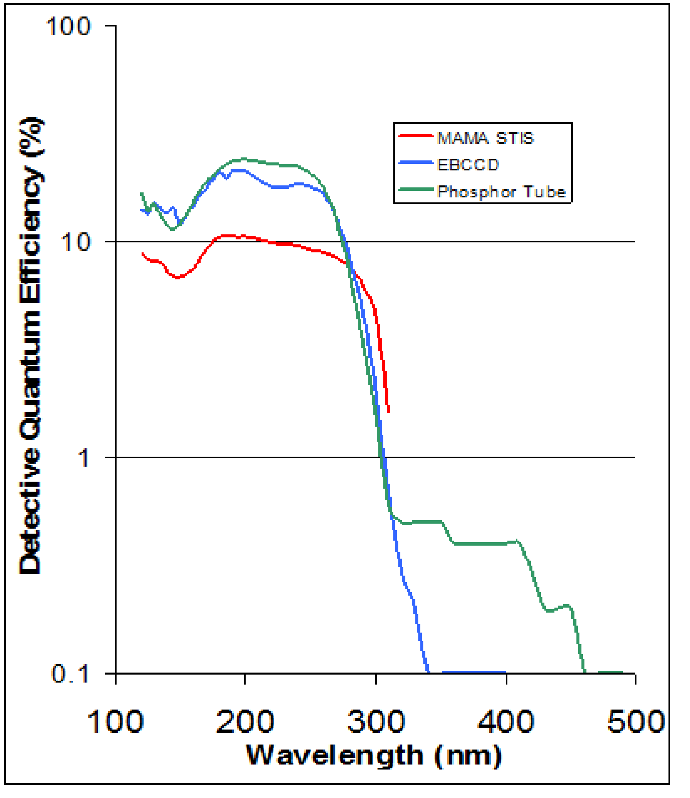


Comparison of UV photocathode materials in opaque and semi-transparent (S.T.) modes – Carruthers, 2000.

N.B. not coated MCPs

MUV Photocathode & Detector

- Solar-blind Cs_2Te
  - QE: 34% at 254 nm
    - cf. HST-STIS QE: 9%
  - Optical wavelength rejection
    - two orders of mag. >350 nm
    - zero red leak
  - Cut-off wavelength can be tuned
  - Short wavelength performance needs characterization
- Sealed tube
  - No door mechanism or contamination
  - Lower mass, complexity, cost
  - Downside: MgF_2 window cut-off



MCP UV Imager technologies

- New technology developed for Large Area Picosecond Detector (LAPPD)
  - LAPPD collaboration – instigated by Frisch, Chicago
  - LAPPD – primarily developed for HEP apps
- Glass capillary array
  - Developed by Incom – fibre optic heritage
  - Borosilicate construction – up to 200 x 200 mm^2
- ALD technology originally developed for Si-MCP
  - Arradiance Inc. Nanofilm technology
  - Provides resistive and emissive layers
  - Order of magnitude improvement in detector lifetime

