Microchannel plate single photon imaging detectors for astronomy

Do they need to be replaced?

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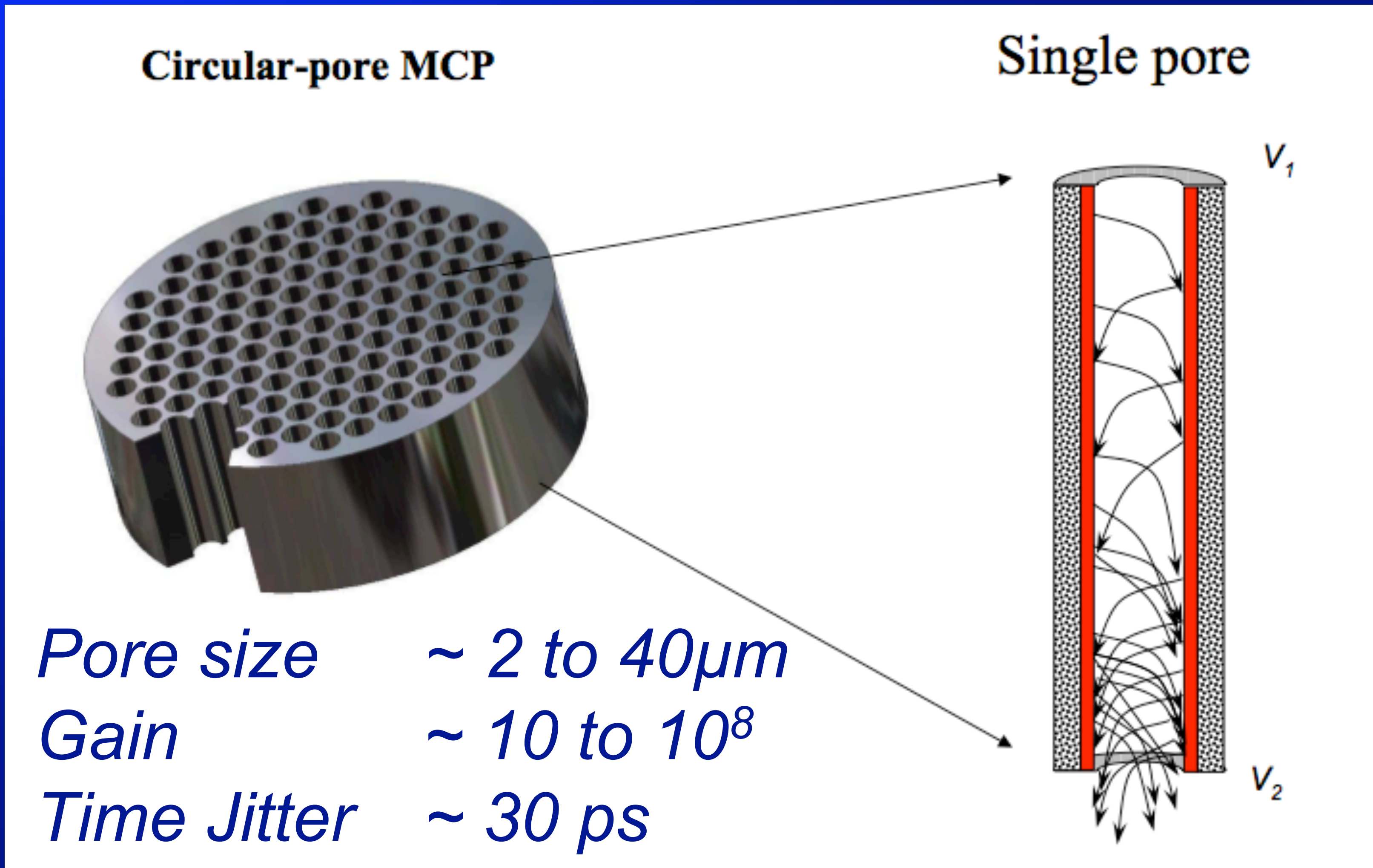
Microchannel Plate

electron amplifier that retains position information



Pore size ~ 2 to 40µm

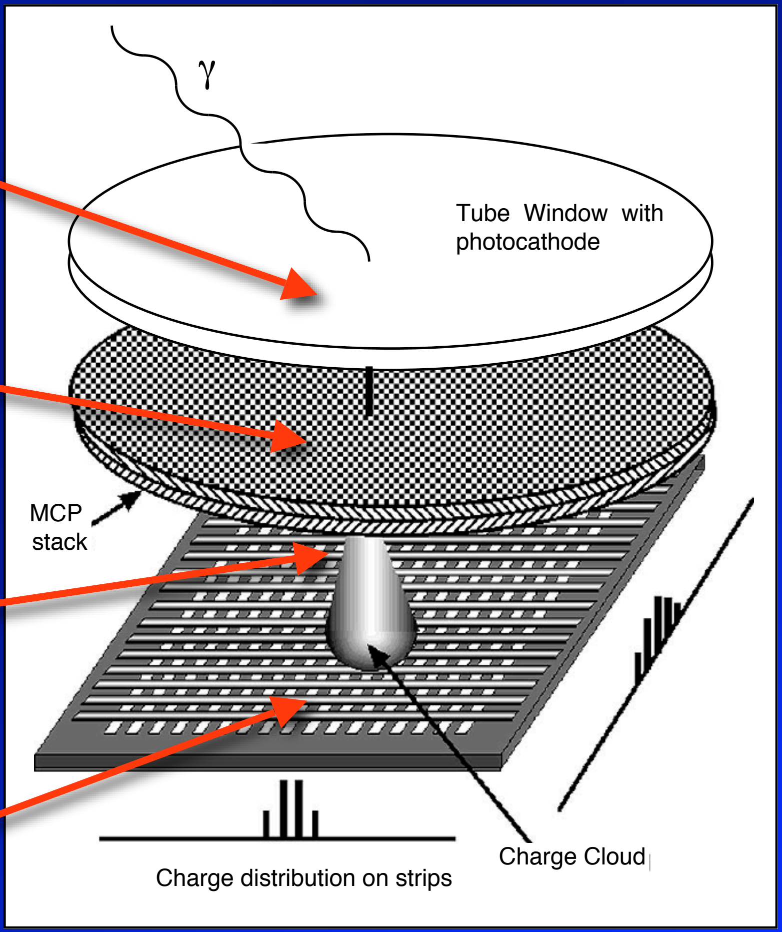
Gain ~ 10 to 10^8

Time Jitter ~ 30 ps

Microchannel Plate Detector

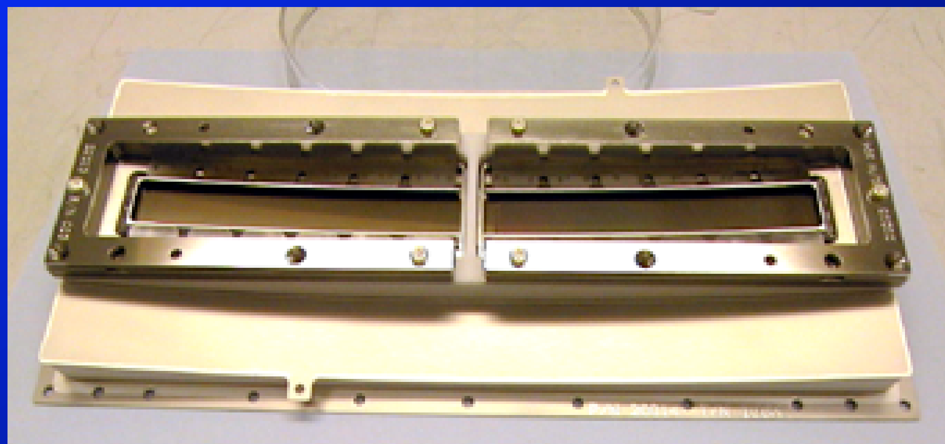
Photon counting, imaging, with event time tagging

- Photocathode converts photon to electron
- MCP(s) amplify electron by 10^4 to 10^7
- Rear field accelerates electrons to anode
- Patterned anode measures charge centroid



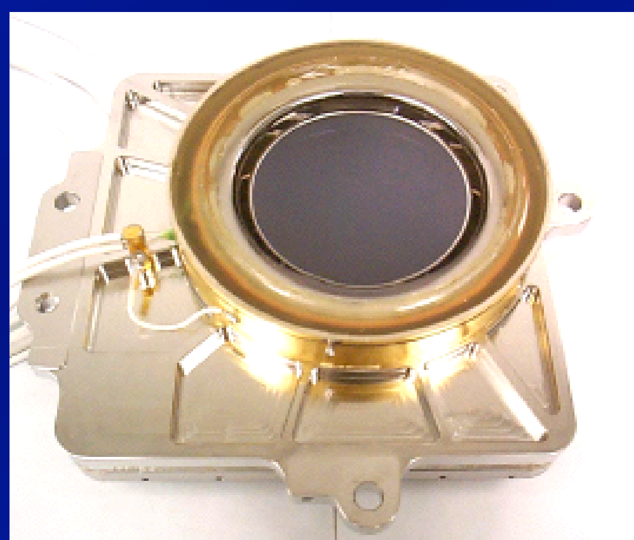
MCP Detectors at SSL Berkeley

COS FUV for Hubble (200 x 10 mm windowless)



