A new solid state tracking detector: Electron Emission Membranes and a MEMS made vacuum electron multiplier

only ideas: no data

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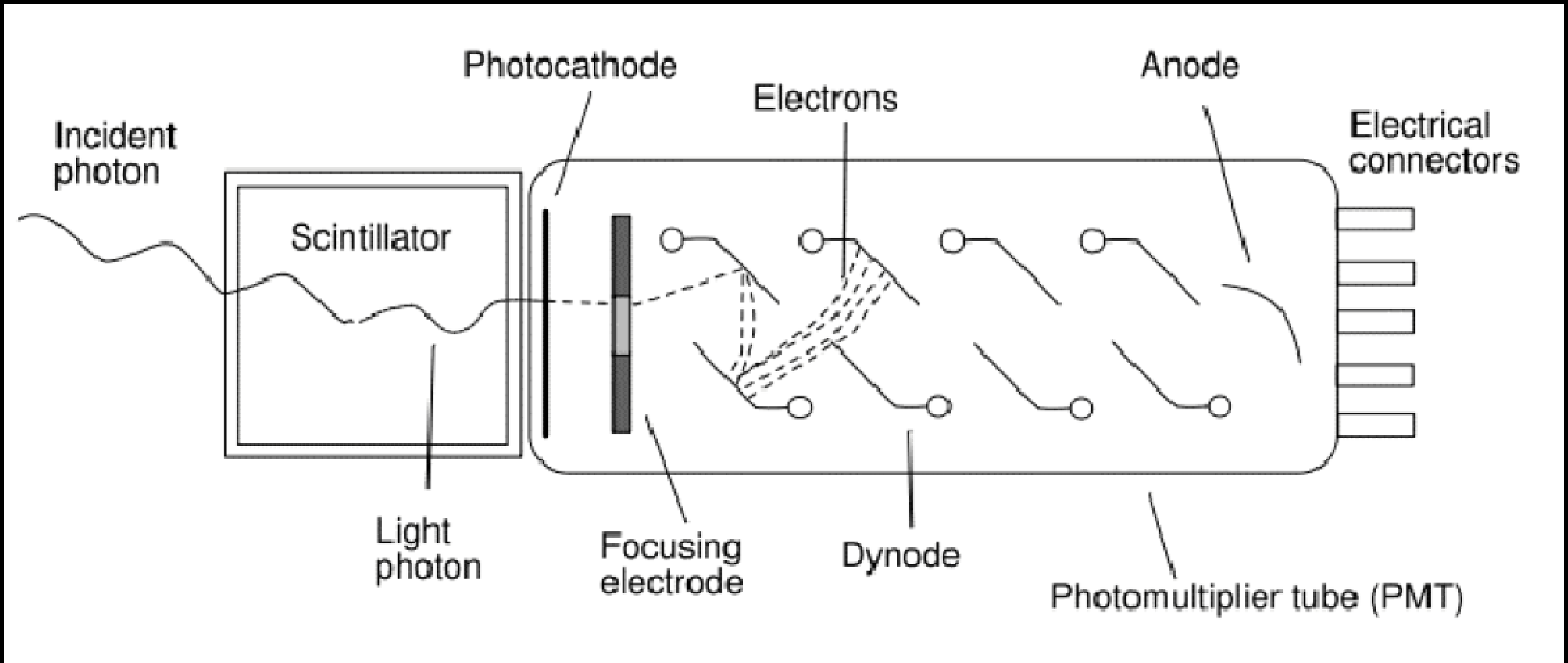
Nikhef, Amsterdam

TIPP 2011, Chicago, Il
Saturday June 11, 2011
12:20 h [522]

A very successful photon detector: the Photomultiplier (1948)



- good quantum efficiency
- rather fast
- low noise
- little dark current, no bias current
- radiation hard
- quite linear

- voluminous & heavy
- no position resolution
- expensive
- quite radioactive
- can't stand B fields

Reduce size of dynodes (volume downscaling):

- keep potentials as they were (V_{step} ~ 200 V)
- (non relativistic) electron trajectories same form, but smaller (volume)
- multiplication yield: identical
- 1^{st} dynode: focussing, yield
- pixel input source capacity: only ~ 10 fF
- required gain ~1000 = $2.5^{4\,=}$: 5 dynodes sufficient

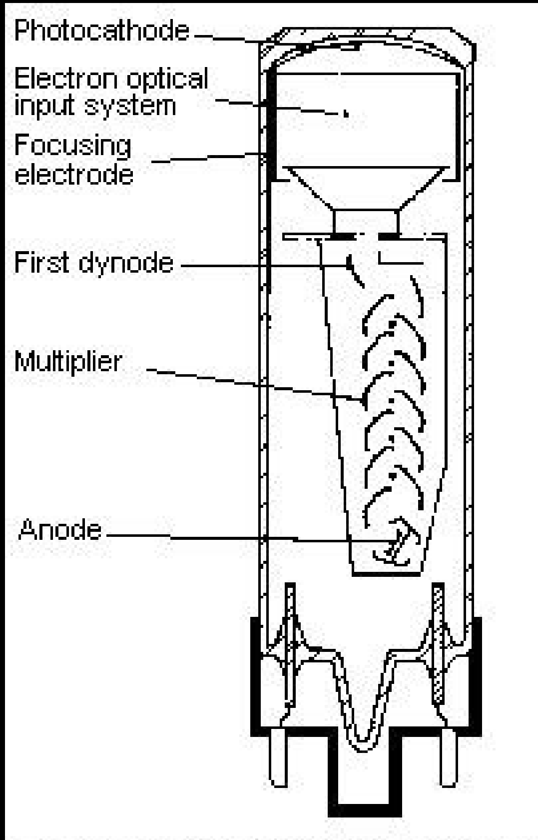
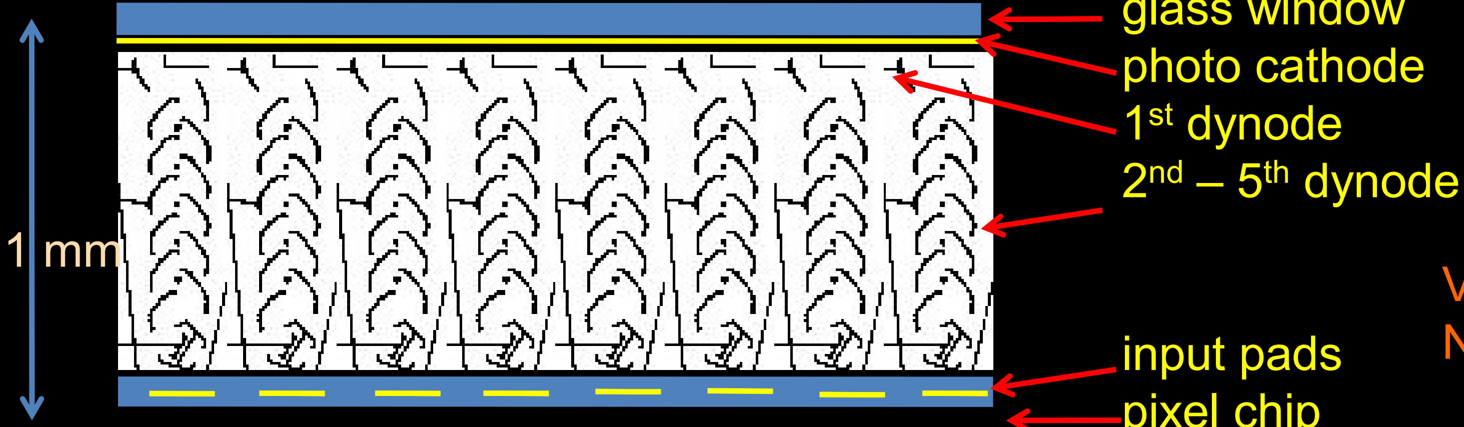


Fig. 8.1. Schematic diagram of a photo-multiplier tube (from *Schonkeren* [9.1])

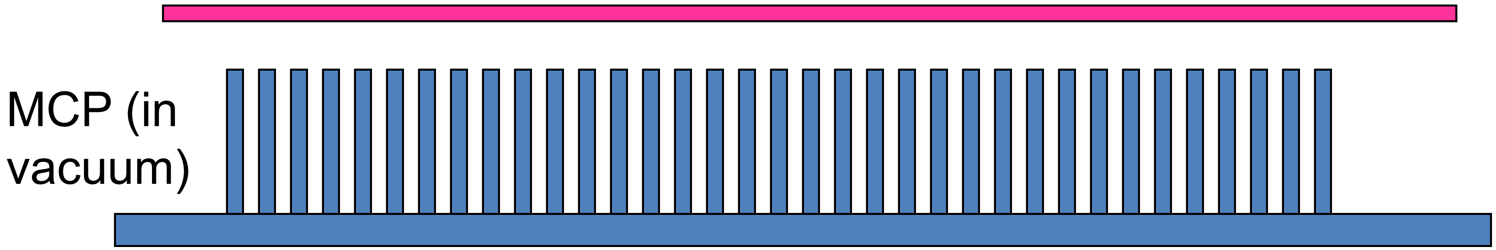
Apply MEMS Technology



VACUUM!

No ‘gas amplification’

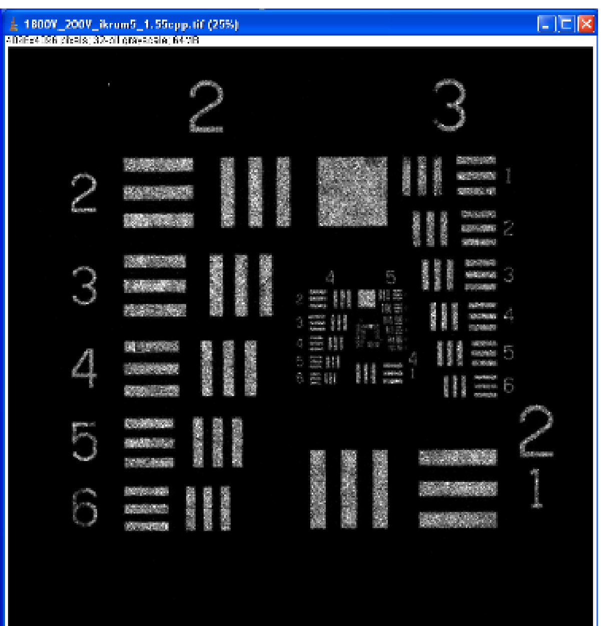
Use a MicroChannelPlate MCP?

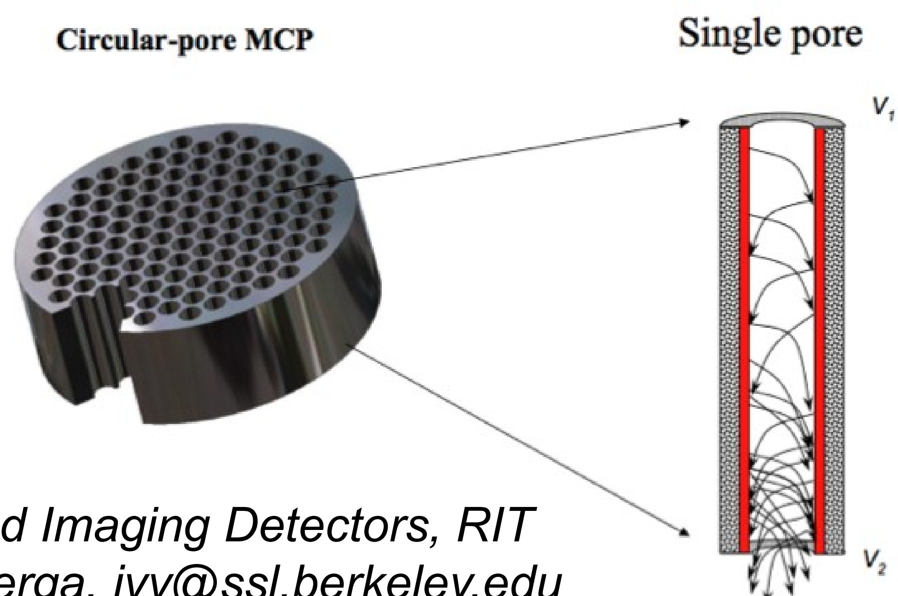


John Vallerga: TimePix + MCPs

We do not know how to make MEMS made MCP.

