Nano-engineered ultra high gain microchannel plates

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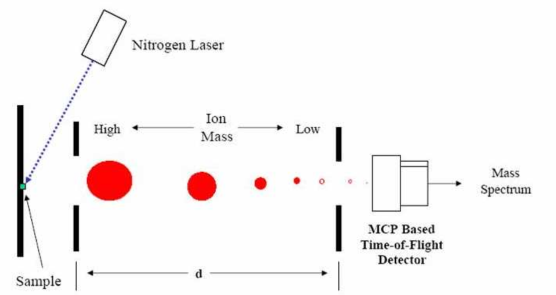
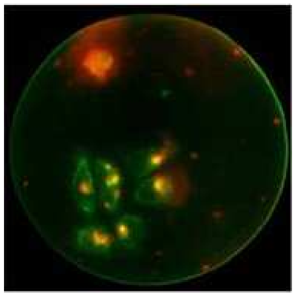
Outline

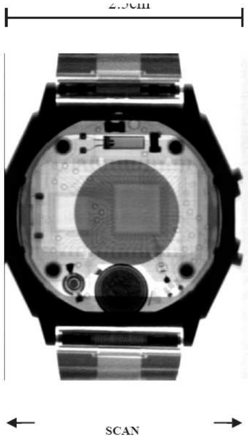
- Present MCP technology
  - Areas of MCP applications
  - Glass-based structures, manufacturing
  - Present limitations and drawbacks
  - Previous alternative technologies
- Improvement of the glass MCP characteristics
  - Gain
  - Lifetime
  - Ion feedback
- Novel substrate-independent manufacturing technology

Areas of MCP detector applications

- Night vision goggles
- Mass spectroscopy
- Astrophysics
- Synchrotron instrumentation
- Biomedical research (FLIM, FRET,…)
- X-Ray and UV photon detection
- Neutron radiography and Bragg edge spectroscopy







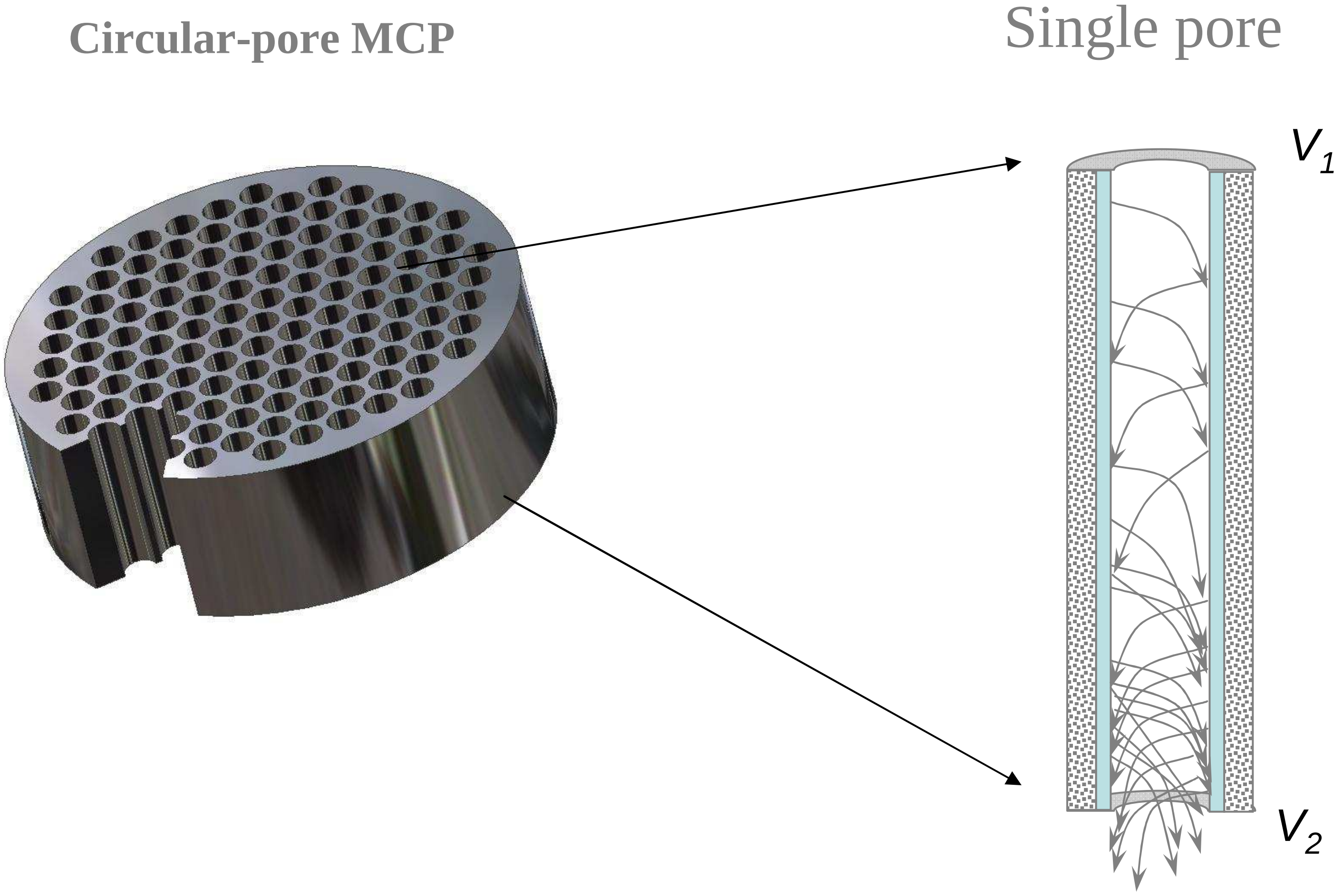
Advantages of MCP detectors

- Event counting
- Very low dark current
- Sensitivity to photons, ions, electrons neutrals, neutrons, alpha particles
- Simultaneous high spatial (~10 µm FWHM) and temporal (~100 ps FWHM) resolution
- Different geometries (e.g. hole in the middle)
- Solar blindness
- Large active area