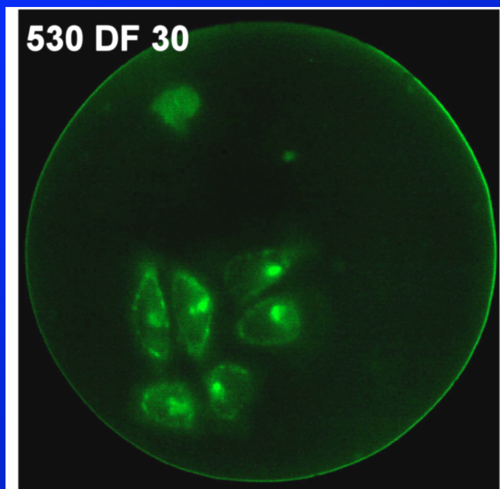
18 mm Optical Tube

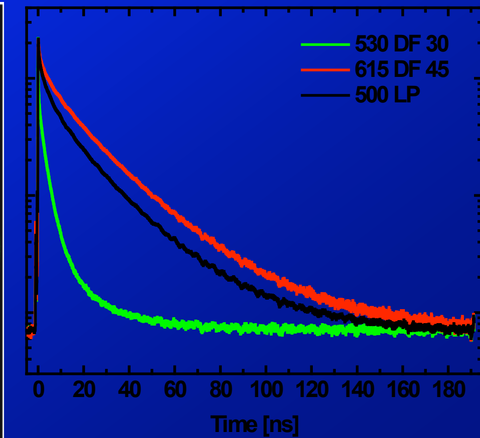
GALEX
68 mm NUV
Tube



200+ “detector years” in space including mission to Pluto

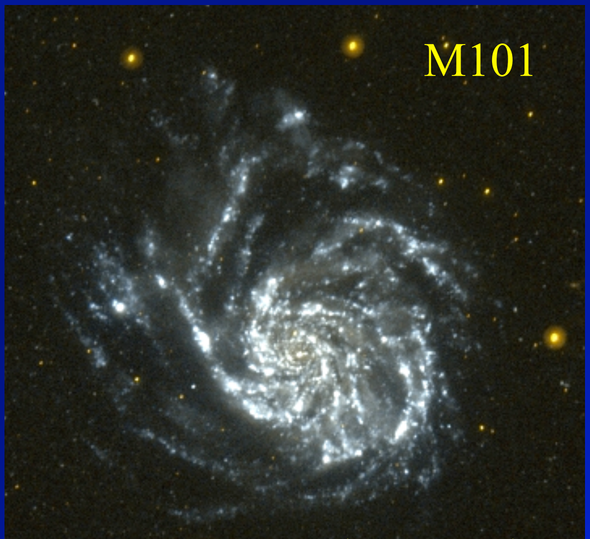
Microchannel Plate Sensor Applications





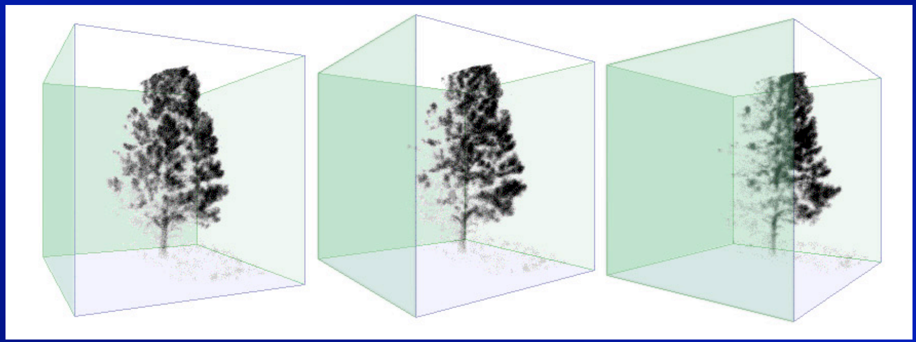
Fluorescent dye decay time

Biological lifetime fluorescence imaging (UCLA)



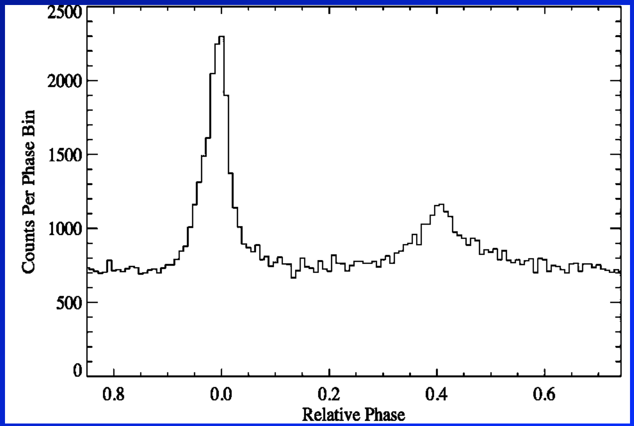
UV Astronomy (GALEX)

Low Light Ladar - 3D imaging



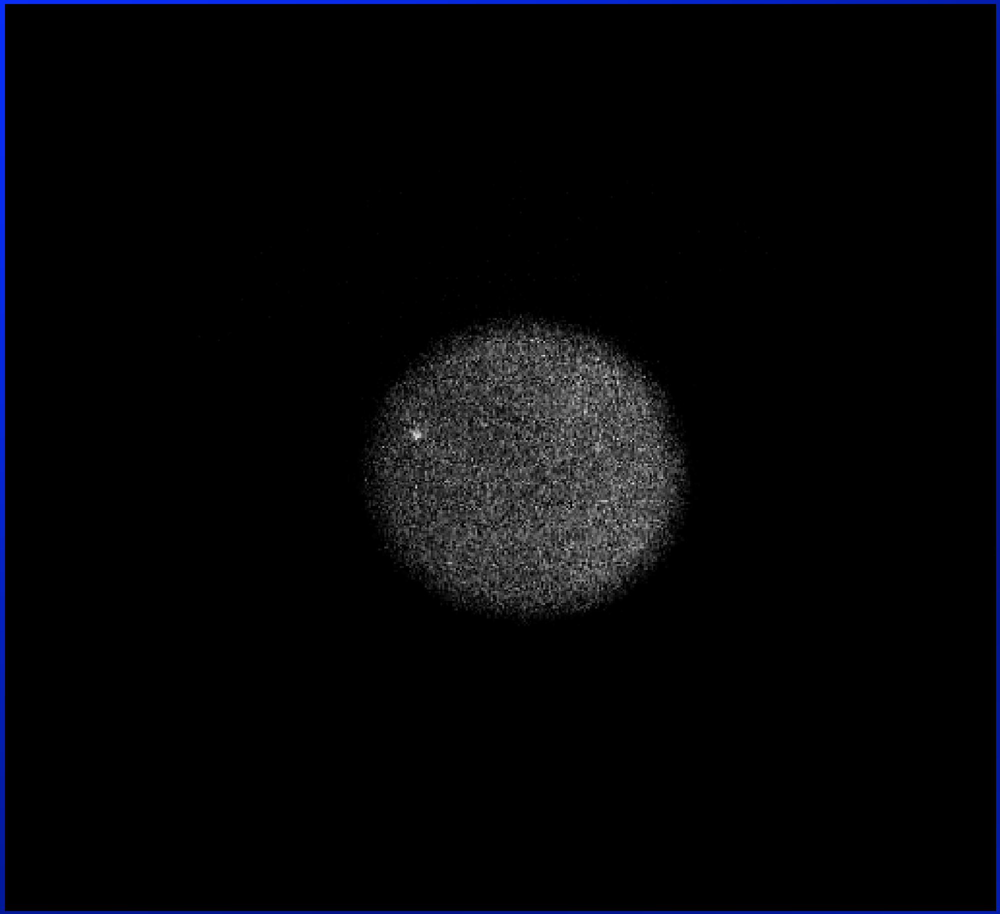
Ponderosa Pine 3D data cube - RULLI, LANL