Problem: aspect ratio of holes

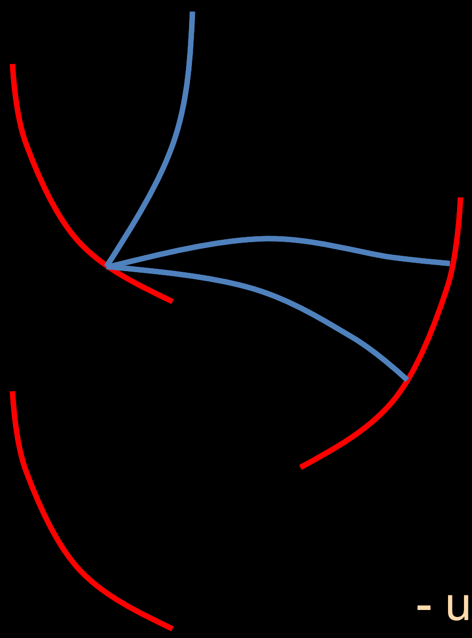


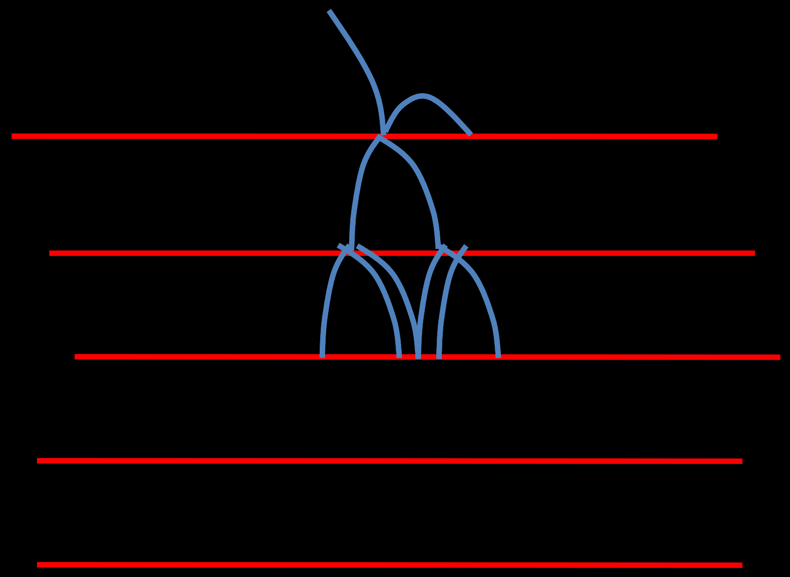


Quantum Limited Imaging Detectors, RIT 2009, John Vallerga, jvv@ssl.berkeley.edu

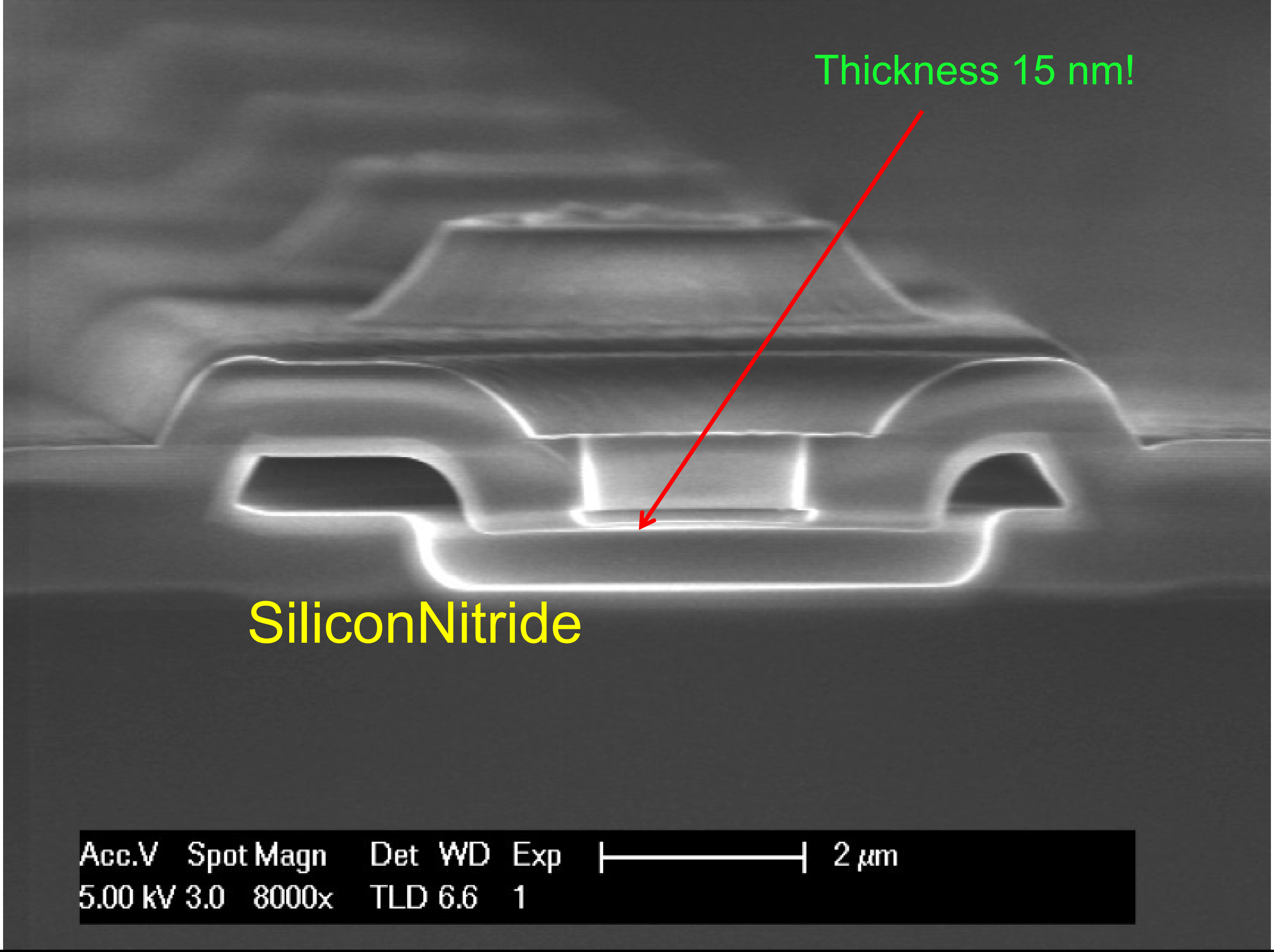
The transmission dynode: ultra thin (20 - 100 nm) layers

diamond
SiNitride (Si_3N_4) Si doped (SiRichNitride, SRN)
CsI
doped SiO_2

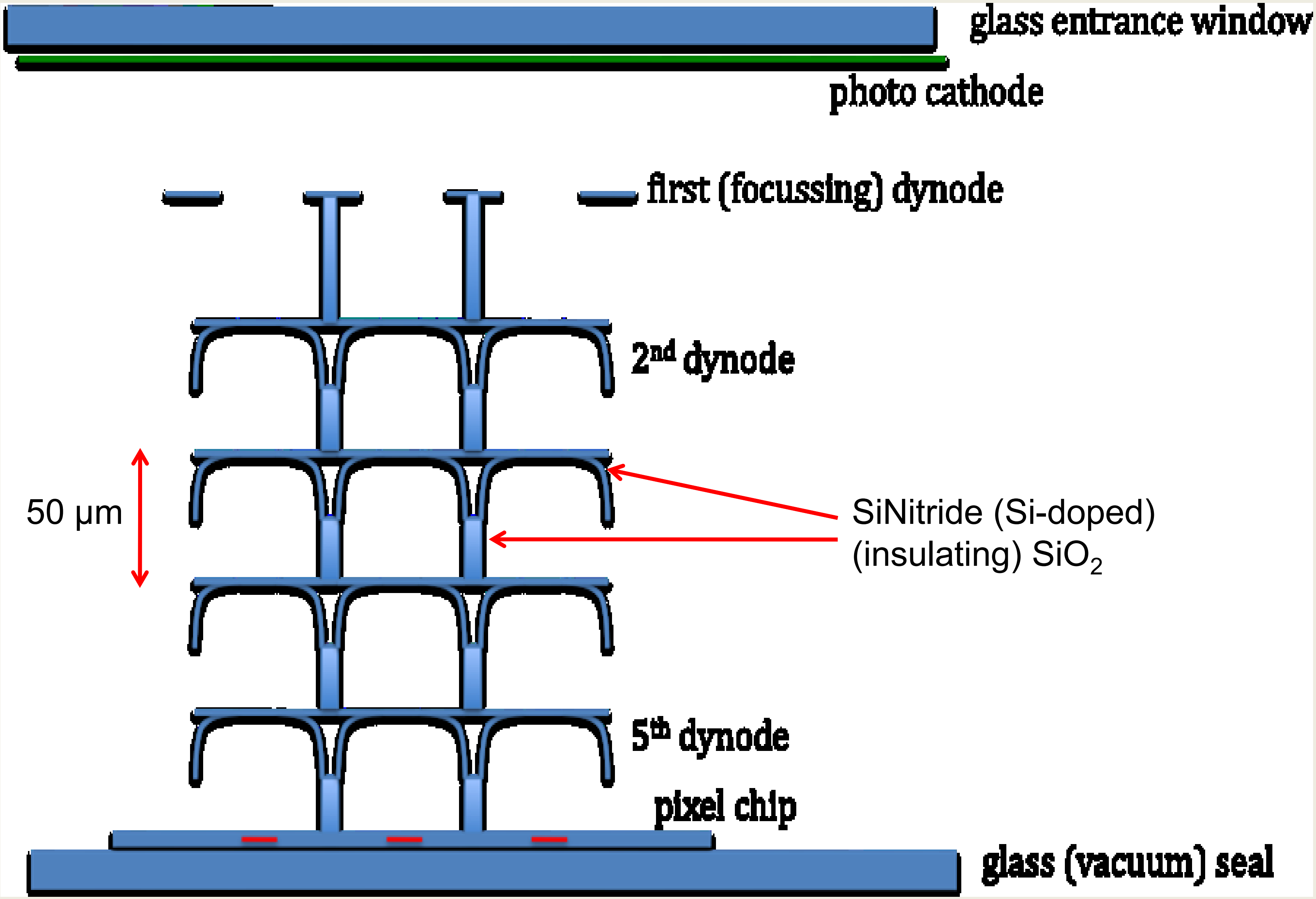


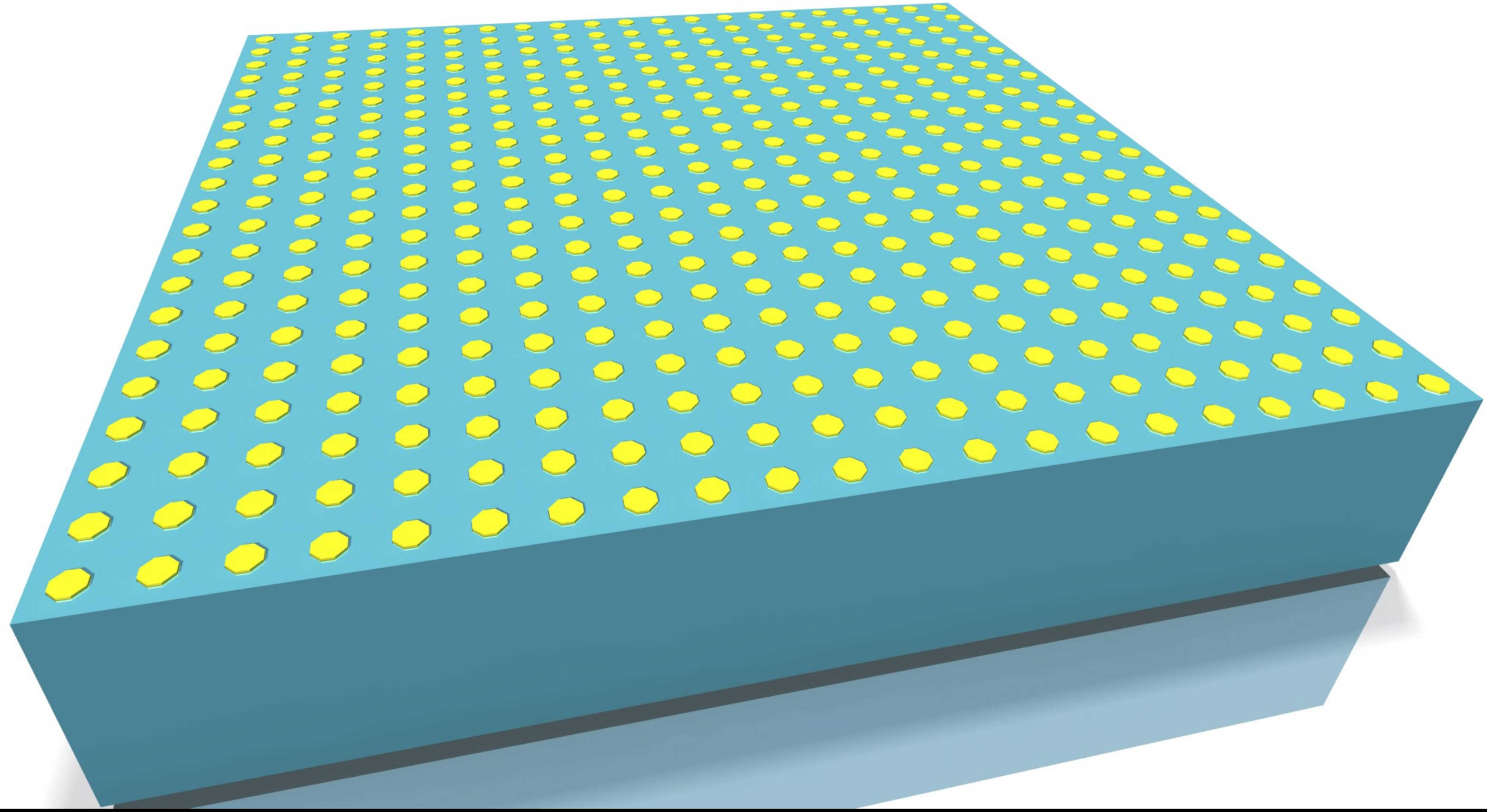


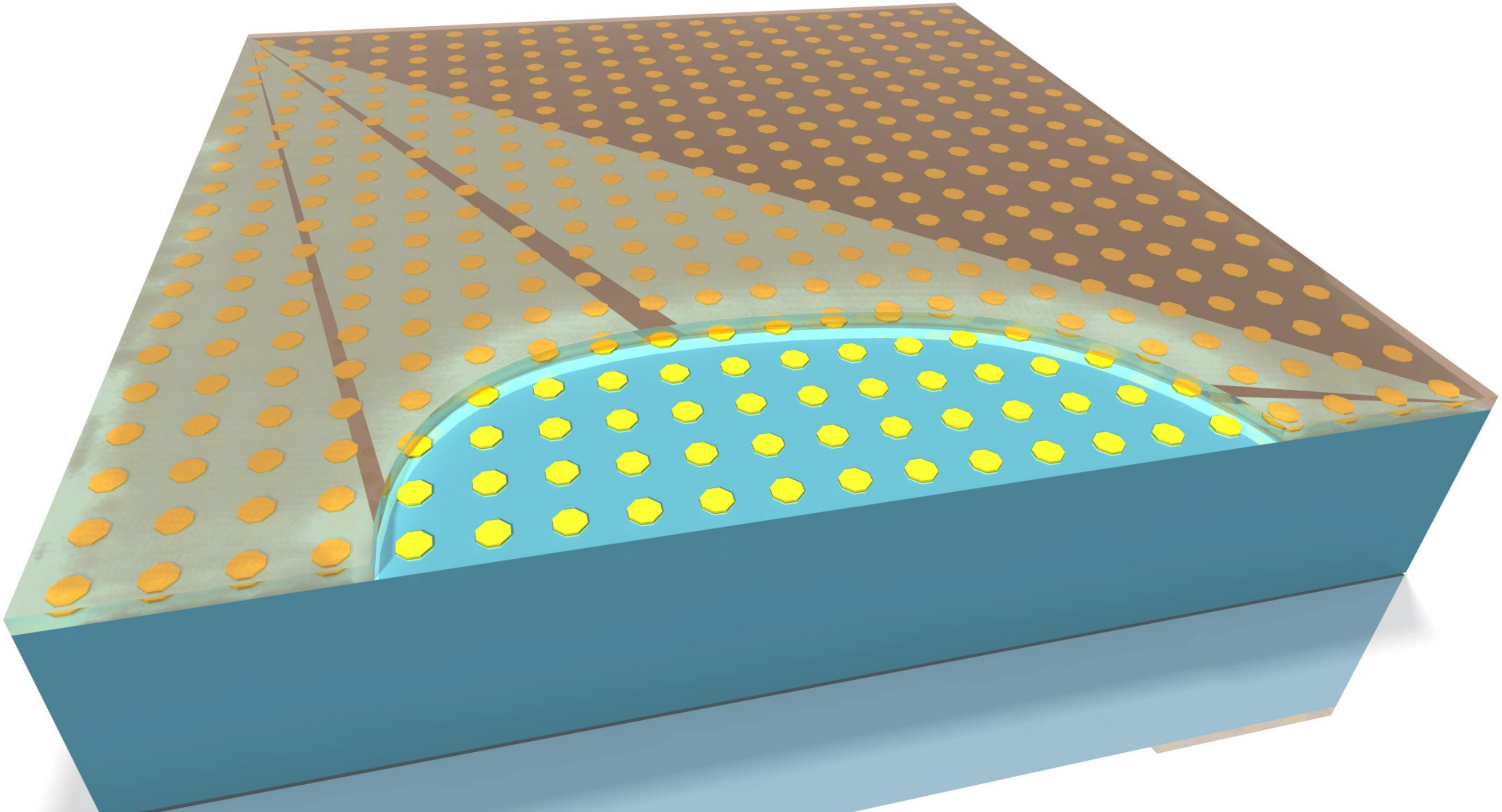
- ultra fast (single electron) detector: σ = 10 ps
- E-force much larger than Lorenz force: operates in B-field
- radiation hard
- low mass