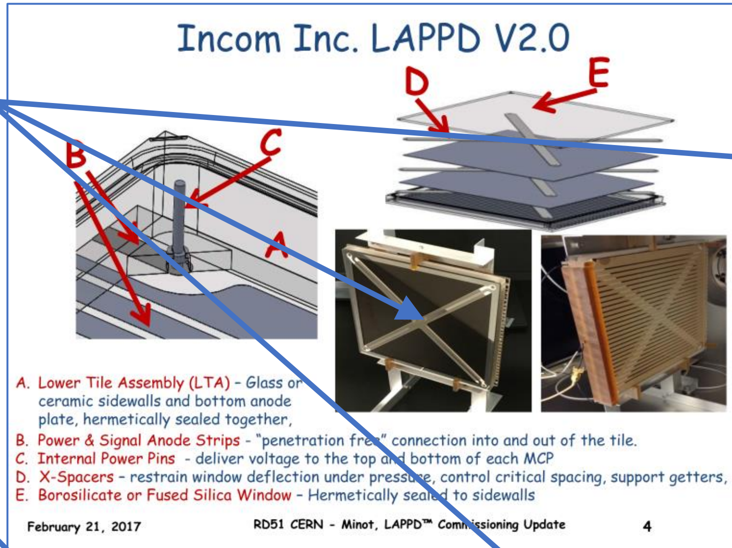
MCP UV Imager technologies

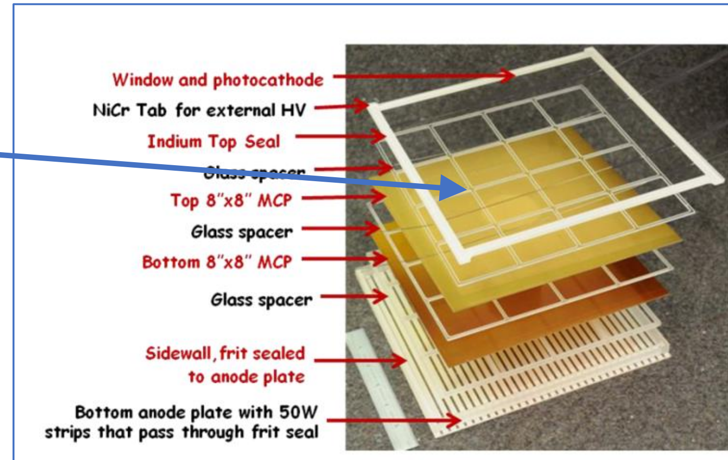
- Glass Capillary Arrays
  - Borosilicate glass – more durable that lead-glass MCPs
    - e.g. similar to Pyrex
  - Manufactured by hollow core draw – no etching
  - Stronger, less warpage
    - Allows MCPs > 100 mm – limited by lead-glass fragility
  - No lead content, reduced Potassium, Rubidium
    - Lower gamma ray x-section and intrinsic background
- Atomic Layer Deposition
  - Resistive layer for continuous dynode
  - Emissive layer for electron gain
  - No leaching of hydrogen cf. lead-glass MCP
    - Reduced photocathode ageing and MCP gain sag
    - Longer detector lifetime

Important issues from LAPPD

Dead area due to support bars

20 µm pore size – limits resolution



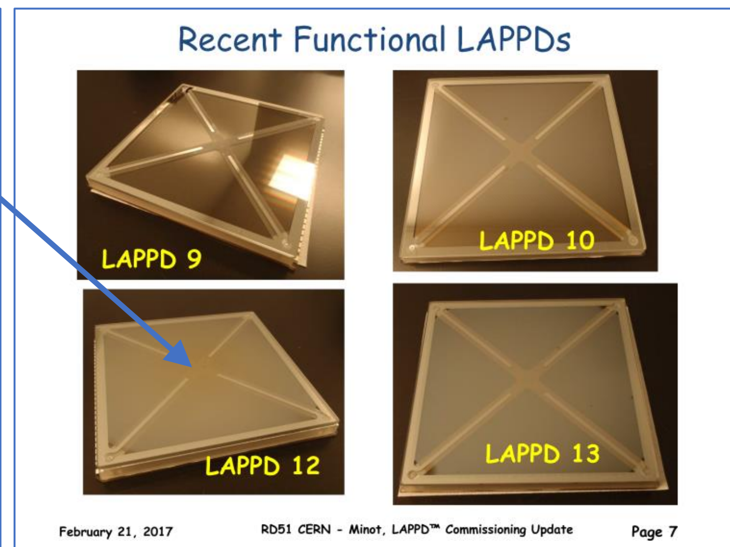


Craven - Large Area Micro-Channel Plates for LAPPD, 2014

INCOM LAPPD: "LARGE AREA PICOSECOND PHOTODETECTOR"

DESCRIPTION	DEMONSTRATED PERFORMANCE
Housing Size (mm)	220 mm X 230 mm X 22 mm thick
Housing Material	Borosilicate, Fused Silica or Ceramic
Window	Borosilicate, or Fused silica
Photocathode	Multialkali (K_2NaSb)
Wavelength sensitivity	300 nm to 700 nm
QE (@ 365 nm and 23 C)	≥ 20%
Microchannel Plates	• Chevron Pair Active Area = 203 mm X 203 mm • ALD-GCA MCPs with an Al_2O_3 SEE layer • 20-micron pores, 65% Open Area, Typical Gain = 10^7
Anode configuration	28 metallic strips, nominally 50 ohms
Maximum Operating Voltage	3000 V
High voltage distribution	Five independent taps voltage control to the photocathode and entry and exit of MCPs
Time Resolution	Single-PEs: Typically < 60 ps, Large pulses < 5 ps predicted
Spatial Resolutions	Single-PEs: Several-mm, Large pulses: sub-mm
Low Noise	Low-alkali, borosilicate glass MCPs contain minimal K40