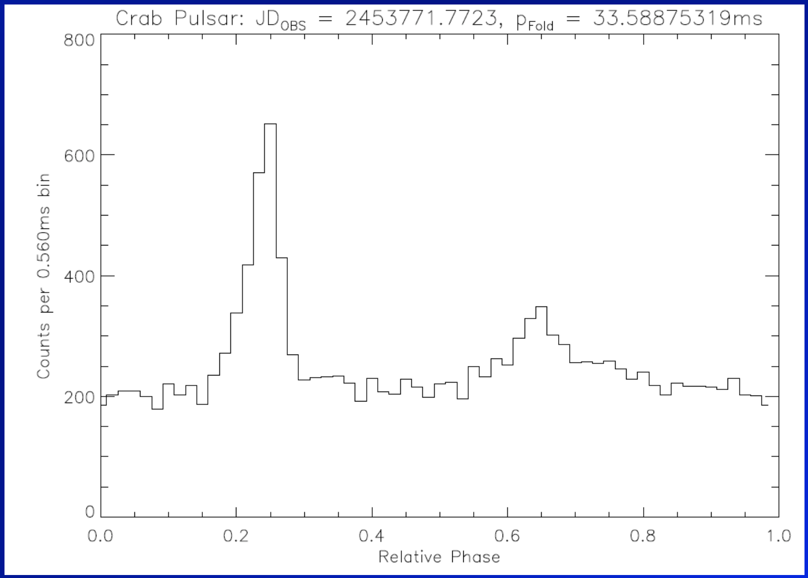
High time resolution Astronomy



33ms period, 250μs resolution
1m Lick observatory telescope

High Speed Imaging Astronomy





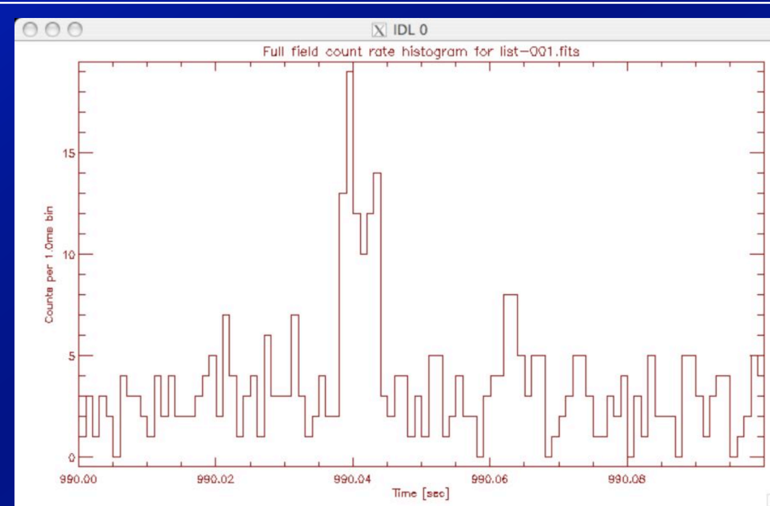
Crab Pulsar B band light curve

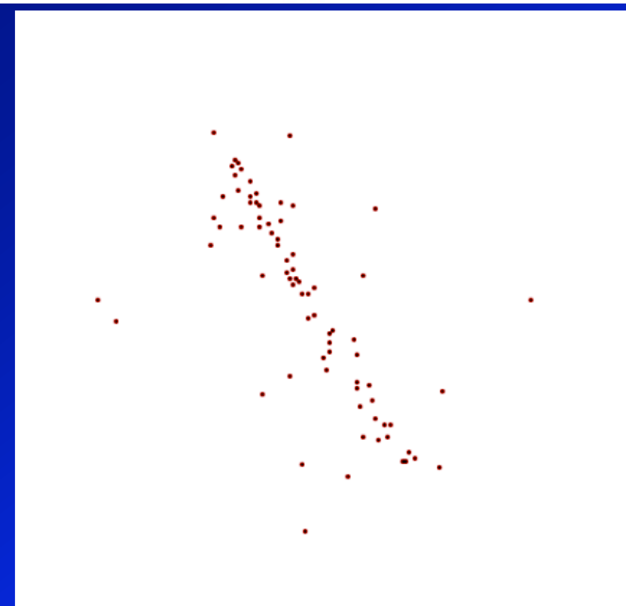
(1 m telescope on Moonlit night)

Meteor & Satellite Detection

Meteor track in AH-Her field

5 ms to cross 6’ FOV.
~11 km/sec if at 30 km

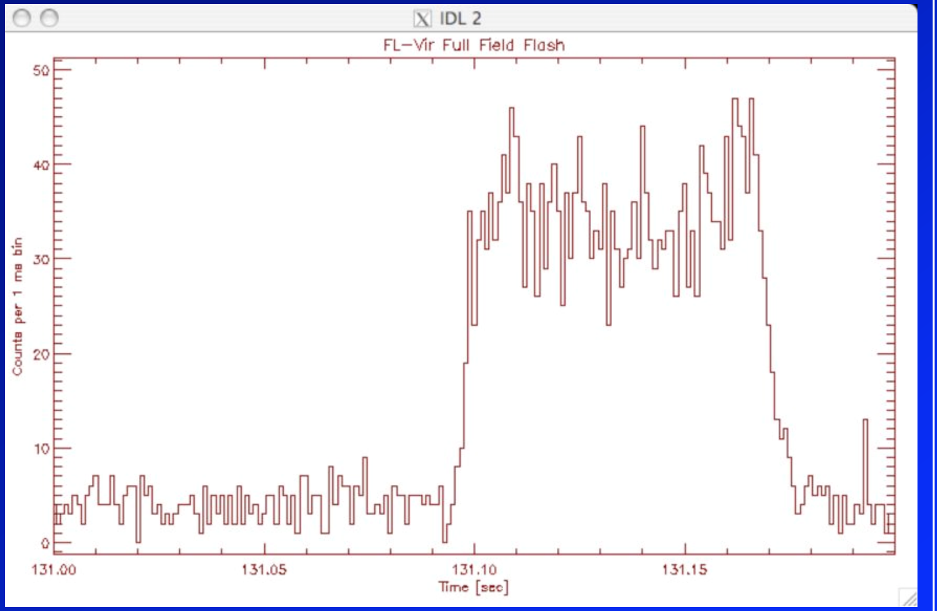




Meteor & Satellite Detection

Satellite track in FL-Vir field

~8.5 km/sec in low earth orbit



Photon Counting MCP Detectors

Advantages

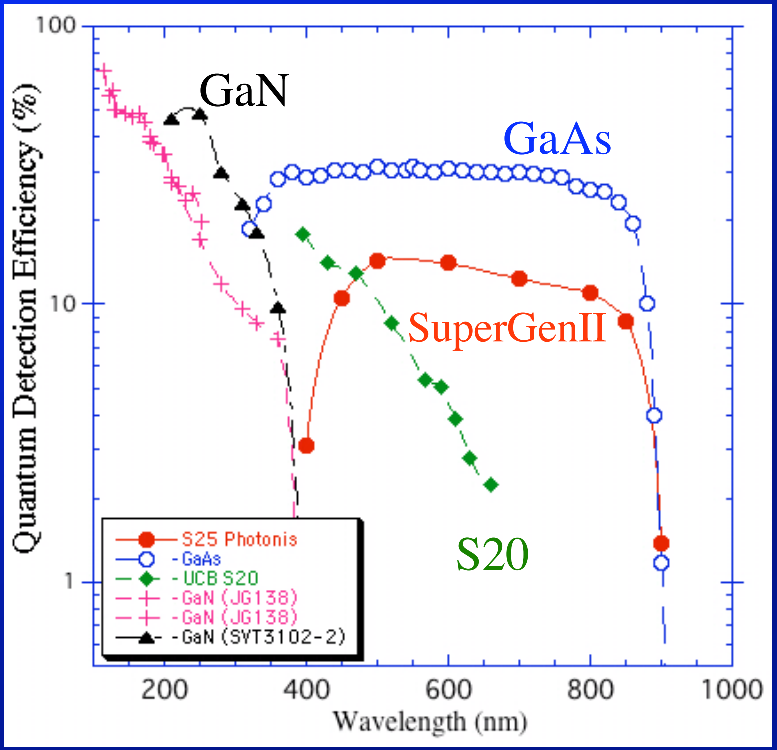
Spatial resolution	*< 12µm FWHM*
Temporal resolution	*< 100 ps*
Format	*> 100 mm*
Dynamic range	*> 10^8*
Radiation hard	
Curved focal planes	
Room Temperature	

Disadvantages

Vacuum operation	*pumps, tubes or space*
Lifetime	*~ Coulombs cm^{-2}*
Photoelectric QE	*~ 50% to 10^{-12}*