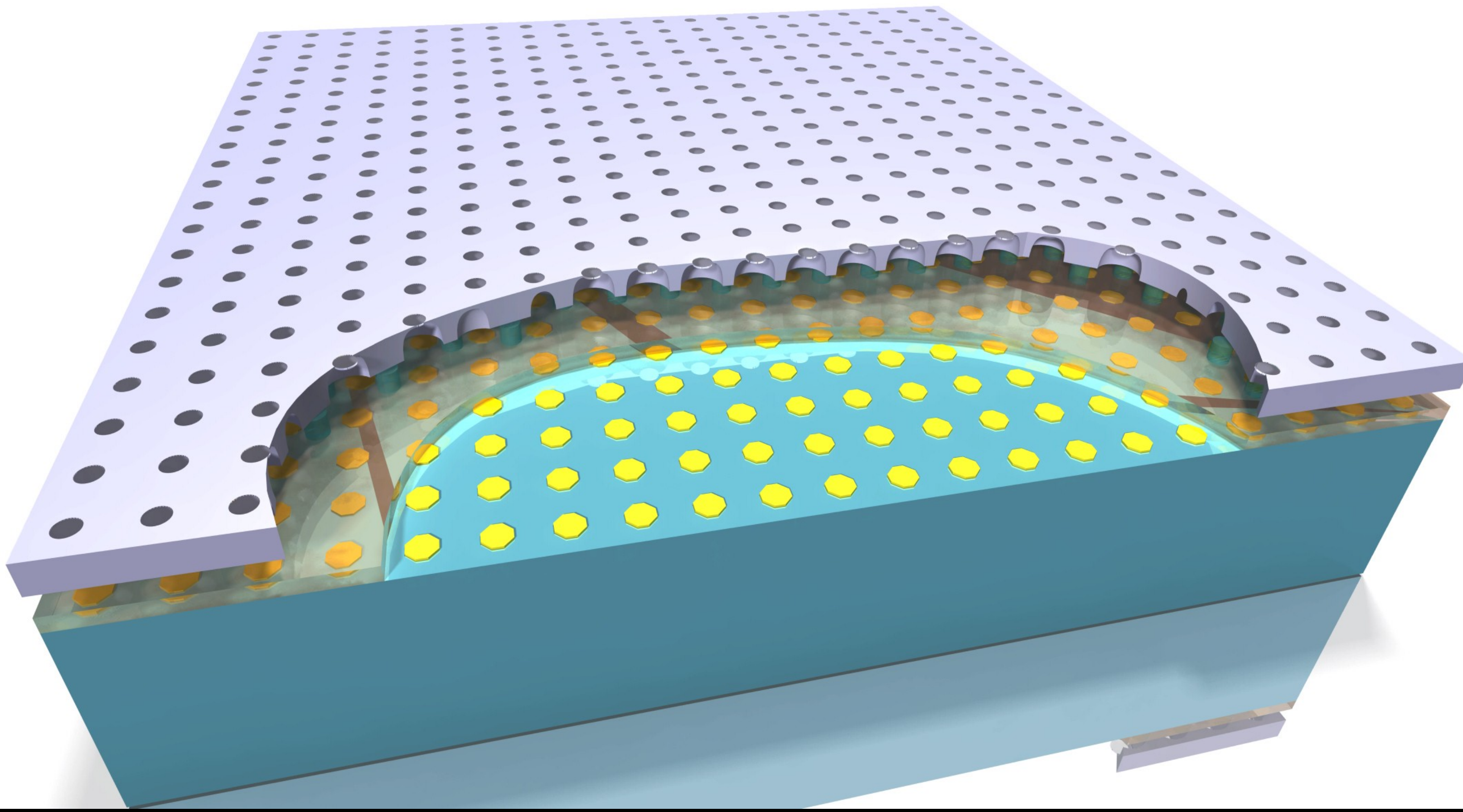


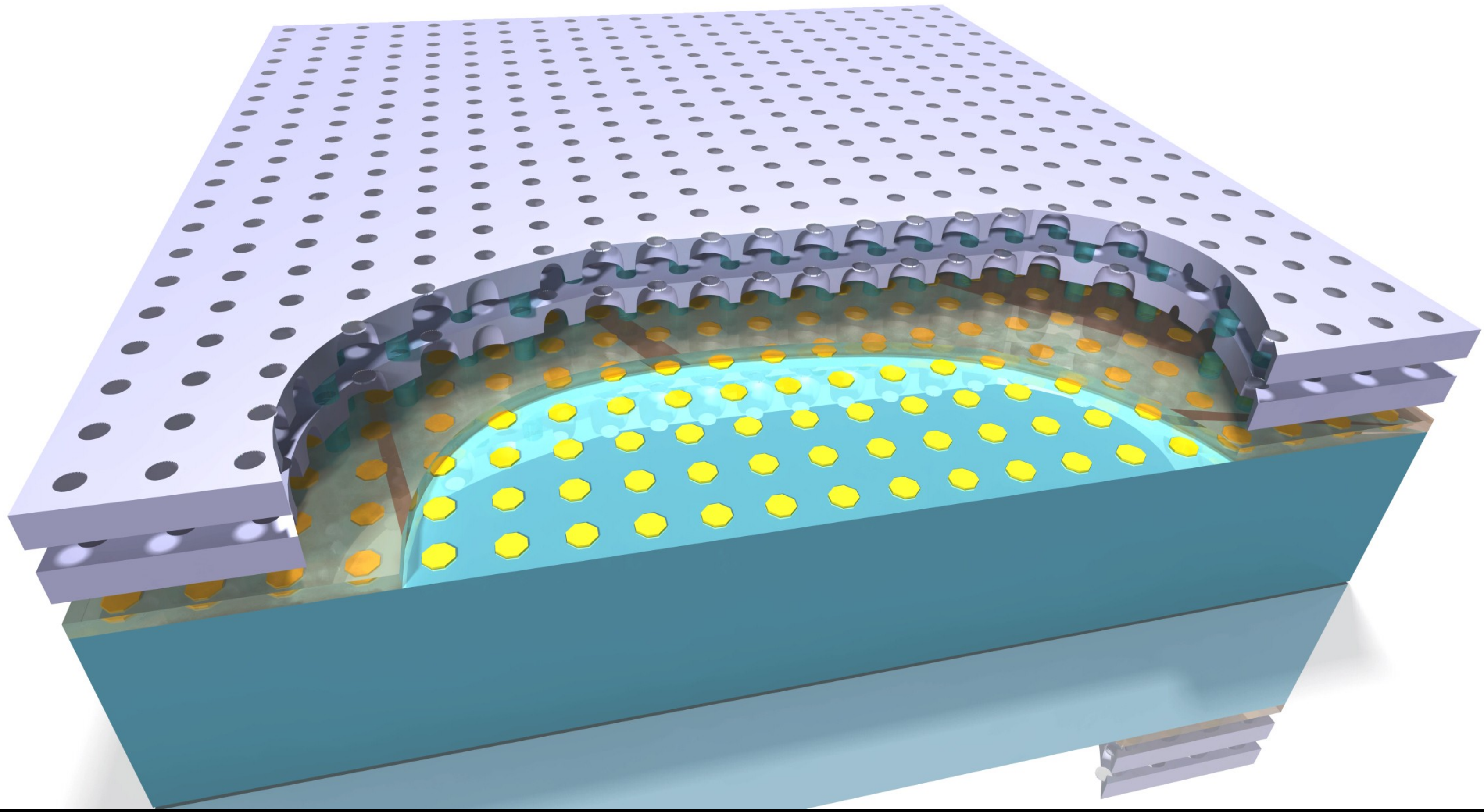
Delft University of Technology: DIMES

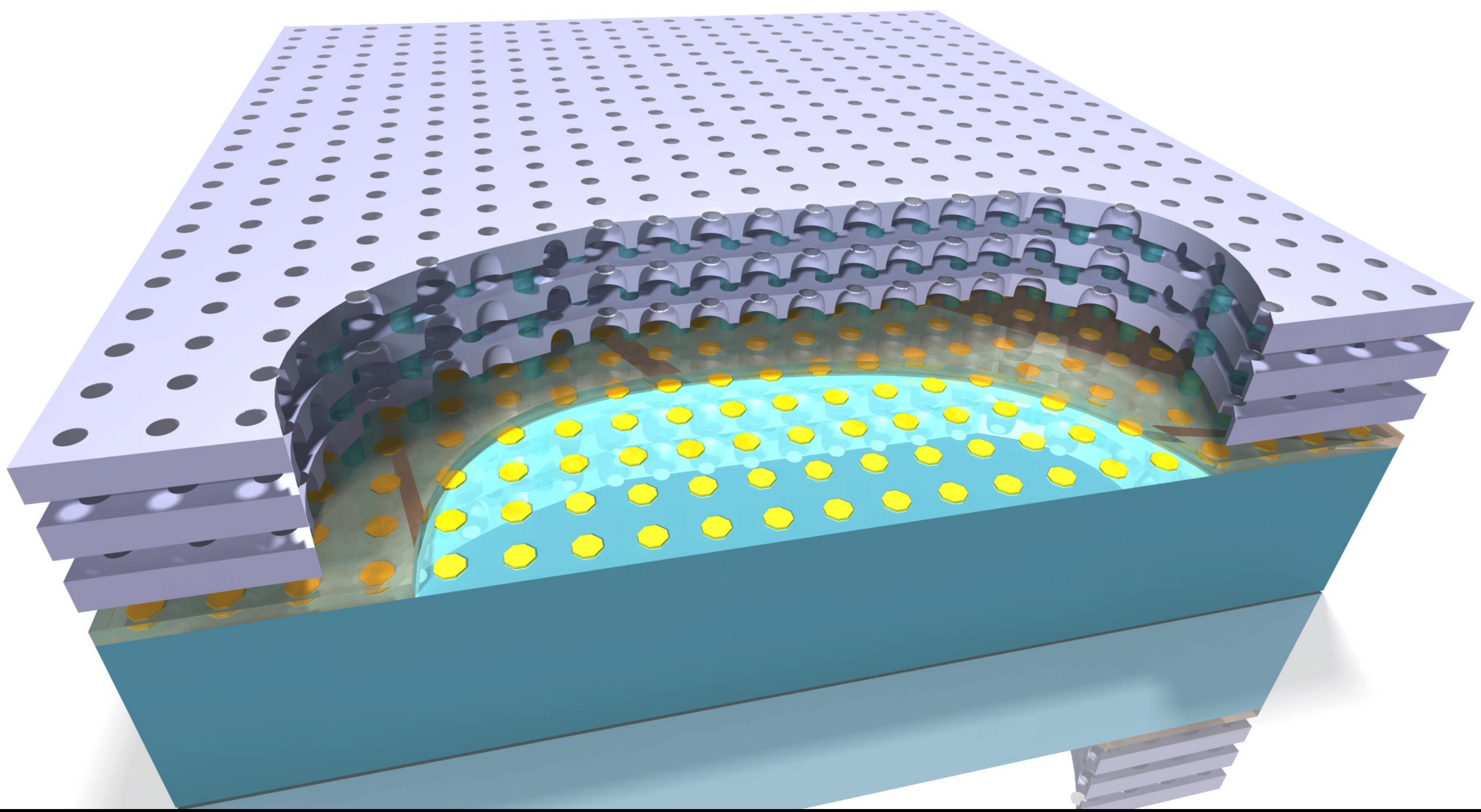

glass entrance window
photo cathode
first (focussing) dynode
2nd dynode
50 µm
SiNitride (Si-doped)
(insulating) SiO2
5th dynode
pixel chip
glass (vacuum) seal