February 21, 2017 RD51 CERN - Minot, LAPPD™ Commissioning Update 25

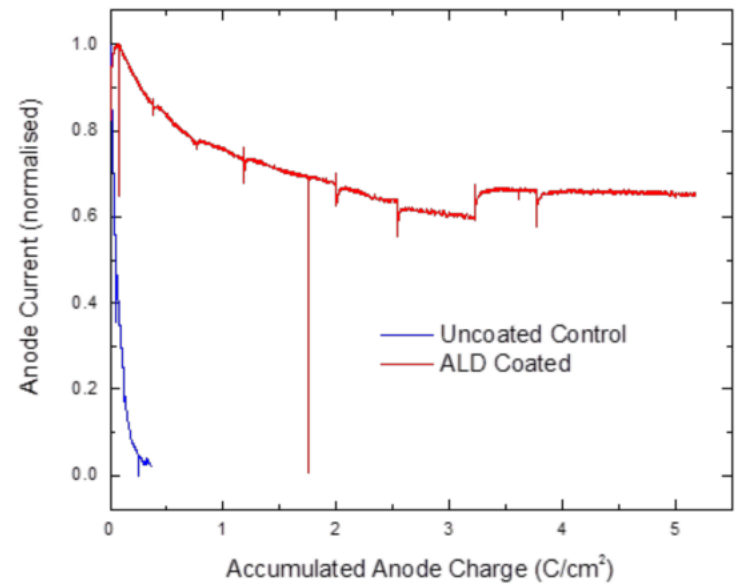


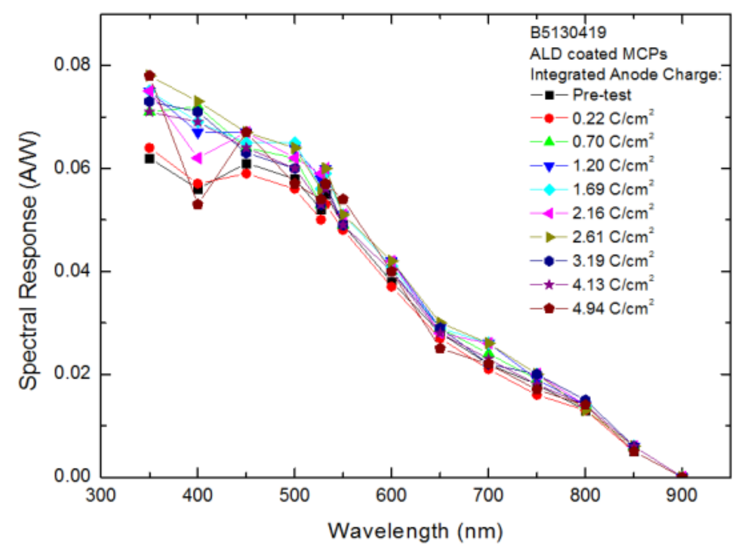
Large area detector issues

- 20 μm resolution – requires smaller (10 μm) pore ϕ
  - LAPPD only down to 20 μm pores so far
  - Rocket flight will only prove 40 μm pore technology
- Typical L/d of 60:1 → 1.2 mm thickness
  - 10 μm pore MCPs will be 600 μm thick!
  - Practical limit to size/thickness ratio – when will it be reached?
  - If feasible, likely to need even more internal support
- Inherent dead-space due to support bars
  - alternative would be to mosaic smaller detectors
  - Added advantage of redundancy
- Semi-transparent photocathodes
  - Proximity focussing gap limits resolution – especially in the UV
  - Typically scales with detector size due to practicalities
  - Spatial resolution limited by transverse photoelectron momentum
- BUT – there is time and people have inclination to develop this technology