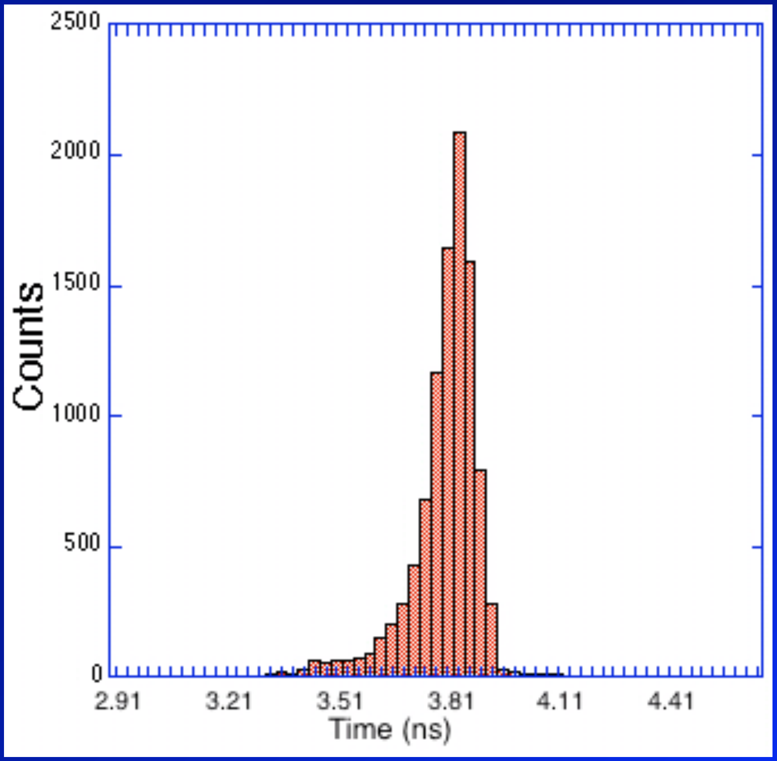
Performance examples

Photocathode QE



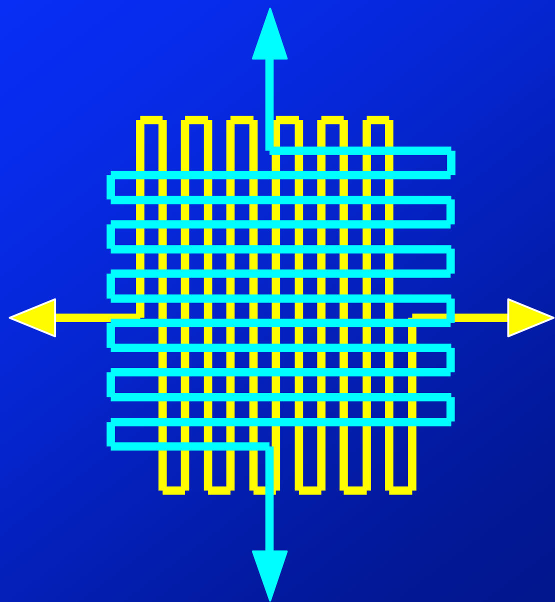
Photocathode types for UV, visible & NIR are improving.

Temporal resolution



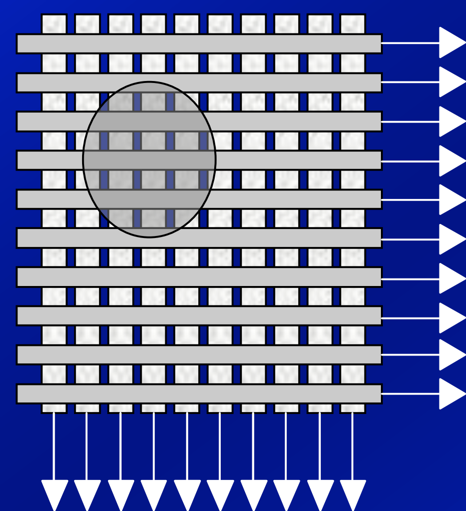
MCP timing jitter ~100 ps FWHM measured with pulsed laser

Readout Anode Types (partial list)



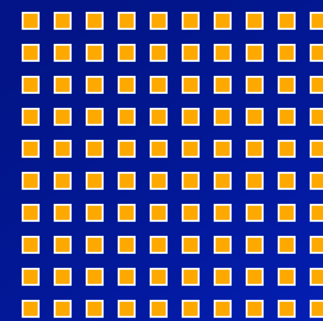
Cross Delayline
(XDL)

4 amps
Gain ~ 10^7
Rate ~ 200kHz
Δt ~ 100ps



Cross Strip
(XS)

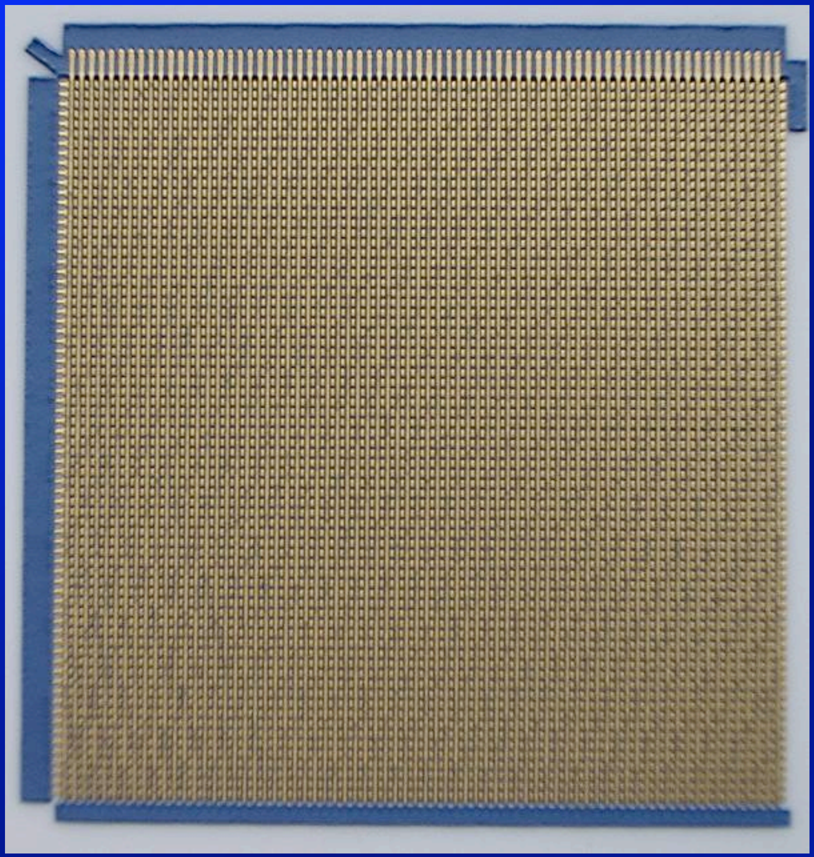
2 x N amps
Gain ~ 10^6
Rate ~ 2MHz
Δt ~ 100ps



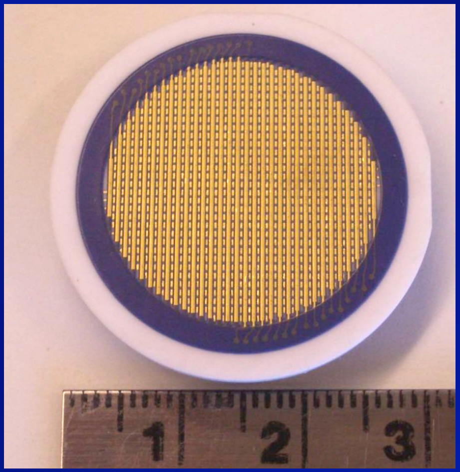
Medipix ASIC
Intensified CCD

N x N amps
Gain ~ 10^4
Rate ~ 200MHz
Δt ~ 1 ms

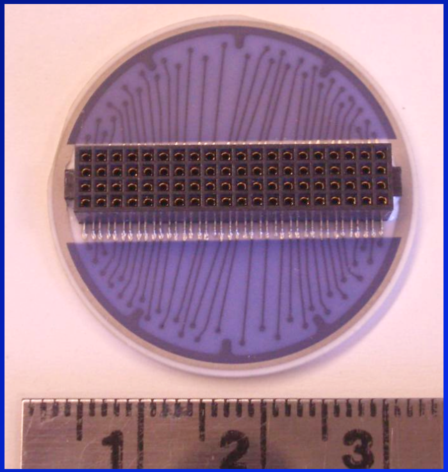
Cross Strip Anode Designs



45mm square Cross Strip Anode with 0.64 mm finger period. All metal and ceramic.