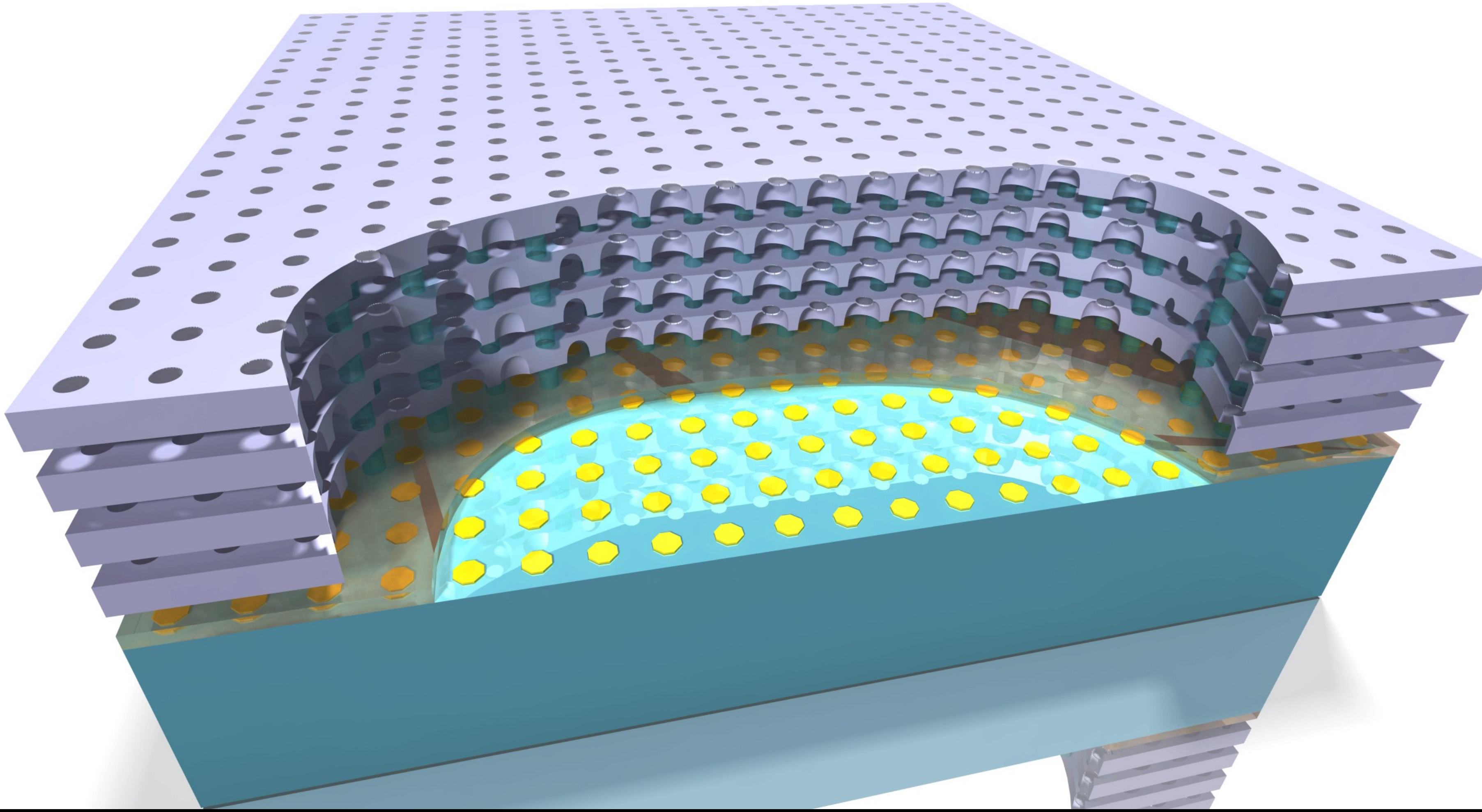


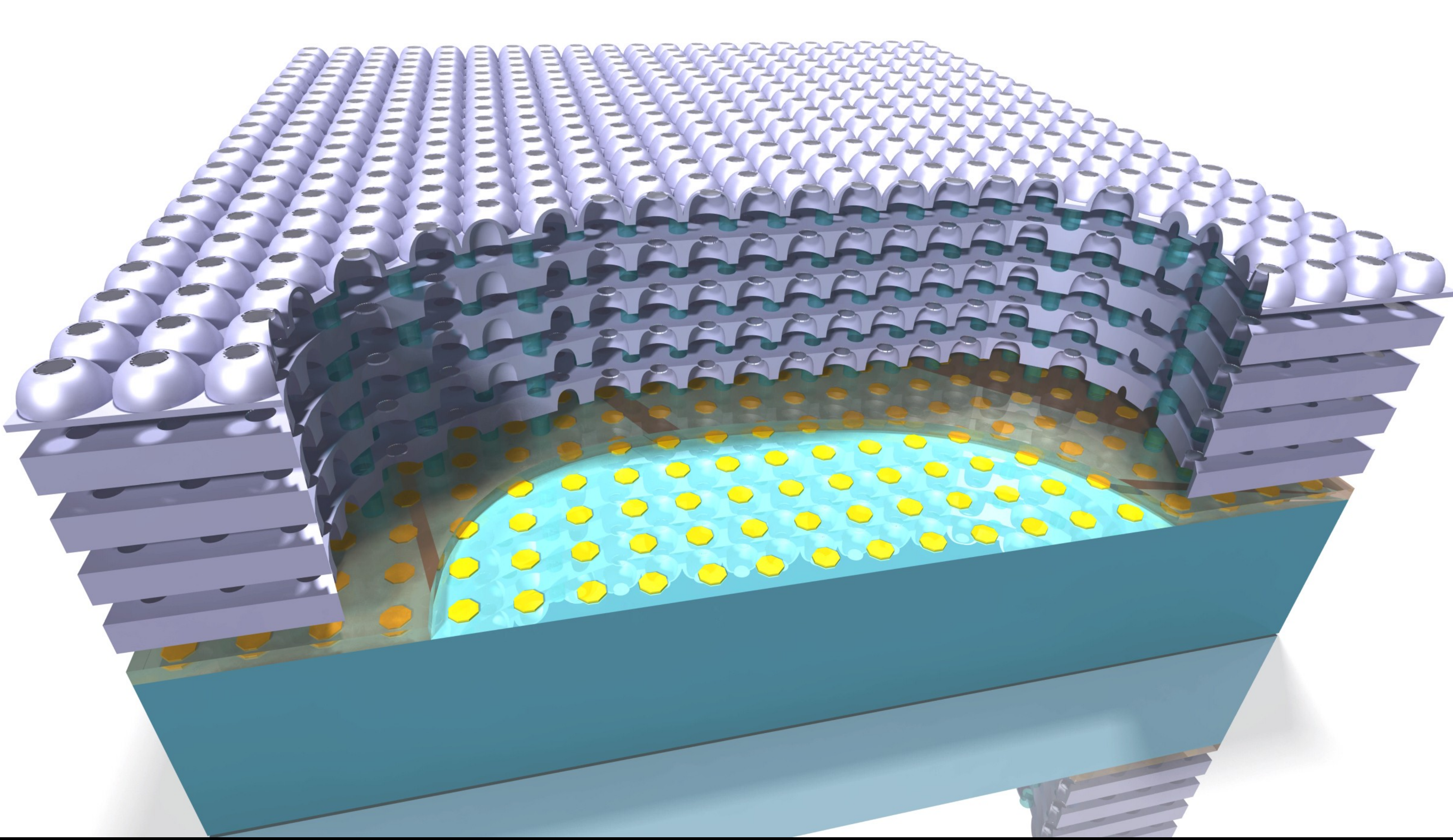


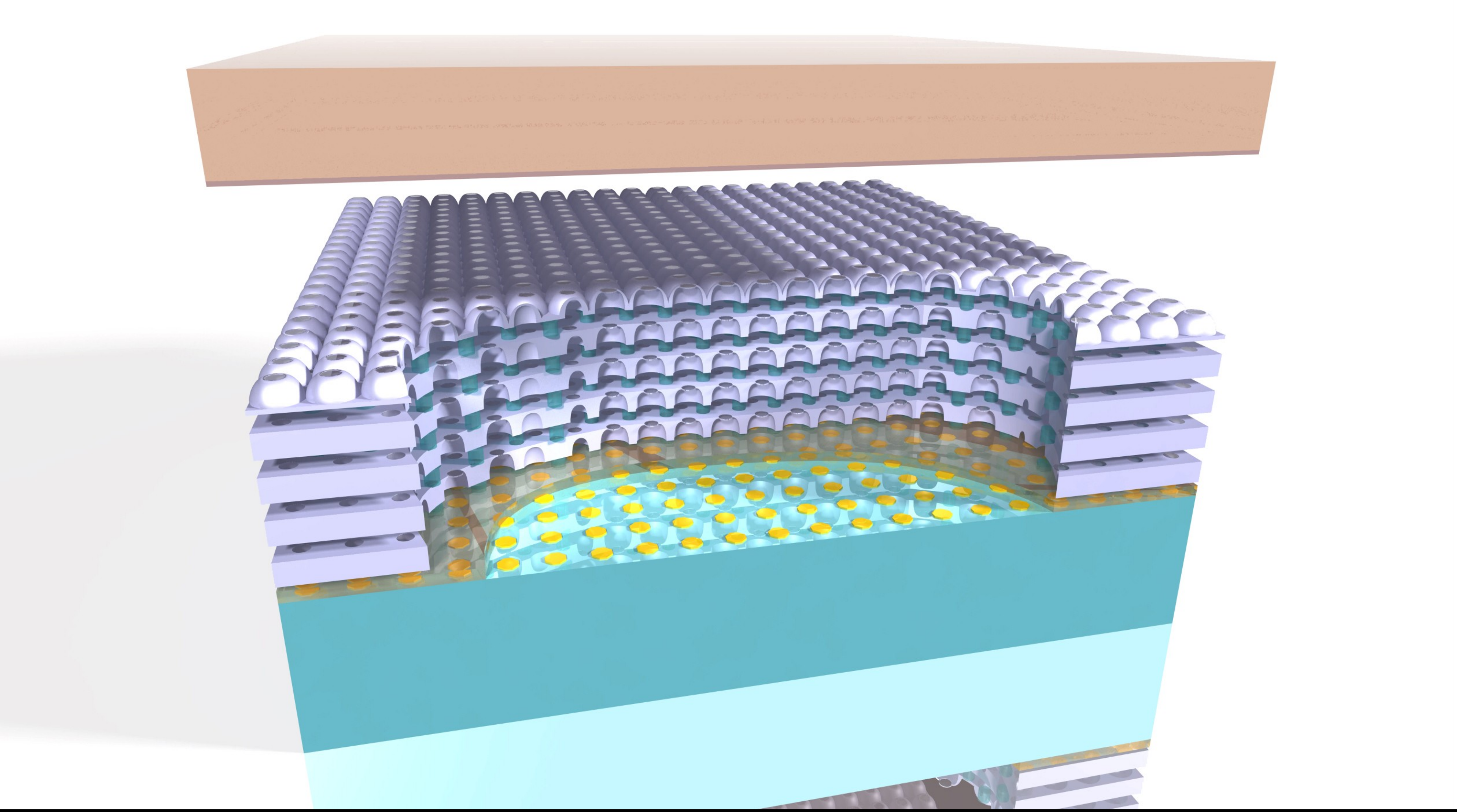


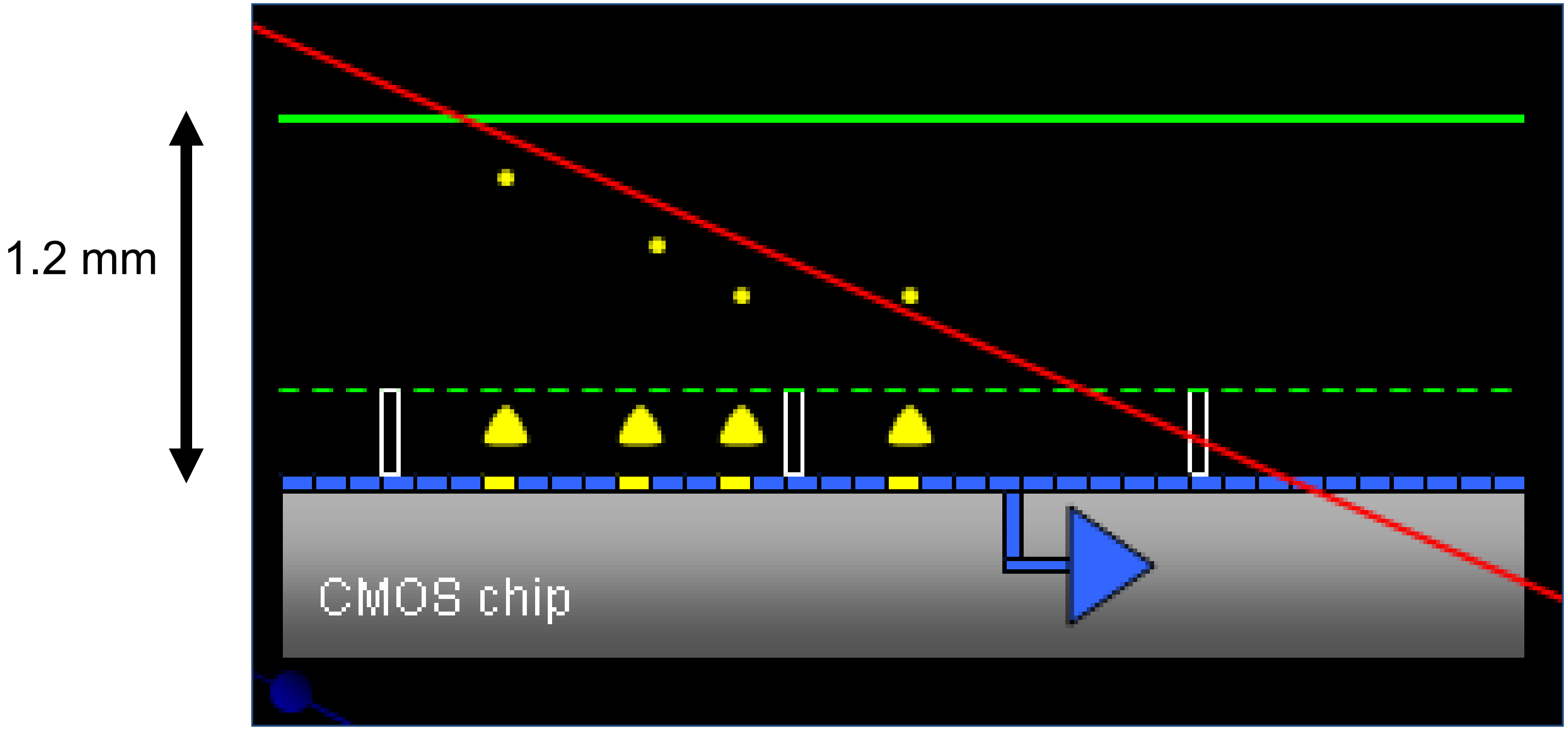




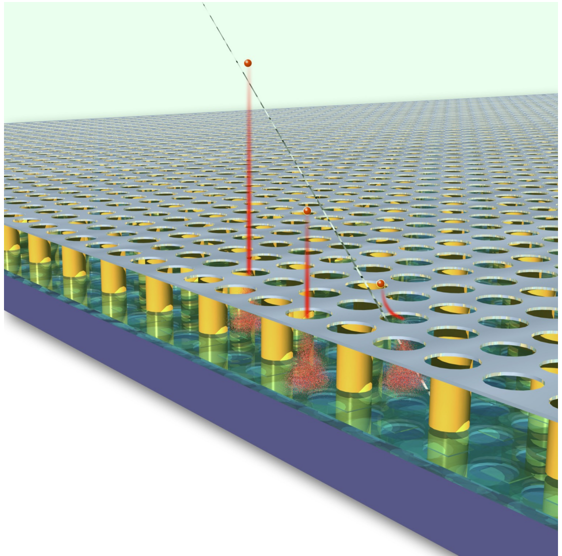


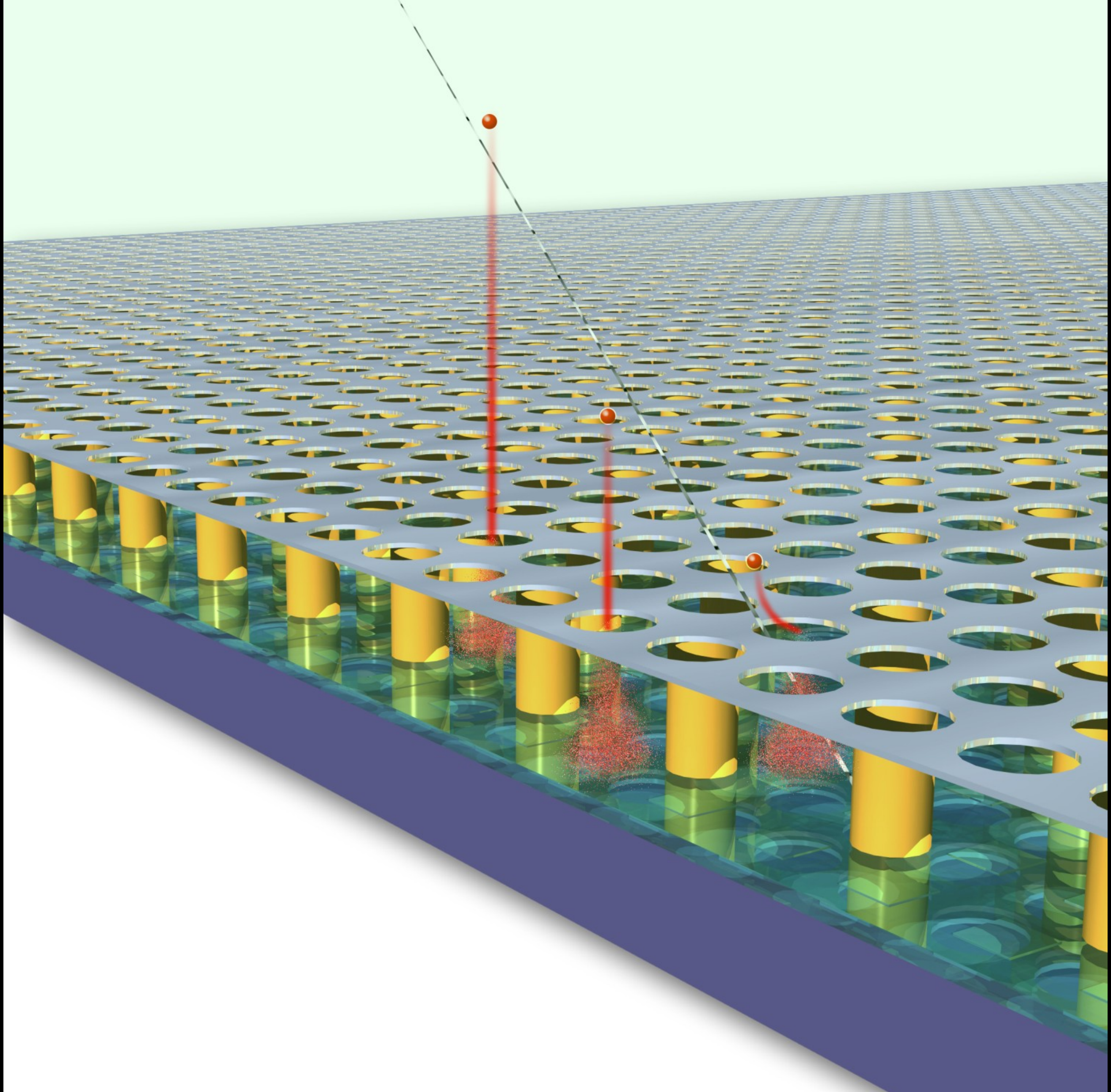






GridPix Gaseous Detector:
a readout of Time Projection Chambers

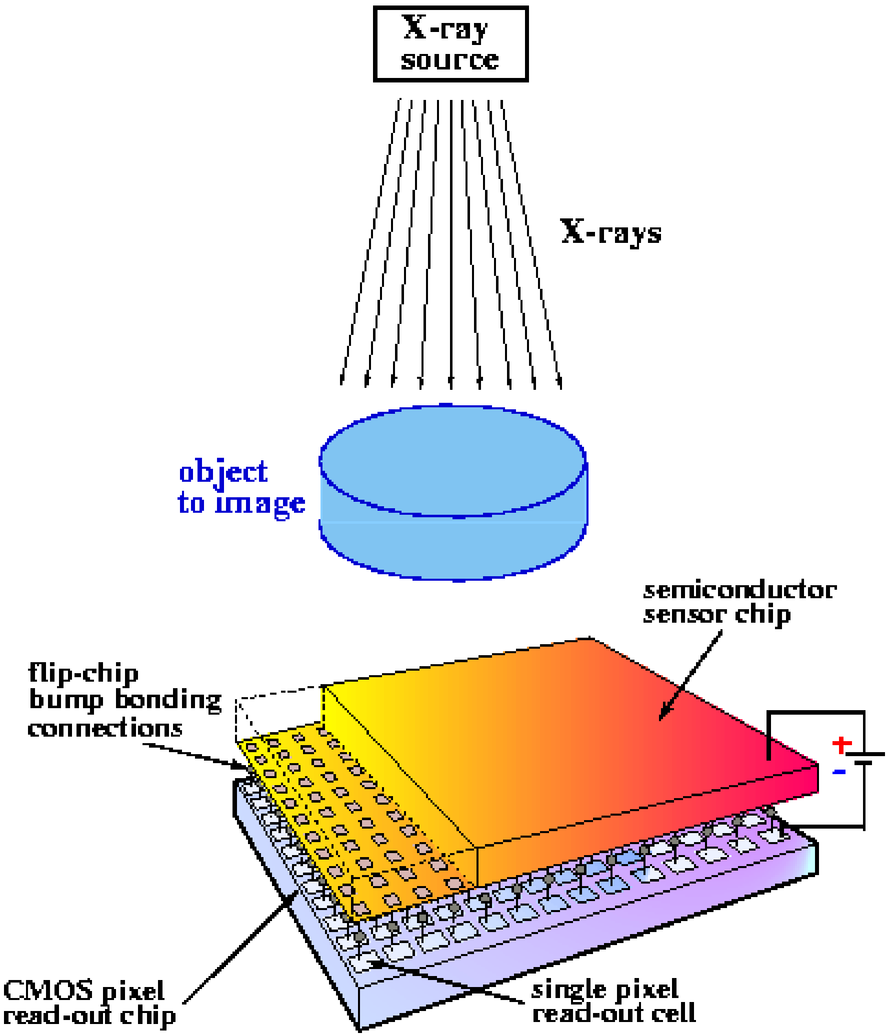




The MediPix2 pixel CMOS chip

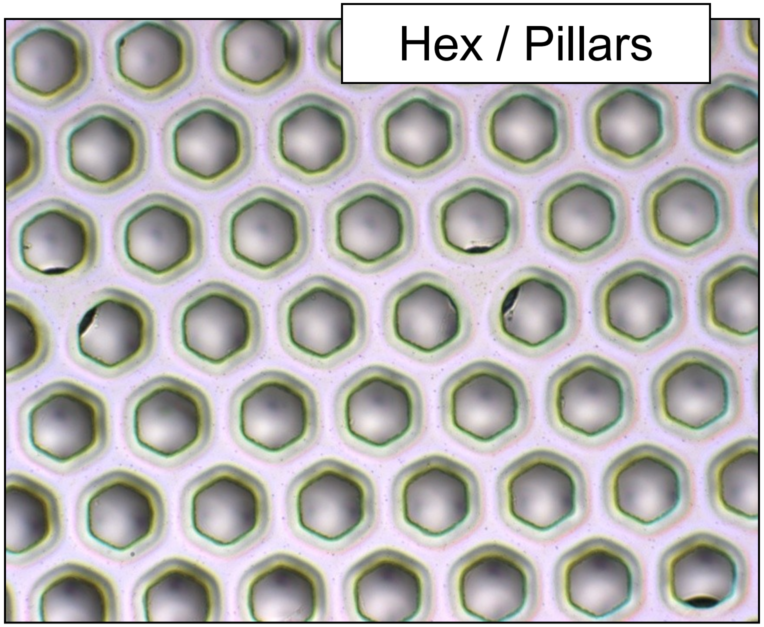
256 x 256 pixels
pixel: 55 x 55 μm^2
per pixel: - preamp
- shaper
- 2 discr.
- Thresh. DAQ
- 14 bit counter

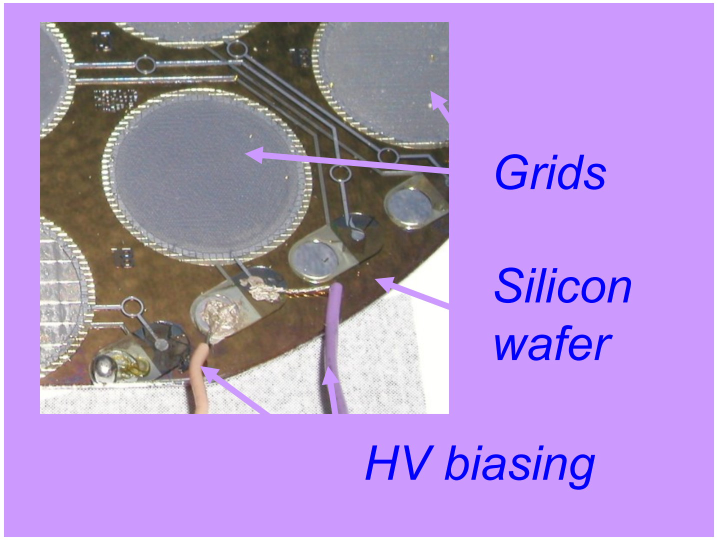
- enable counting
- stop counting
- readout image frame