ALD enhanced MCPs

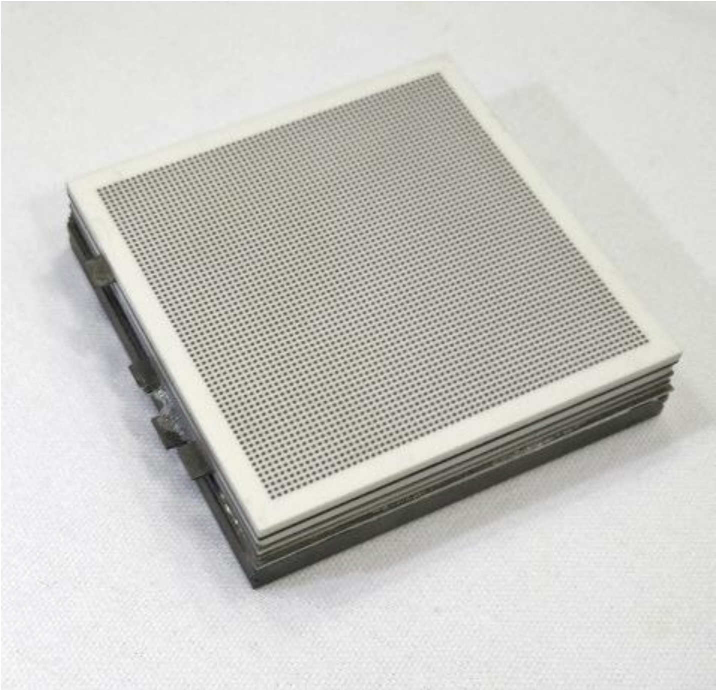
- ALD coated conventional MCPs
- Enhanced secondary electron emission
  - Higher QE due to higher photoelectron detection efficiency
  - Lower operating voltage due to higher gain per bounce
- Increased detector lifetime due to reduced MCP outgassing
  - ALD seals in MCP adsorbates
  - Reduces ion feedback events
  - Reduces photocathode QE fatigue
  - Reduces MCP gain loss





Square format MCP detector

- Thin-walled square tube MCP detector for LHC
- TORCH-Cherenkov detector element of LHCb upgrade
- Thin wall (3.5 mm) allows close packing of tube arrays
- Minimal dead space between active regions
- LHCb programme has enhanced to TRL6
- 64 x 64 pixel^2 multilayer ceramic
- 60 x 60 mm^2 with 57 x 57 mm^2 active area

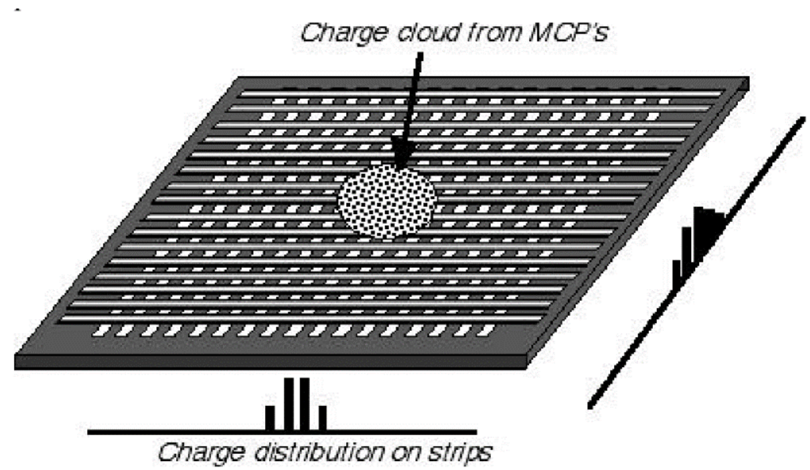


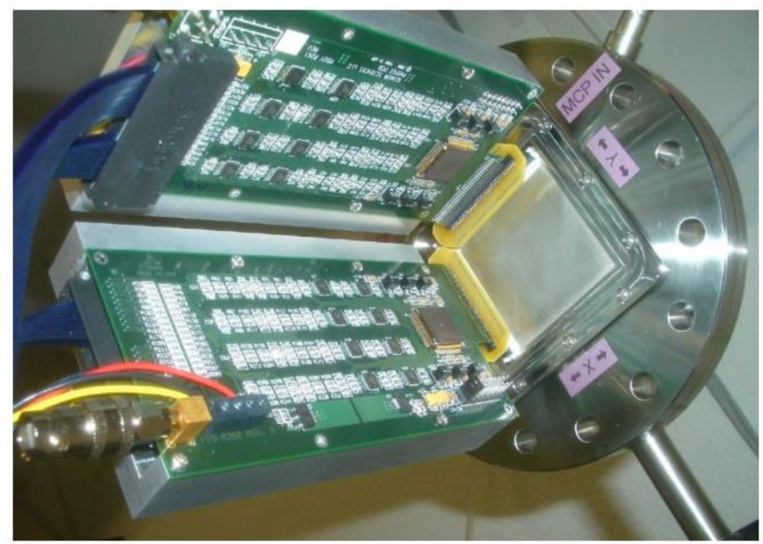
64 x 64 pixel^2 multilayer ceramic readout