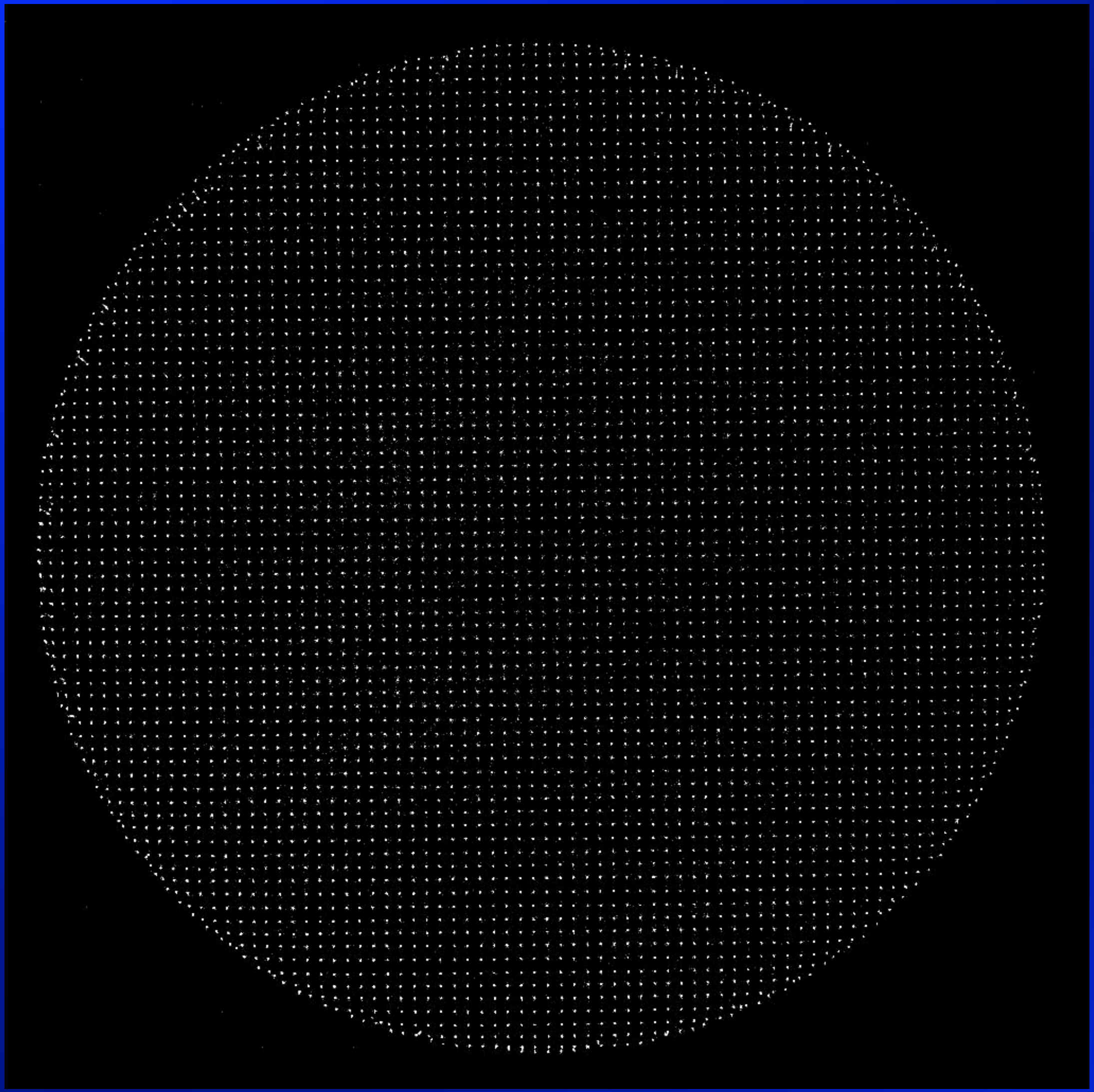


22mm round cross strip

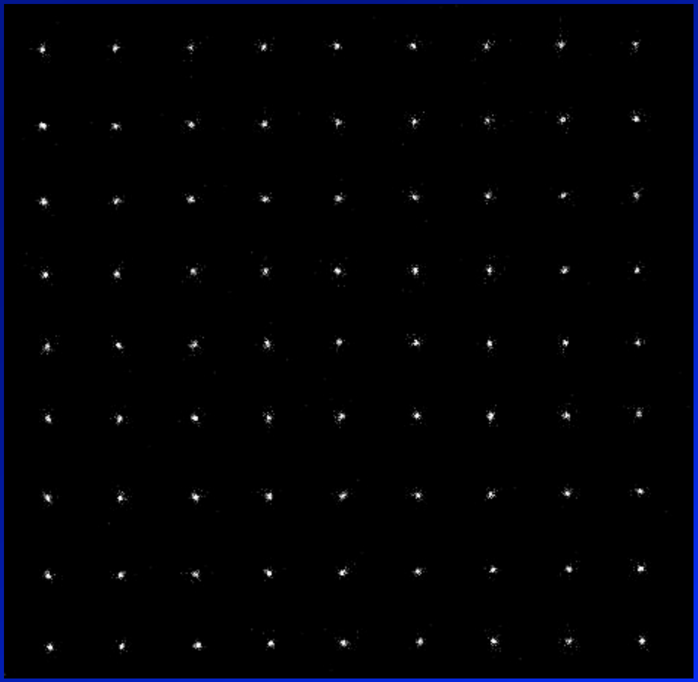


22mm round cross strip showing vias and connector

Imaging tests - resolution

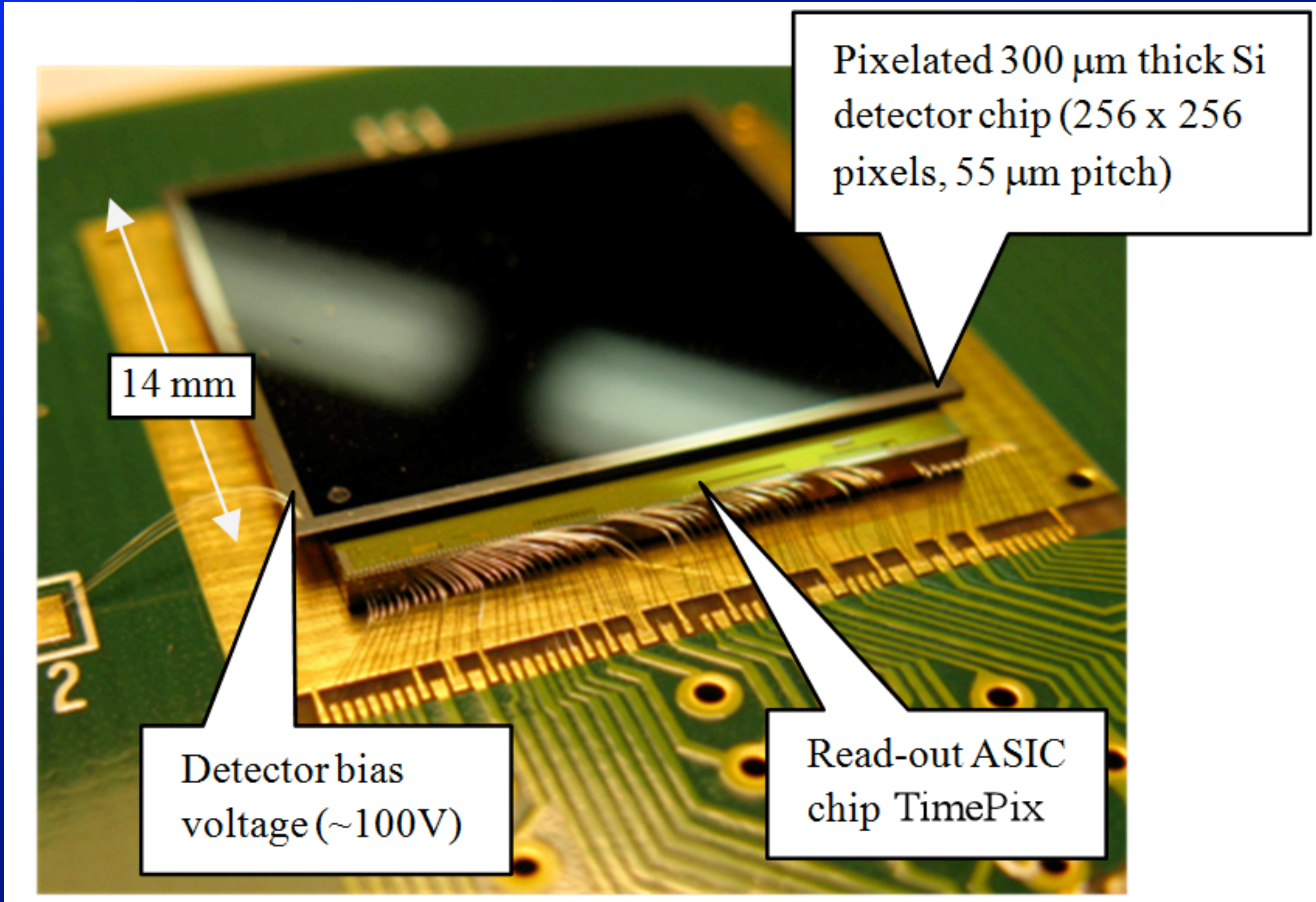


40 mm - 0.5 x 0.5 mm pinhole grid

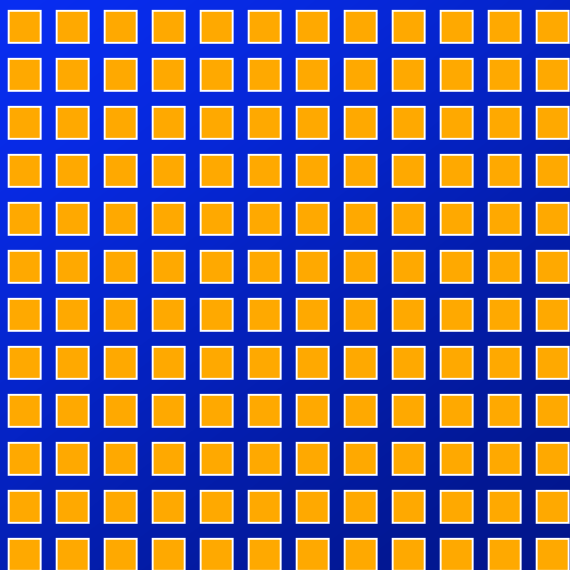


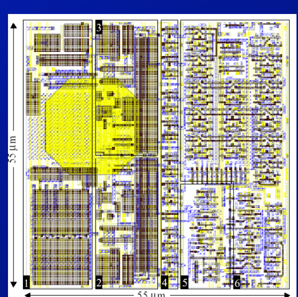
Zoomed - 20 μm FWHM avg.

Medipix/Timepix x-ray imager



Medipix/Timepix ASIC readout





~ 500 transistors/pixel

- 256 x 256 array of 55 µm pixels
- Integrates *counts*, not charge
- 100 kHz/pxl
- Frame rate: 1 kHz
- Low noise (100e$^-$) = low gain operation (2 ke$^-$)
- GHz global count rate
- ~1 W watt/chip, abuttable
- Developed at CERN