- reset



We apply the ‘naked’ MediPix2 chip without X-ray convertor!

Wafer post-processing:InGrid



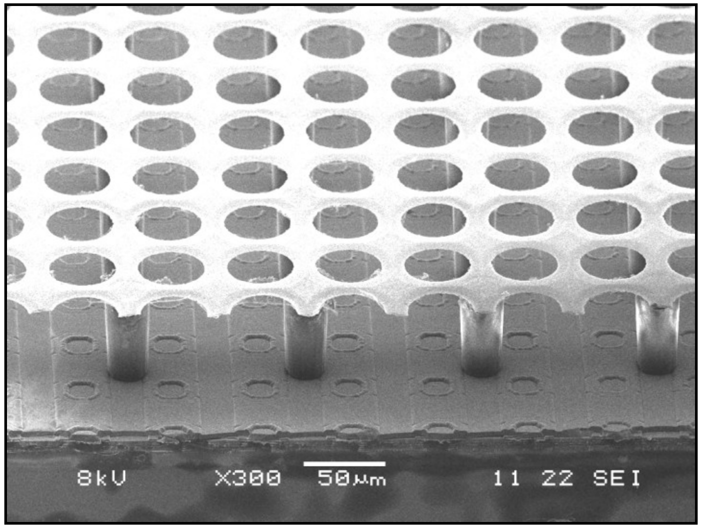


InGrid: an Integrated Grid on Si (wafers or chips)

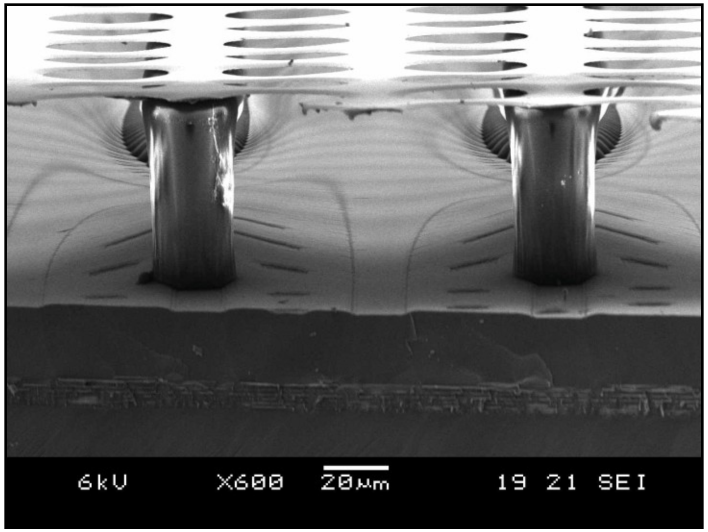
- perfect alignment of grid holes and pixel pads
- small pillars Ø, hidden pillars, full pixel area coverage
- Sub-micron precision: homogeneity
- Monolithic readout device: integrated electron amplifier

Full post-processing of a TimePix

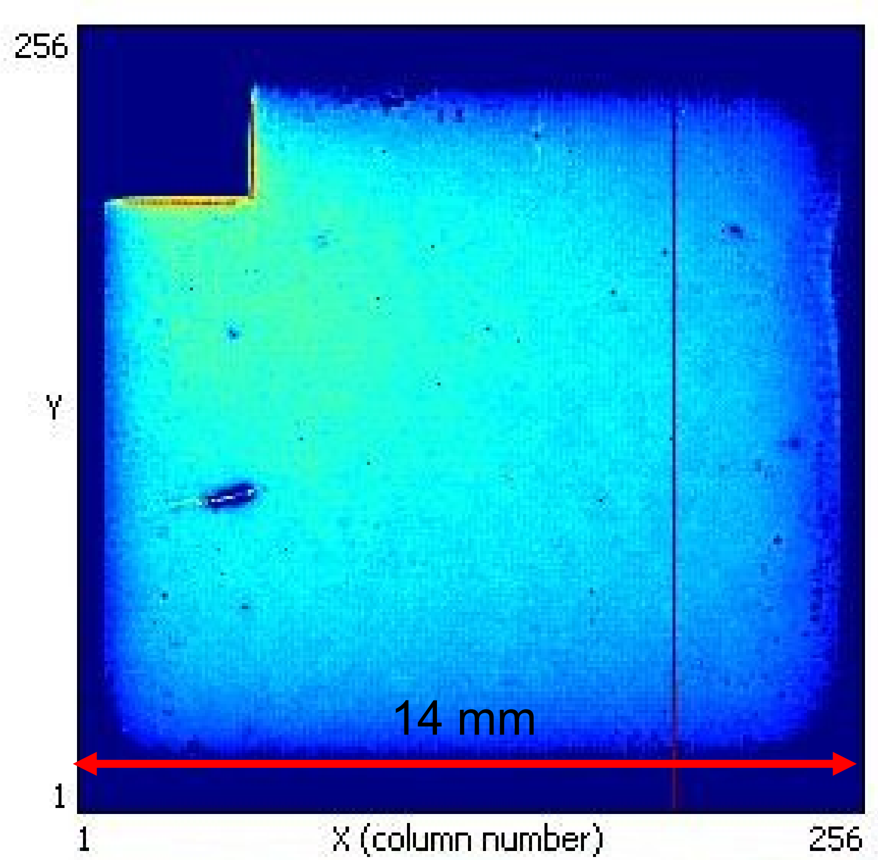
- Timepix chip + SiProt + Ingrid:



MESA+



IMT
Neuchatel

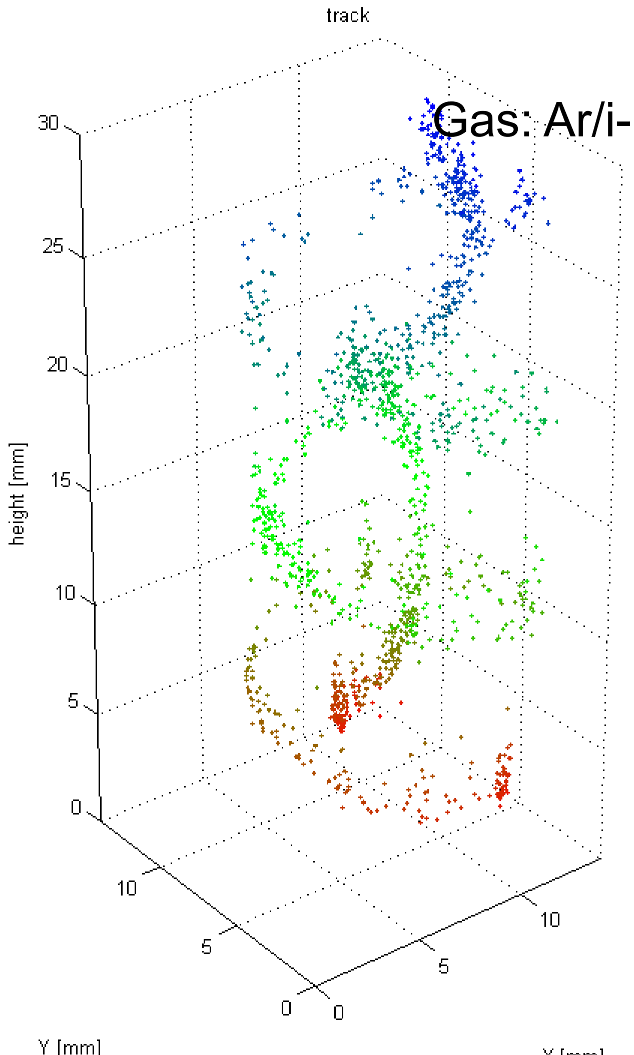


"Uniform"