High speed readout techniques

Cross-strip – Siegmund, Berkeley

- Parallel cross strip (PXS) readout
- < 20 µm FWHM spatial resolution
- count rates ~2 MHz
- Lower gain requirement
- temporal resolution of ~ 1ns
- TRL 6 by using custom ASICs
- lower the power, mass and volume
- "standard" 50mm square active area MCP detector
- qualified for flight (temperature, vacuum, vibration)
- new 50 x 50 mm XS detector (2014)



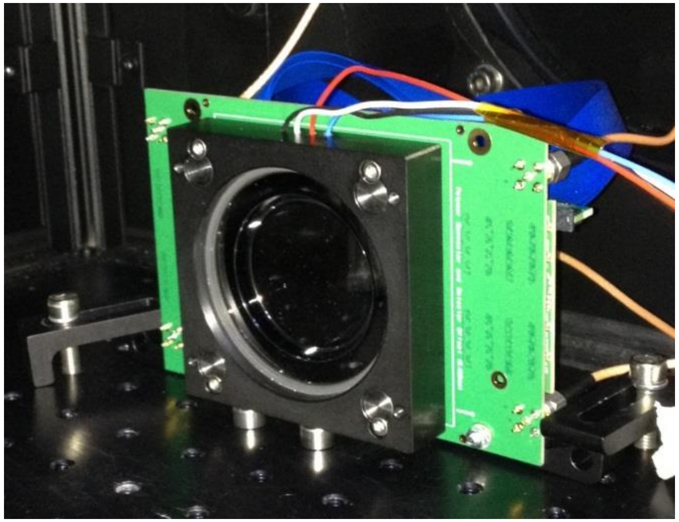


Vallerga 2016

Centroiding Pixel Array

- Square electrode array using "Image Charge"
- Event spread over small number of localised electrodes
- 40 mm CPA prototype at Leicester
- 32 x 32 pixel^2 multilayer ceramic
- Currently optimised for timing electronics
- PetSYS 256-channel event timing ASIC-based system (TOFPET)
- Time over threshold → pulse amplitude for sub-pixel centroiding
- Combined imaging and event timing ≤ 100ps, 600k event/s/channel
- Investigating fast, lower noise multichannel ASICs
    - E.g. TARGET, DRS4 digitizers