Aside: Timepix readout of APD arrays?

Require gains of > 1000 but < 200000

Input pitch is 55µm

256 x 256 array

Can cool CMOS chip to 77K

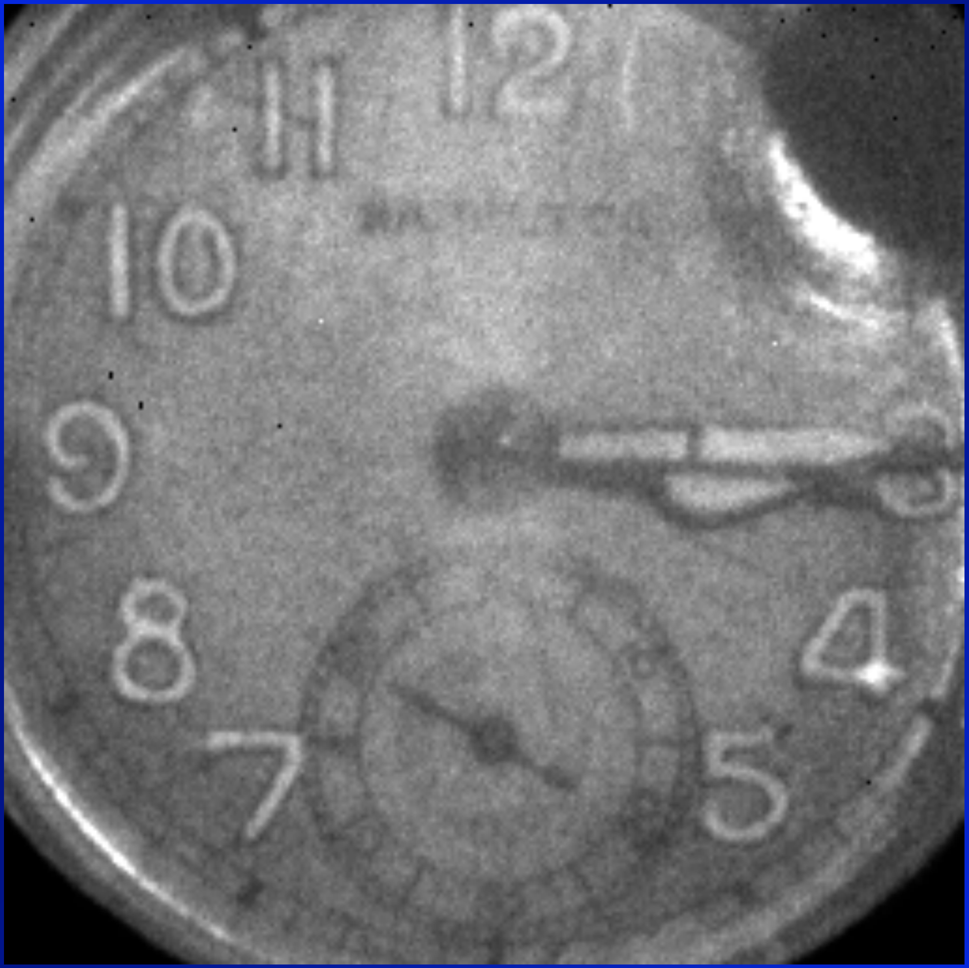
(but 1W per chip is a high load)

Cannot bias pixels separately

Input takes holes or electrons,

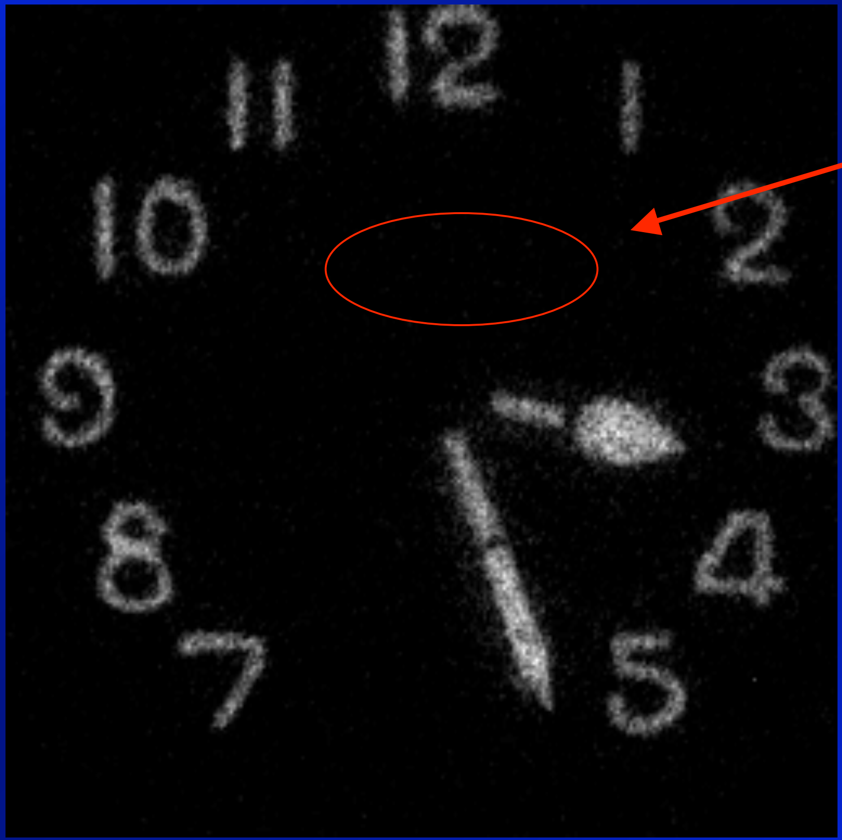
(can sink up to 10nA/pxl)

Old WWII watch movie



66 MHz input rate

Old WWII watch movie 2



Bkgd

.002 ct/pxl/s

Room Temp

(radium dial)

MCP pores (10 on 12 micron)

Evolution of MCP detectors

	1985	2010	Improvement
Count rate (cps)	5000	$5x10^6$	1000
Spatial Resolution (µm)	100	10	10
Lifetime (cts/mm)	10^9	10^{12}	1000
Optical QE (%)	~15	~30	2

Limited by MCP technology!