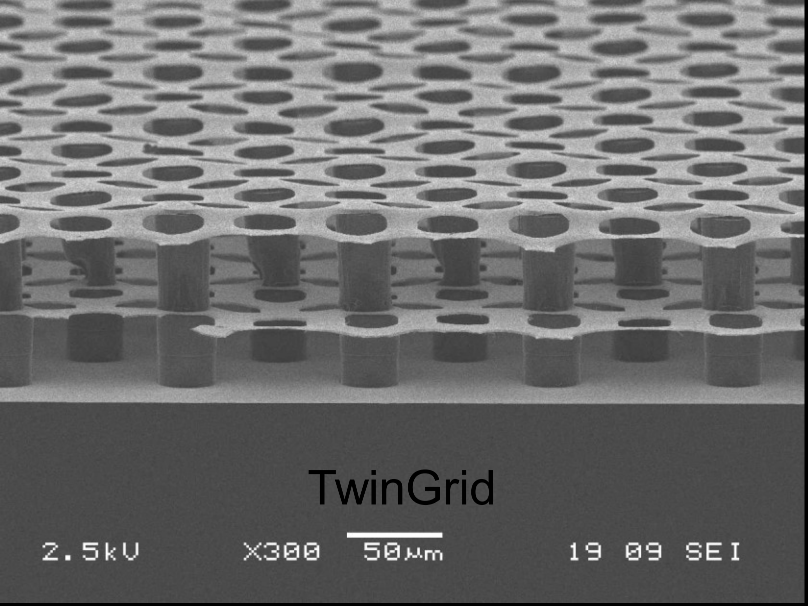
Charge mode

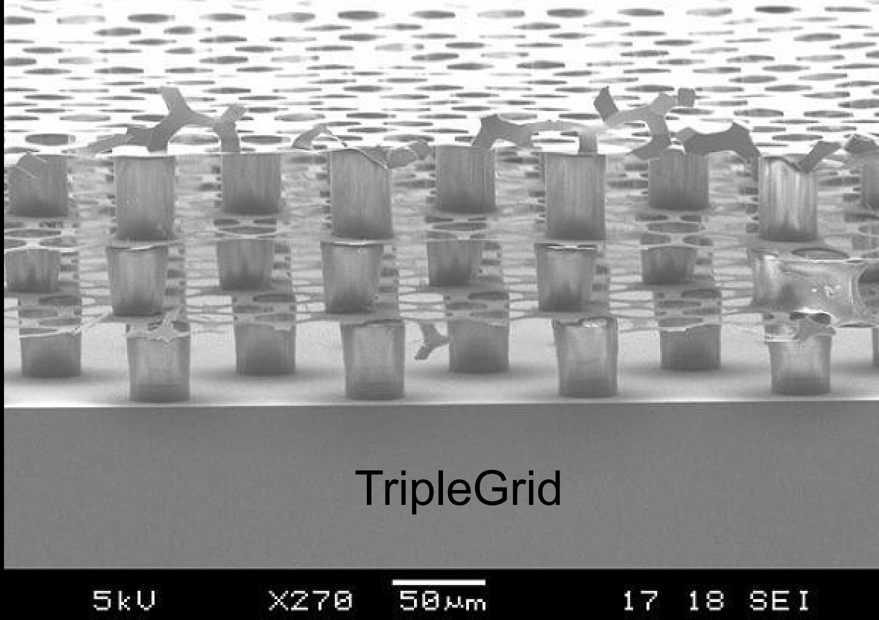
[90]Sr β events

Gas: Ar/i-butane 80/20



Efficiency to detect single electrons > 95 %

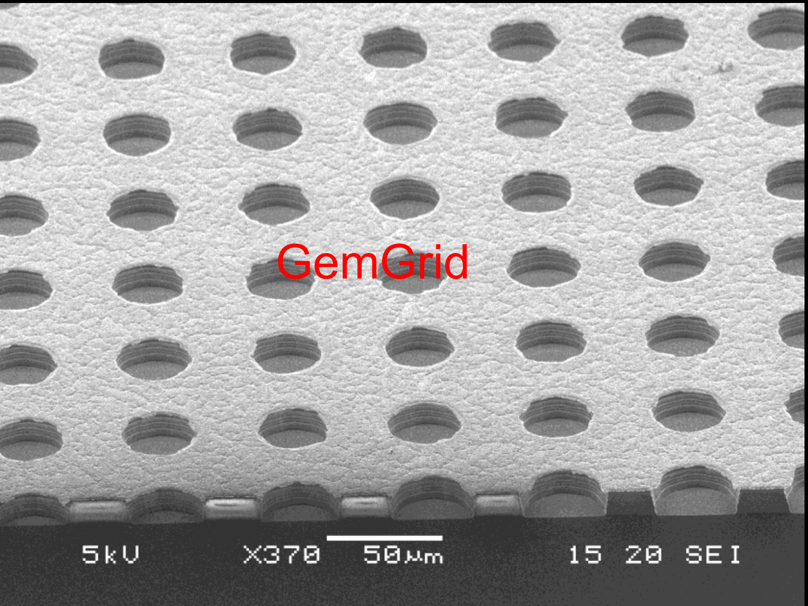


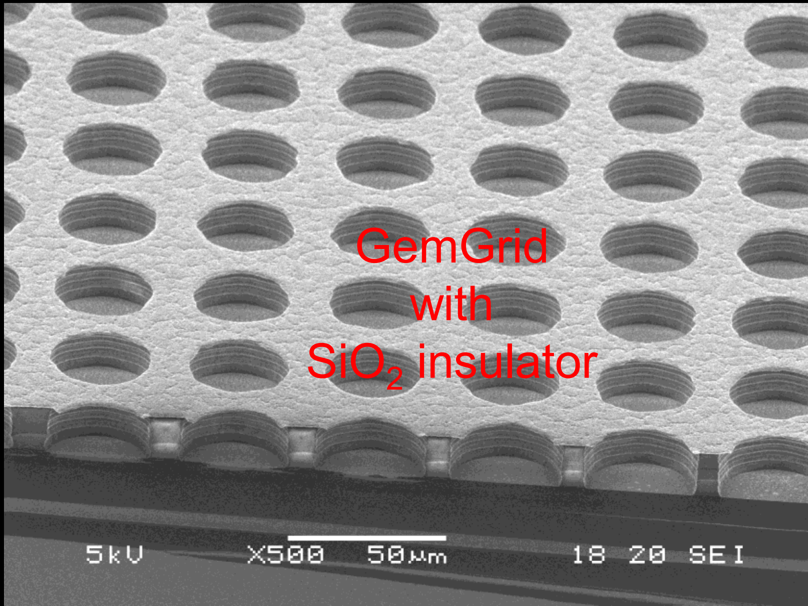


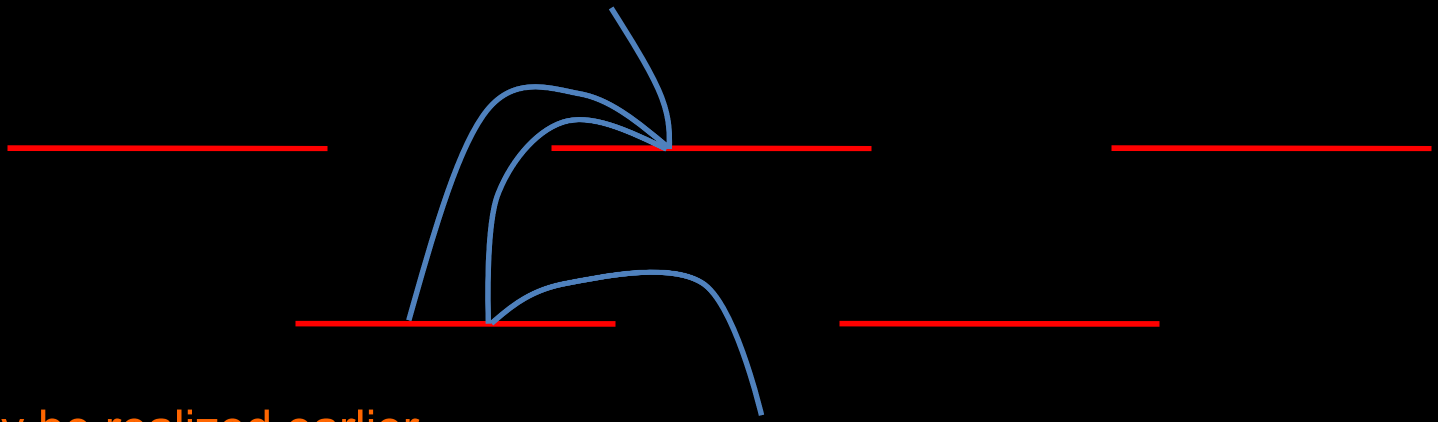
Development of MEMS technology

Wafer Post Processing

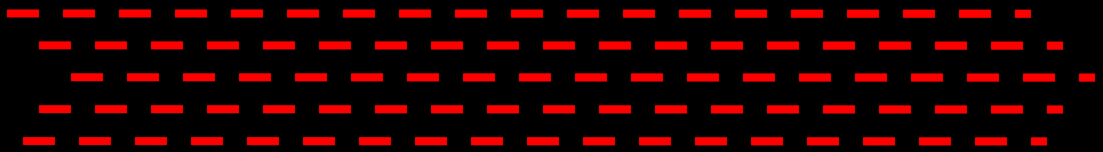
'There is plenty of room at the top' supported by Dutch Economical Affairs