  → Higher precision centroiding at high event rate



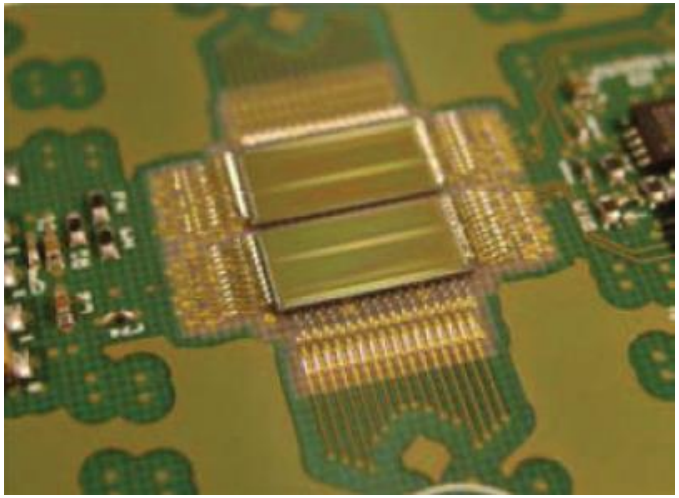
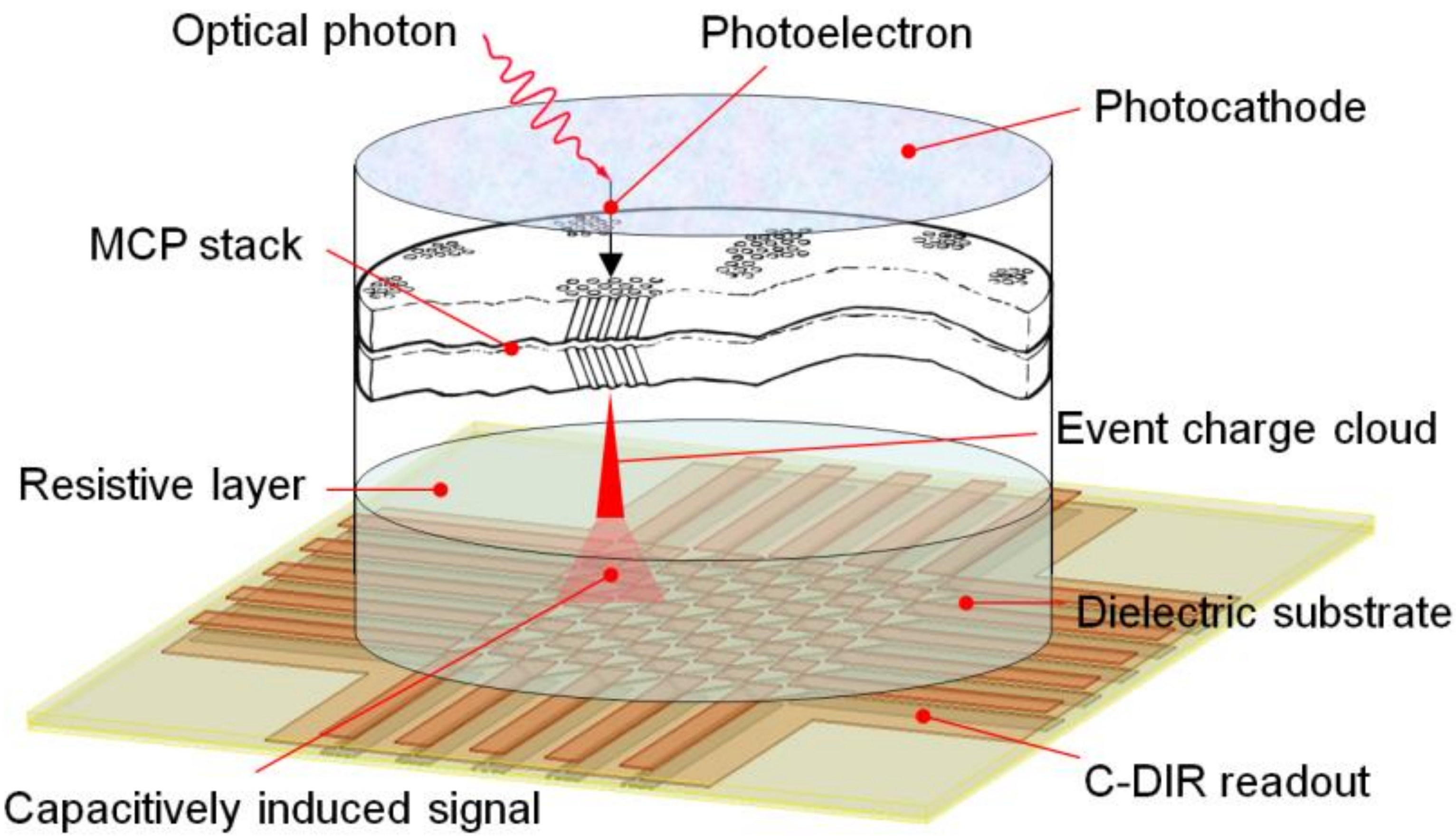


Image Charge technique



N.B. Diagram show a different readout to CPA

Conclusions

- New glass capillary array + ALD MCP technologies important irrespective of MCP size
- Large MCPs (>100x100 mm^2) will become available, but how useful given their intrinsic dead-space?
- Long but narrow detectors (e.g. 150x60 mm^2) may escape this issue
- Mosaiced detectors could be a competitive solution
- Mosaiced detectors also provide levels of redundancy
- MCP electronic readouts with multichannel ASICs suitable for large readouts
- Offer improved local count rates and dynamic range cf. alternatives e.g. iCMOS, iCCD