Size (mm)	100	100	1
Pore diameter (µm)	12	6	2
Lifetime (C/mm)	.01	.01	1

Atomic layer deposition (ALD)

Allows engineering of surfaces after MCP pores are fabricated

- Optimize secondary electron coefficient for gain
- Optimize resistivity

Separates microchannel fabrication from surface preparation

- MCPs can be made from any glass, alumina, plastic
- Lithographic techniques for larger arrays of pores

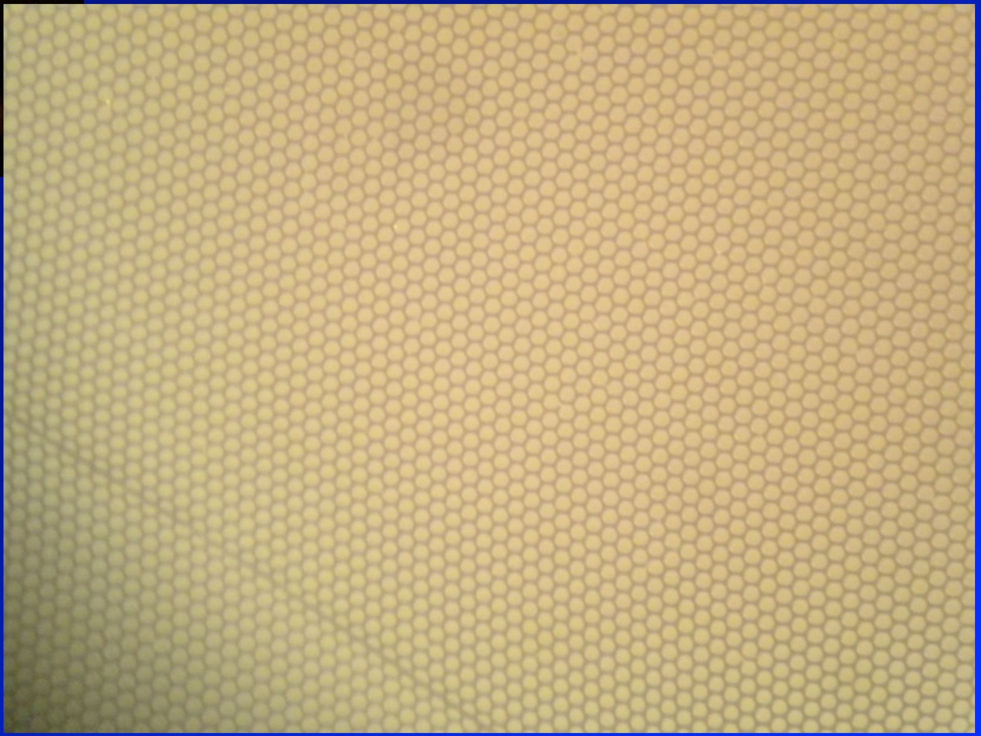
Photocathodes deposited on MCP(?)

- Passivated (Al_2O_3) surfaces
- Higher QE of opaque photocathodes

Borosilicate glass MCP

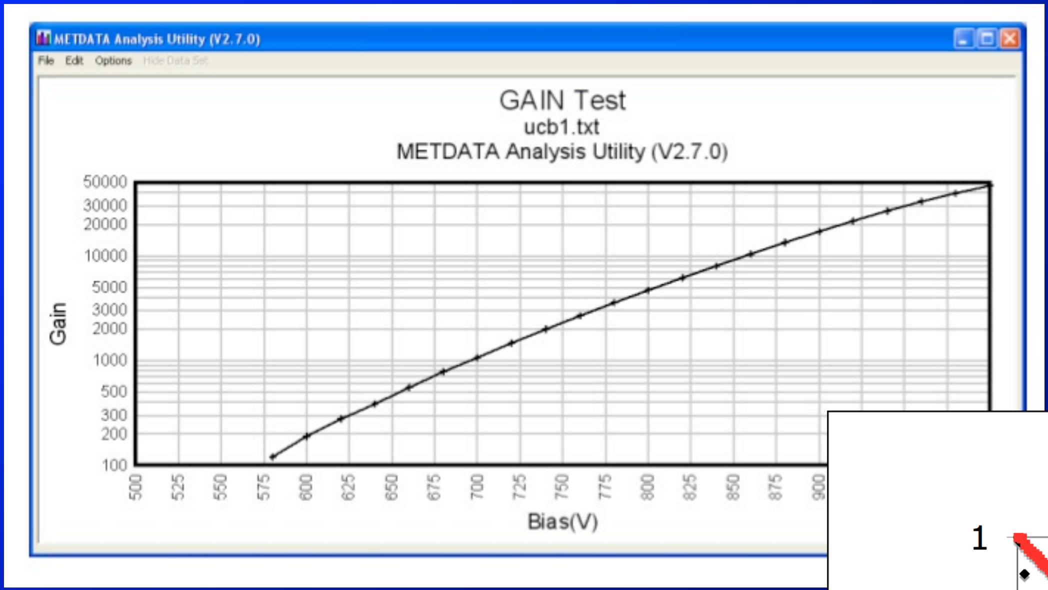
33 mm substrate from INCOM

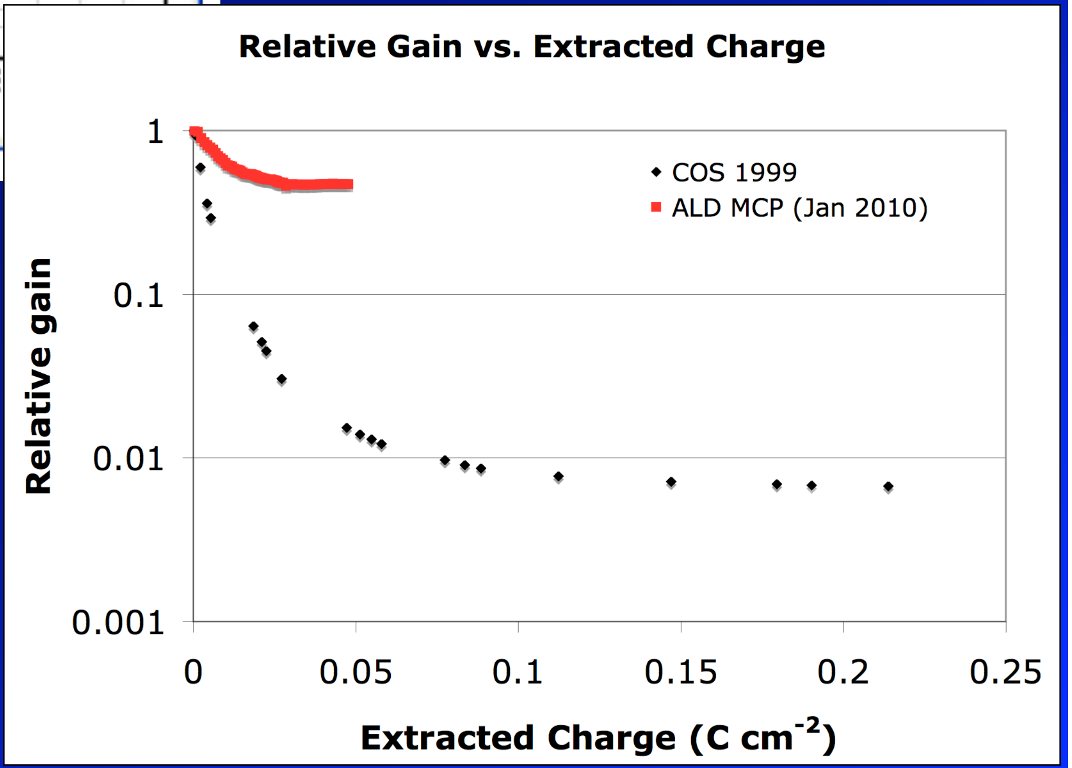
Resistive, SEC, and conductive coatings by Arradiance