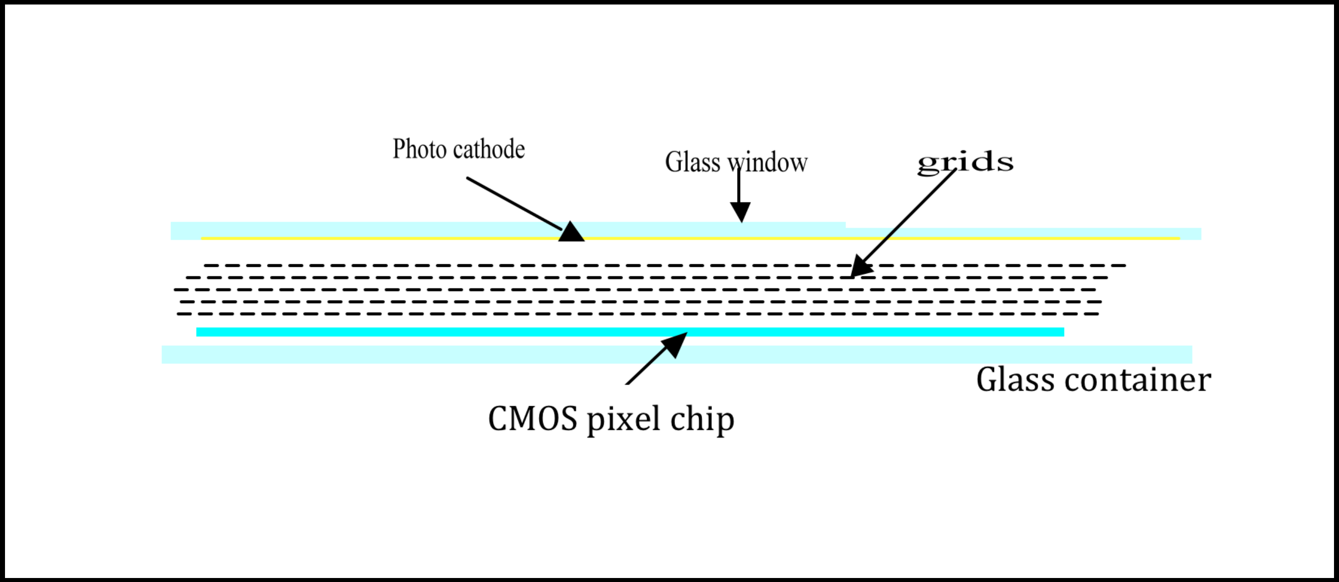


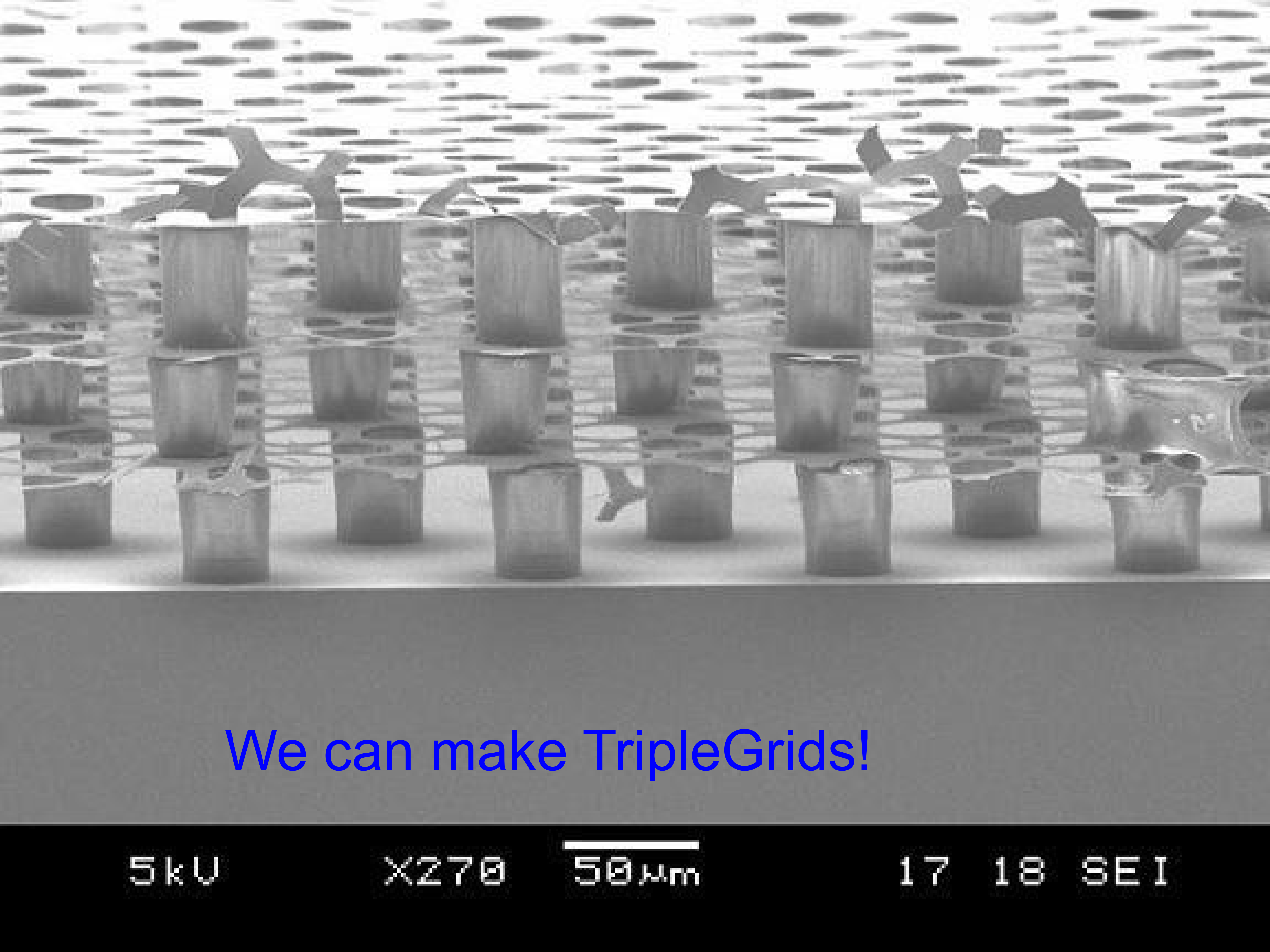




QuintGrid may be realized earlier
Development // Transmission Dynodes



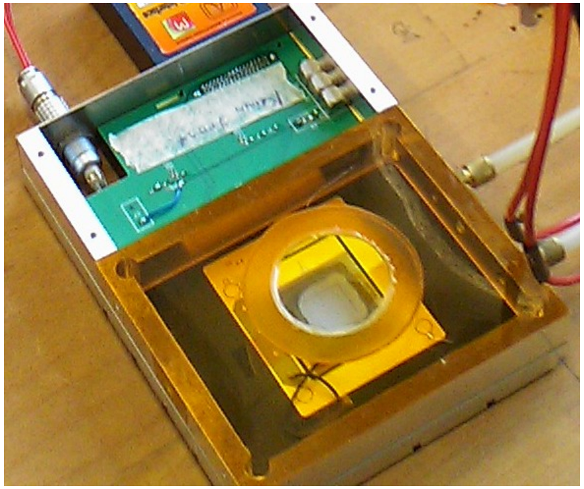


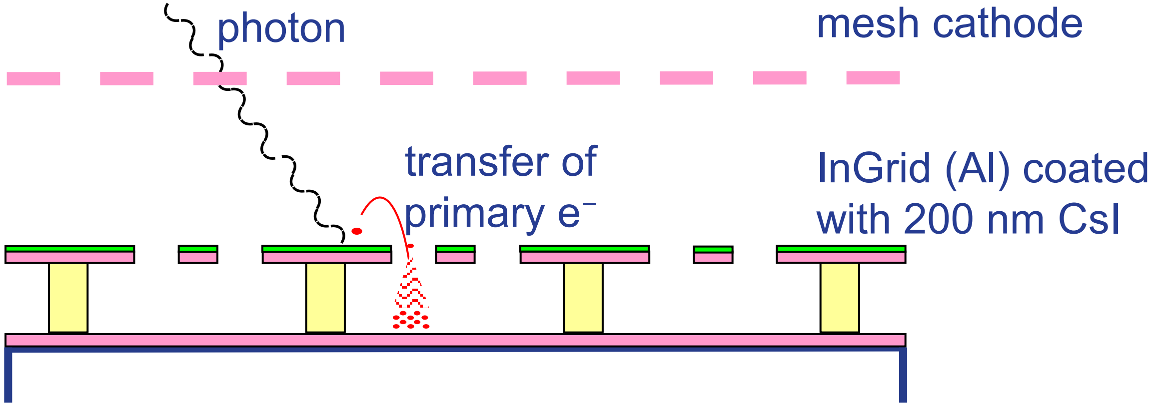

We can make TripleGrids!
5kV
X270
50µm
17 18 SEI

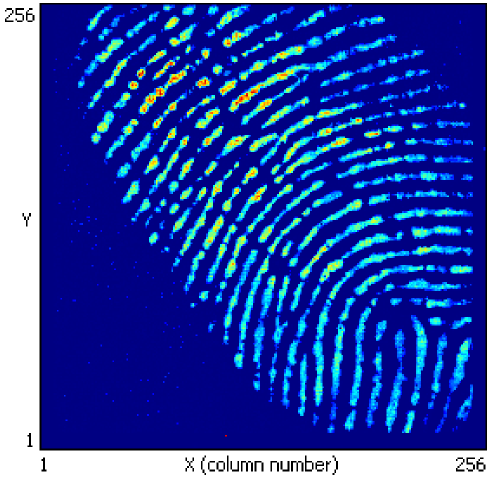
Photosensitive GridPix

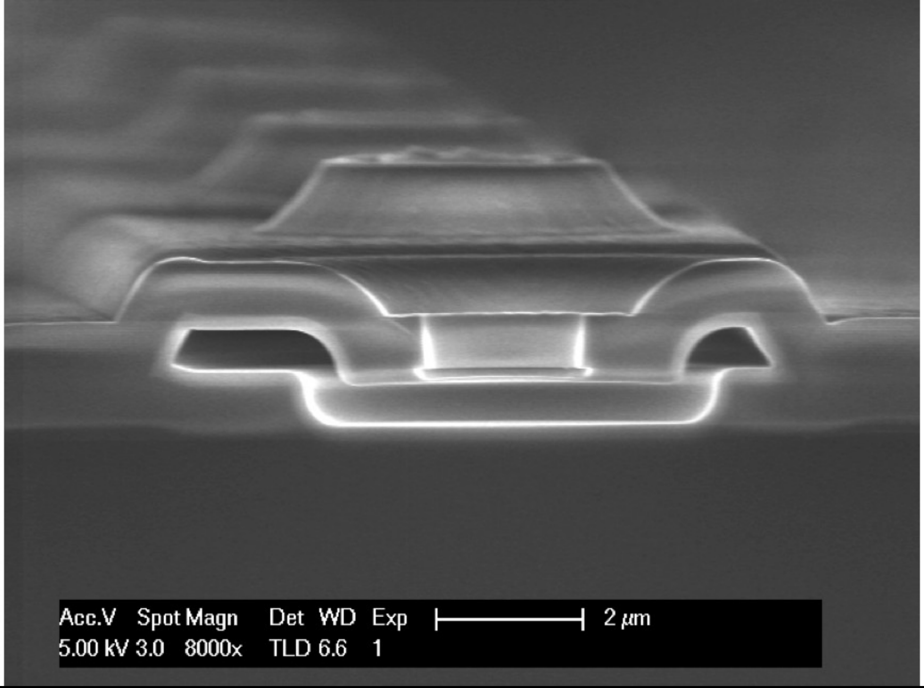
Univ. Twente and Weizmann institute
InGrid with CsI on alu. anode
Detect by means of gasgain
Better anode readout → TimePix

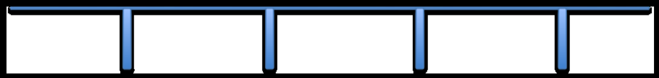
UV light 200-400 nm
First test, InGrid without CsI
UV well absorbed by my fingerprint





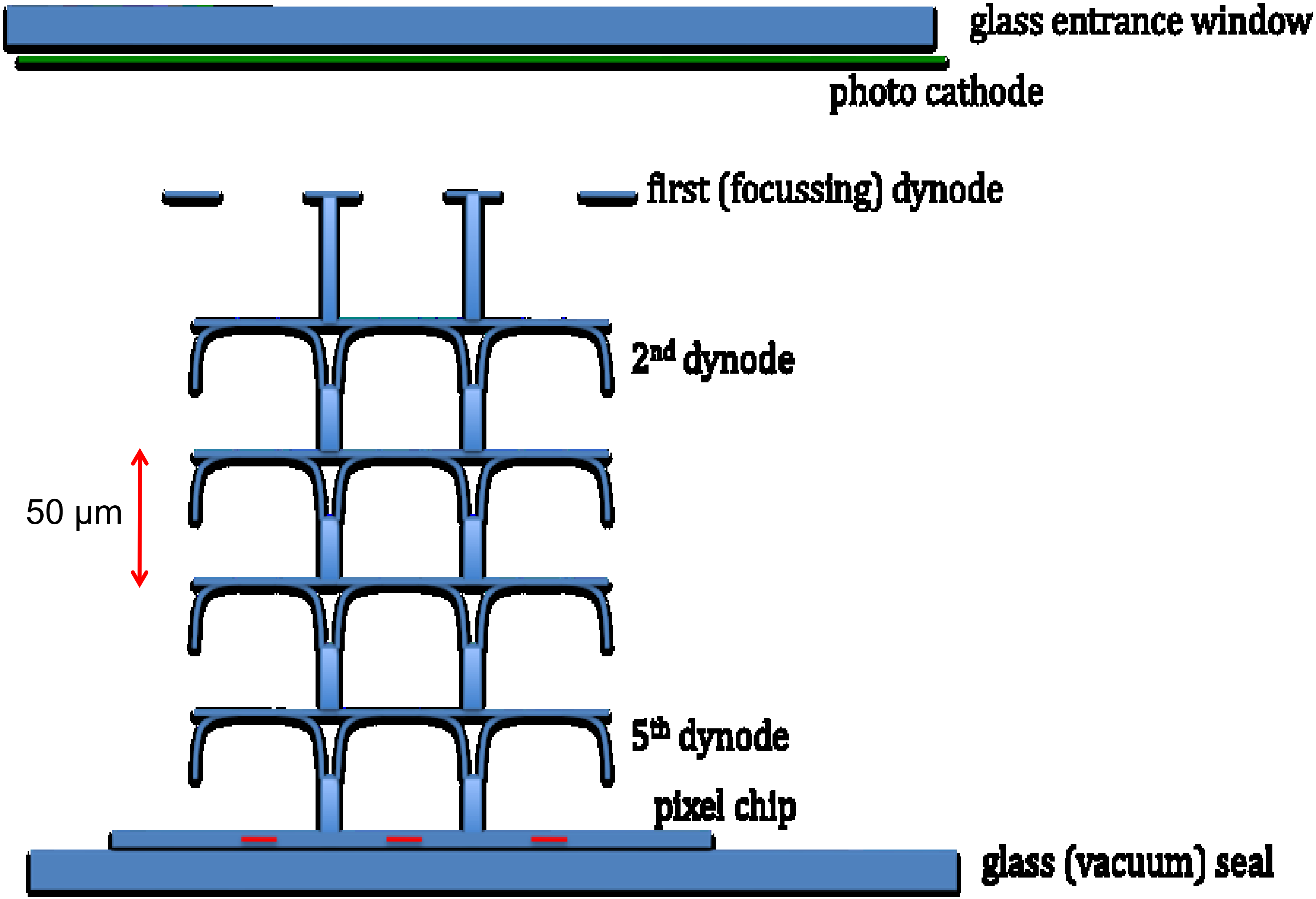


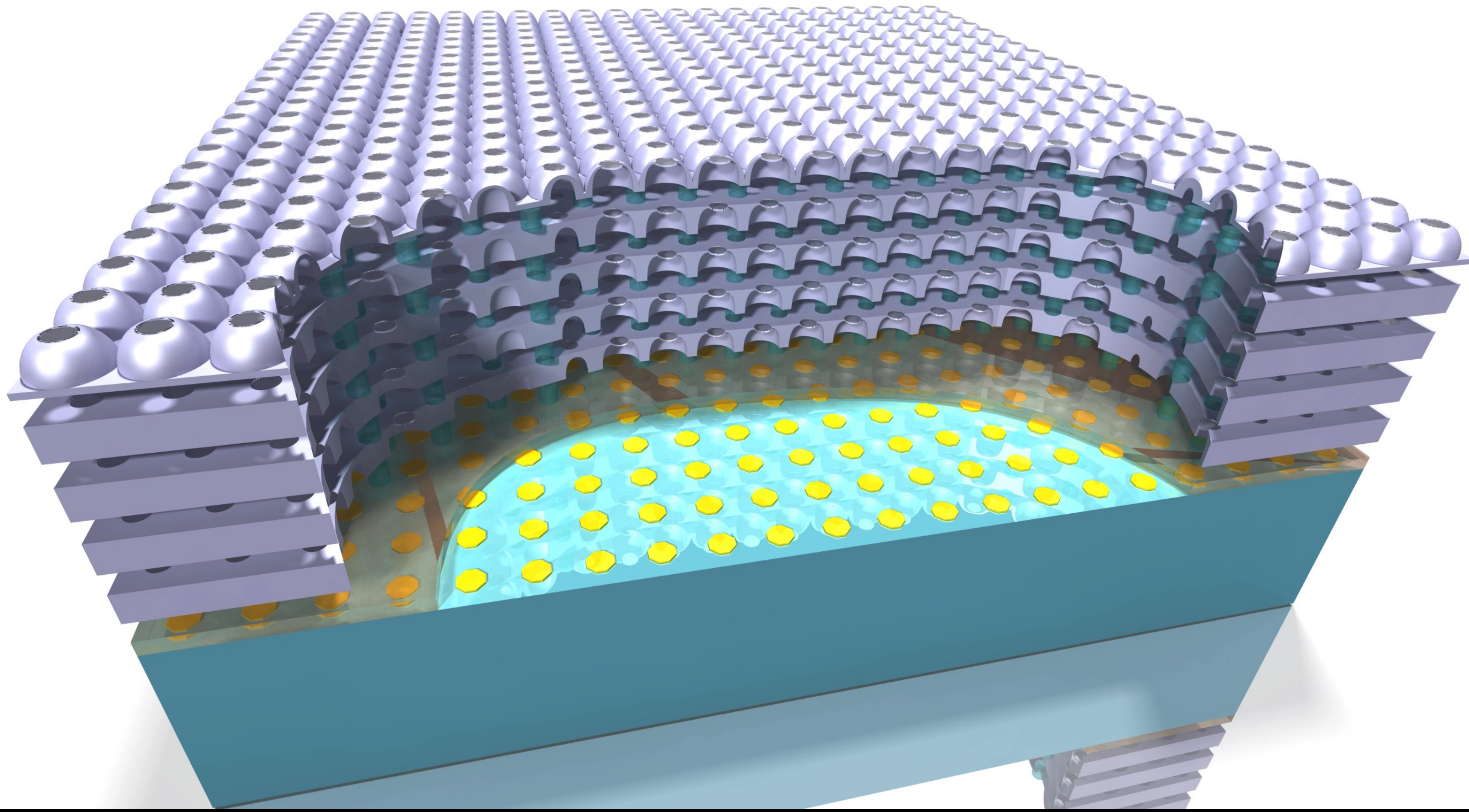




Reinforcement bars required: creates dead regions

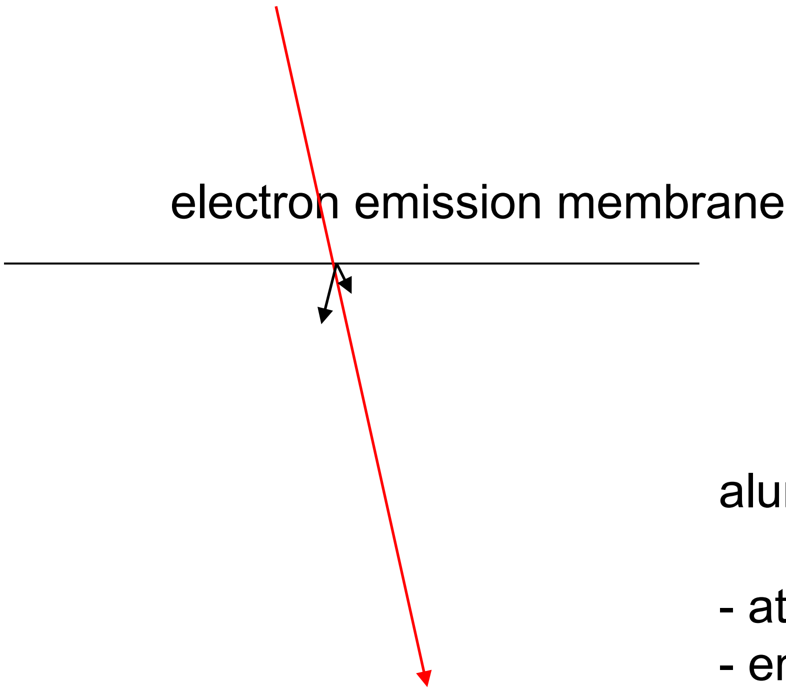
Problematic for 1st transmission dynode


glass entrance window
photo cathode
first (focussing) dynode
2nd dynode
50 µm
5th dynode
pixel chip
glass (vacuum) seal



For tracking of fast charged particles (MIPS):

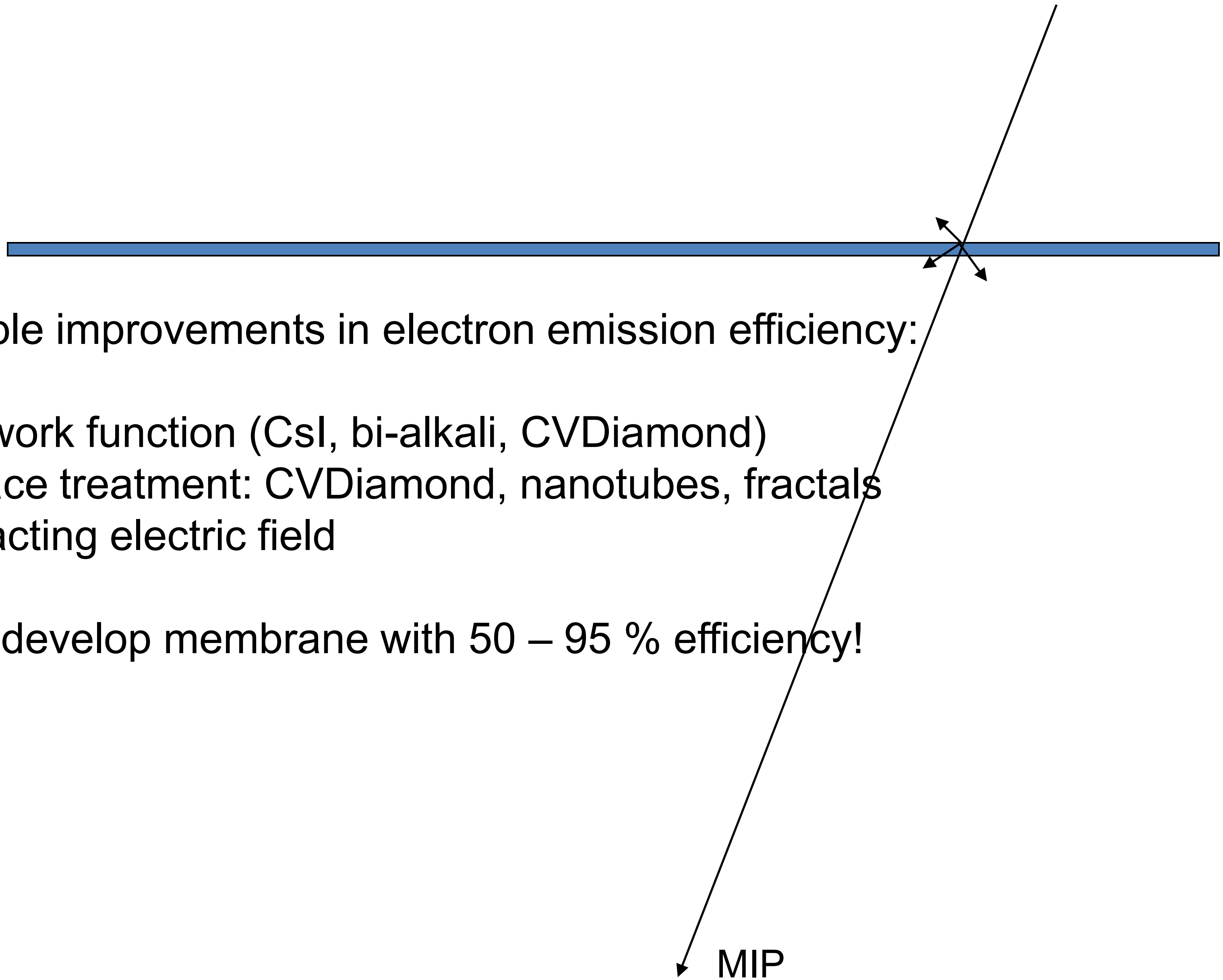
Replace photocathode by **Electron Emission Membrane**



Emits (at least one) electron at the crossing point of membrane surface and MIP, with a high probability

aluminium foil:

- at least 1 electron is emitted in 4 % of the cases
- energy of electron: 0 – 5 eV
- probability depends on surface condition
- increase to 6 % if layer of AlOxide is present

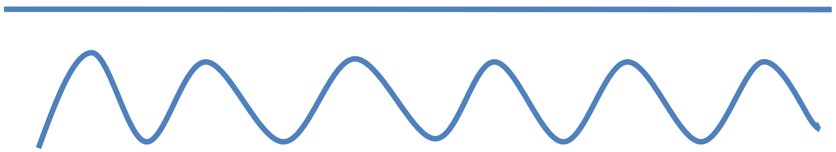


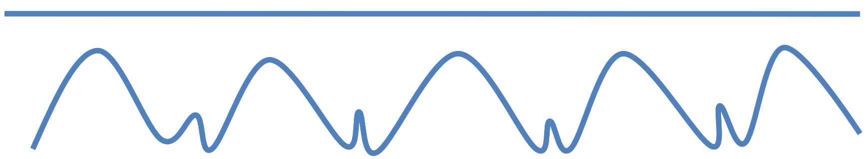
Possible improvements in electron emission efficiency:

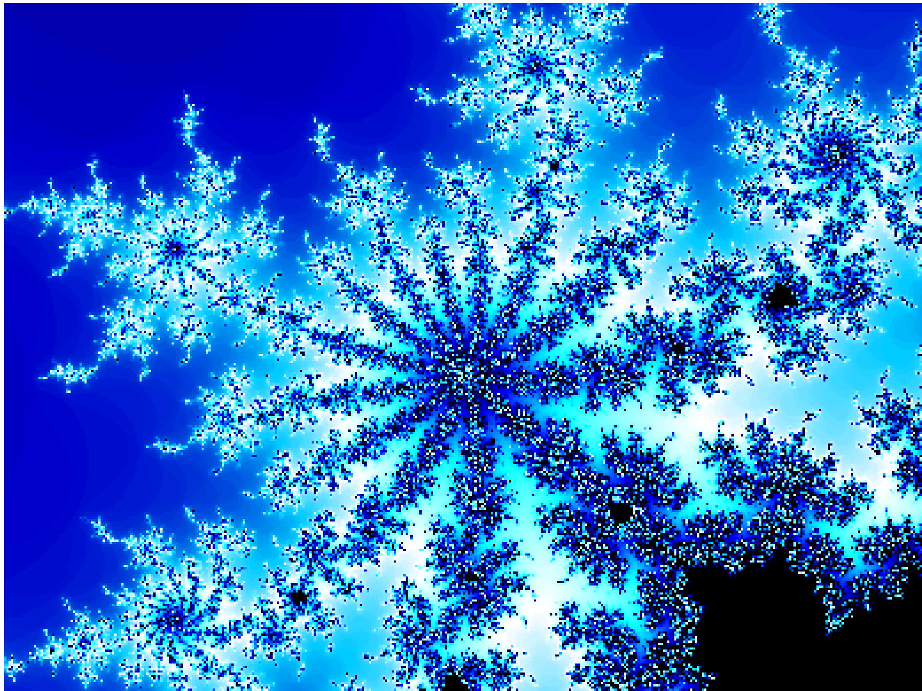
- low work function (CsI, bi-alkali, CVDiamond)
- surface treatment: CVDiamond, nanotubes, fractals
- Extracting electric field

Try to develop membrane with 50 – 95 % efficiency!

Skin effect: only skin of ~ 50 nm participates in EE.
Rise of EE efficiency by surface enlargement: meandering, modulating, roughening







2nd order modulation, 3rd order.….fractals!
Extracting E-field: constant at surface

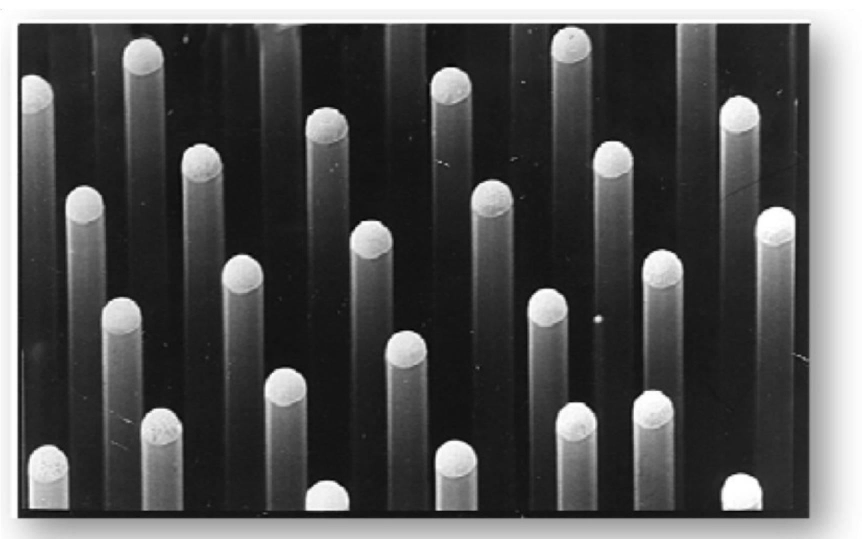
Work function

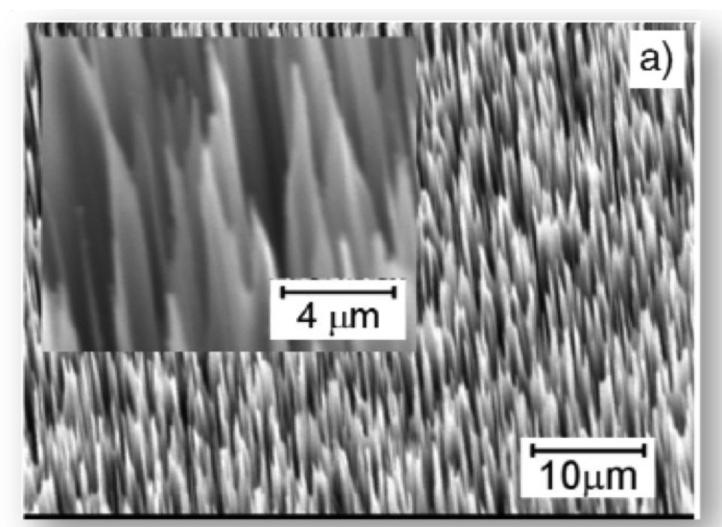
Interesting: - photo cathodes of PMs (bi-alkali etc)
- coating of dynodes of PMs

- Eff Alu, Cu: ~ 4 %
- Eff ceramics (Diamond, CsI, Si_3N_4): 10 - 20 %?

Exctracting electric field (close to cold electron emission)

- nano grass



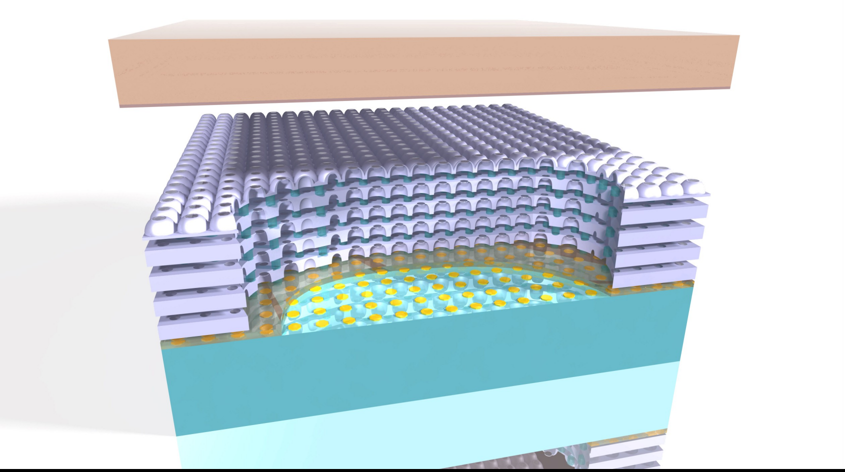


Conclusions

MultiPix
MEMS made vacuum electron multiplier integrated on pixel chip

MultiPix + ‘classical’ photo cathode
Timed Photon Counter TiPC Tipsy

MultiPix + Electron Emission Membrane
MIP tracking detector



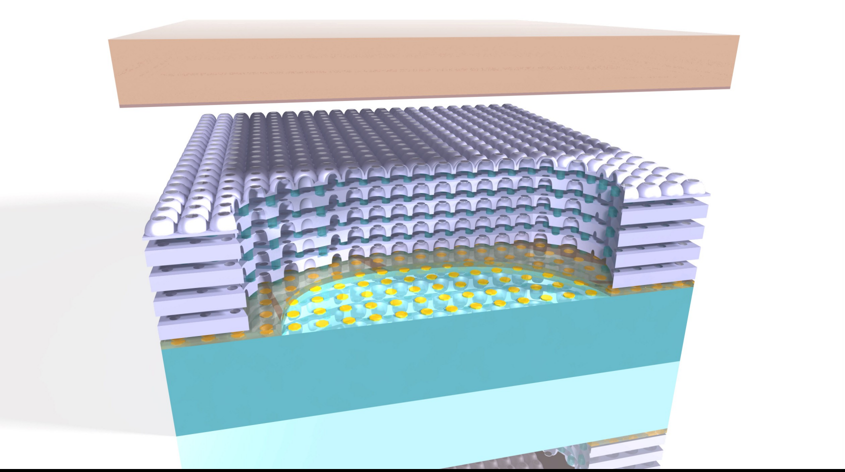
1” x 1”, 2 mm thick

Timed Photon Counter TiPC Tipsy

- good quantum efficiency
- ultra fast, ps time resolution
- low noise
- little dark current, no bias current
- radiation hard
- perfect linear
- flat, thin & light
- 2D position resolution ~ 10 μm
- potentially cheap……!
- little radioactive
- can stand B fields

Potentially outperforms APDs, G-APDs, SPADs, dSiPMs, QUPIDs

Consumer application: 3D pictures by measurement Time-of-Flight…….!



1” x 1”, 500 μm thick

MIP Tracking detector

- moderate track efficiency 50 – 90 %
- ultra fast, ps time resolution
- low noise
- little dark current, no bias current
- radiation hard

- flat, thin & light
- 2D position resolution ~ 10 μm
- potentially cheap……!
- can stand B fields
- no 3D track vector info (GridPix)

Outperforms Si trackers in terms of time resolution
- high rate experiments
- BX timing: ILC/CLIC experiments