Microscope image showing 40 μm holes in hexagonal array with L/d ratio of 40

Results from ALD coated Incom glass

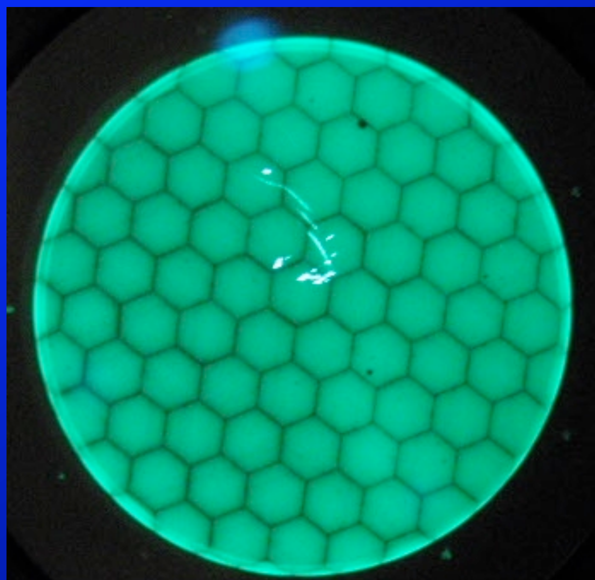




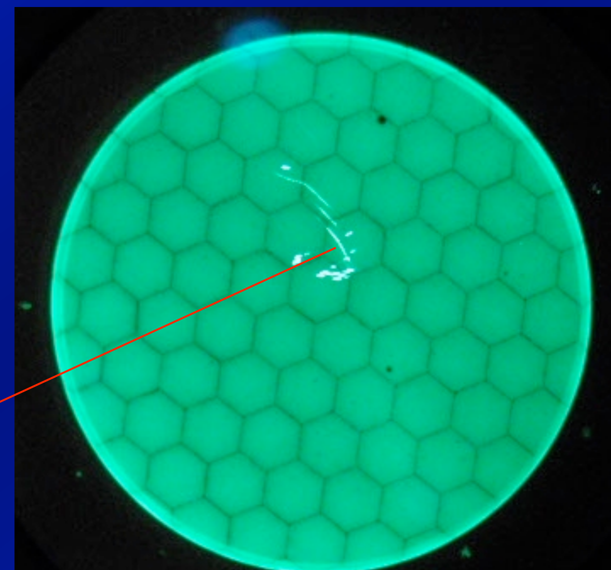
ALD coating done by Arradiance Inc. (www.arradiance.com)

SSL-UCB, ALD/Incom MCP Test

It works!



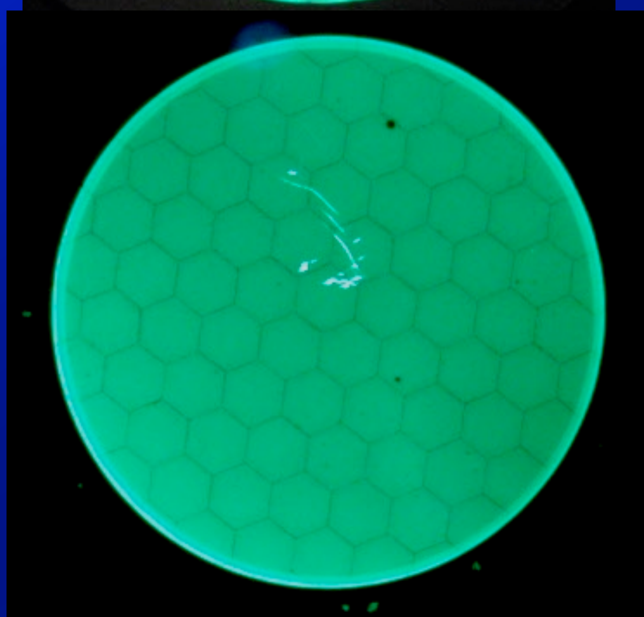
700v



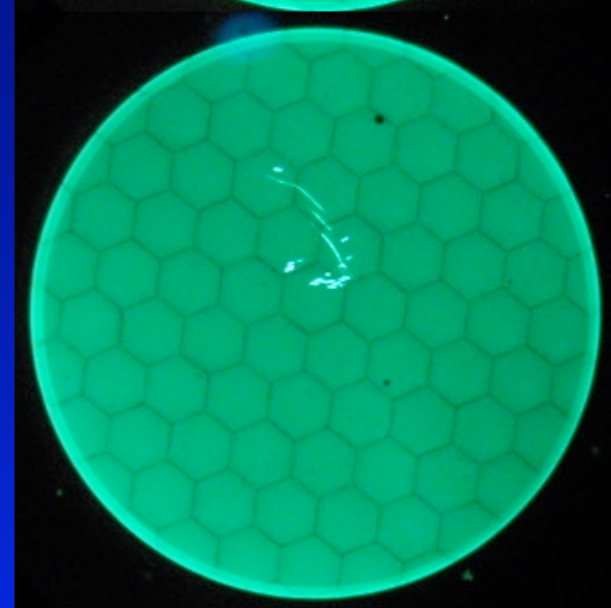
800v

Bright scratch on phosphor

UV light



1000v



900v

Psec Timing Project
(P.I Henry Frisch, U. Chicago, Argonne)

Large area (8”x8”) MCP image tubes for Cherenkov arrays and PET detectors

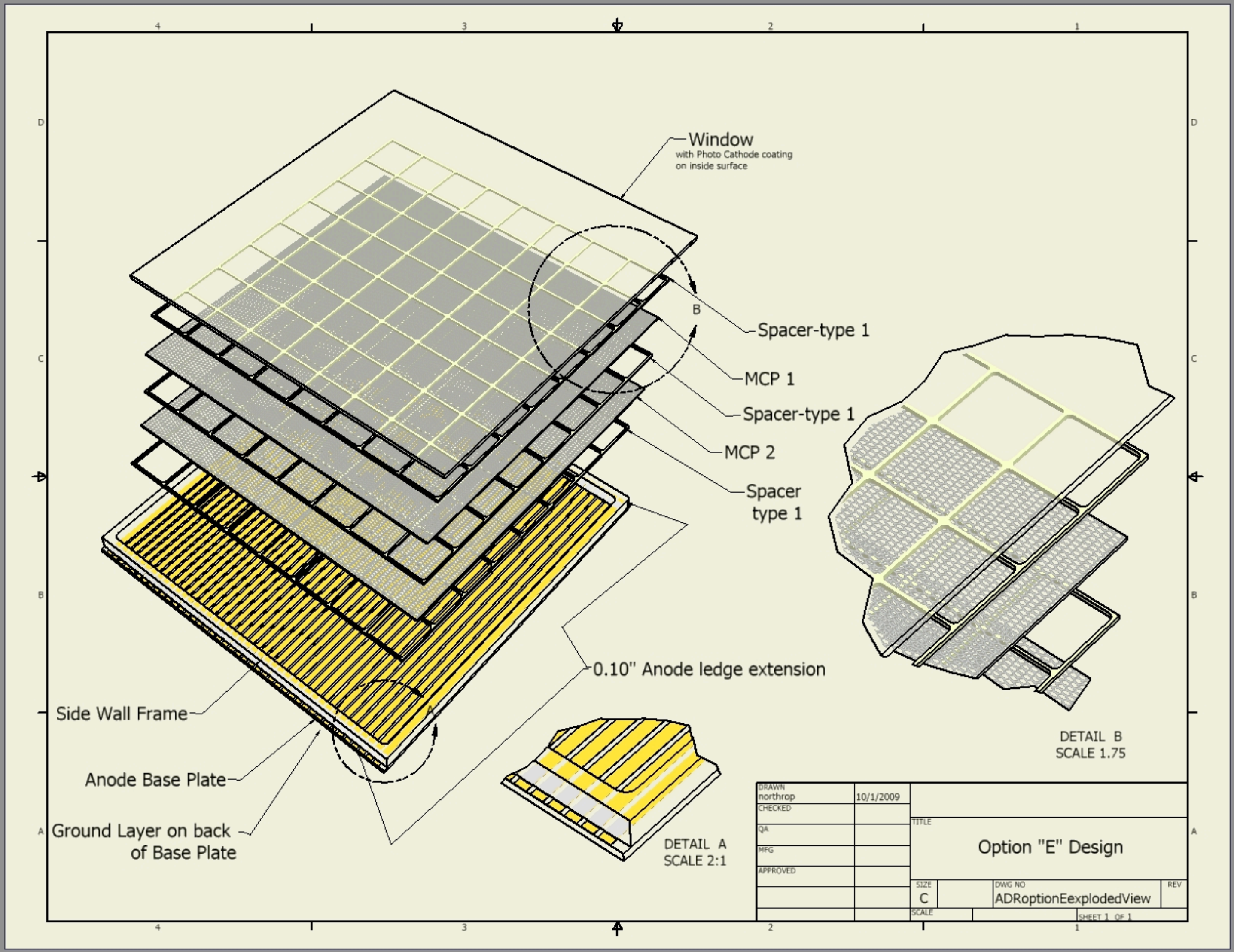
Delayline readout, specialized ASICs

Pulse timing to 1 ps (mulitple photon)

Thousands of tubes

Inexpensive design

8 inch image tube



Concluding Remarks

MCP detectors "in the field" demonstrate what can be done with an imaging photon counting detectors.

They are prevalent in the UV because of their historical QE advantage.

Modern electronic techniques are expanding their niche applications

New developments in optical/near IR photocathodes are pushing this technology to longer wavelengths.

Other know weaknesses (lifetime, cost, etc.) are being addressed with new materials and methods.

There is still life in this old war-horse!

Thank You

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