Disadvantages of glass MCP detectors

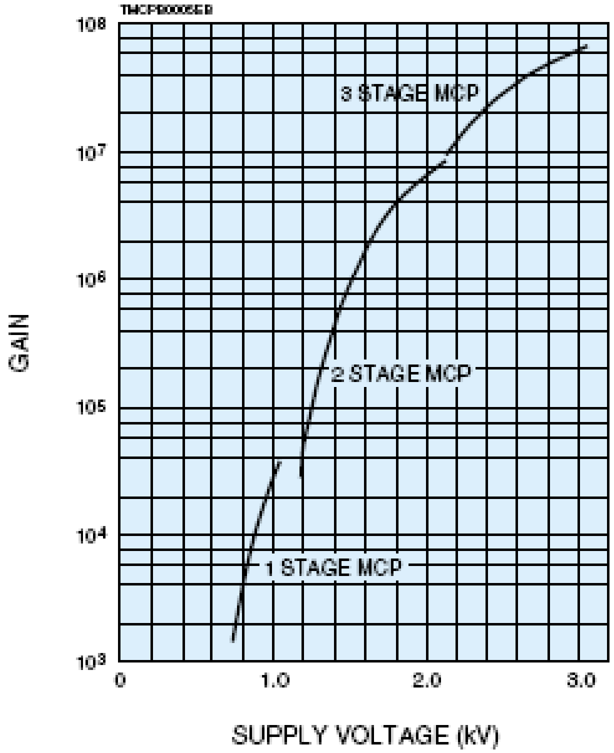
- Limited counting rate capabilities (<100 MHz)
- Difficult photocathode technology for visible range
- High voltage
- Limited lifetime
- Requires vacuum
- Fixed pattern noise
- High manufacturing costs

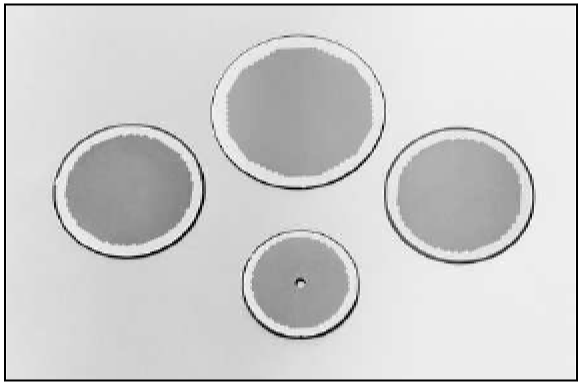
MCP electron amplifier

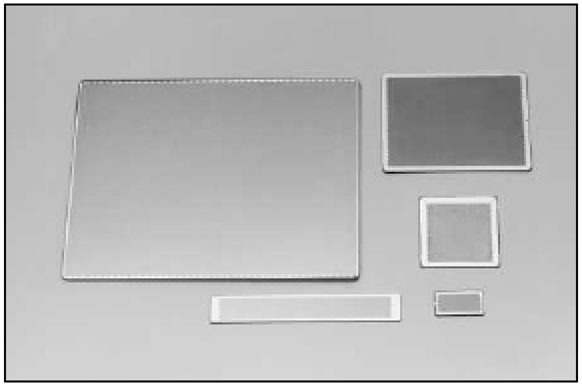


Commercial MCPs: geometry and gain

■MCP Gain Characteristics



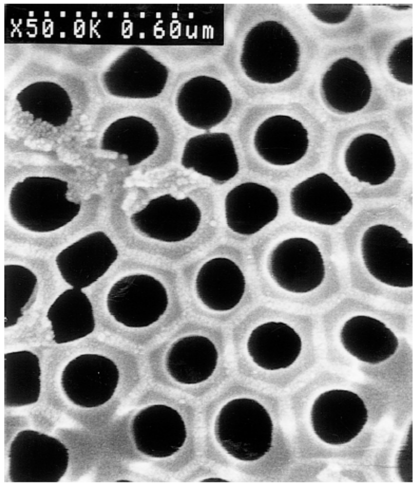




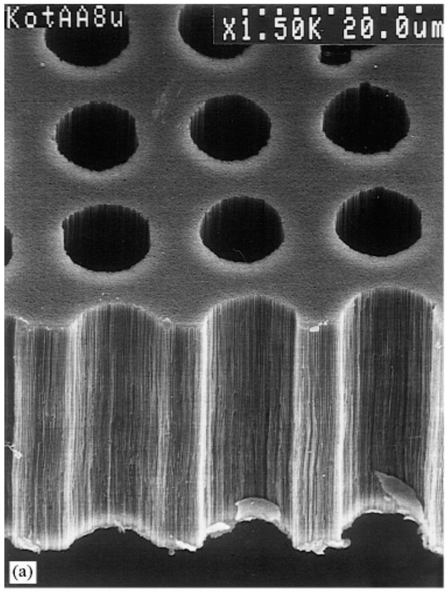
Difficulties of present lead glass MCP technology

- Complex production technology;
- Both conduction and emission layer produced simultaneously and cannot be optimized independently.
- Large parameter deviation and low reproducibility; geometrical distortions unavoidable.
- Image spottiness;
- Not high temperature compatible;
- Limited lifetime;
- Small pore MCPs and large area MCPs are expensive to produce;
- Lead contamination;

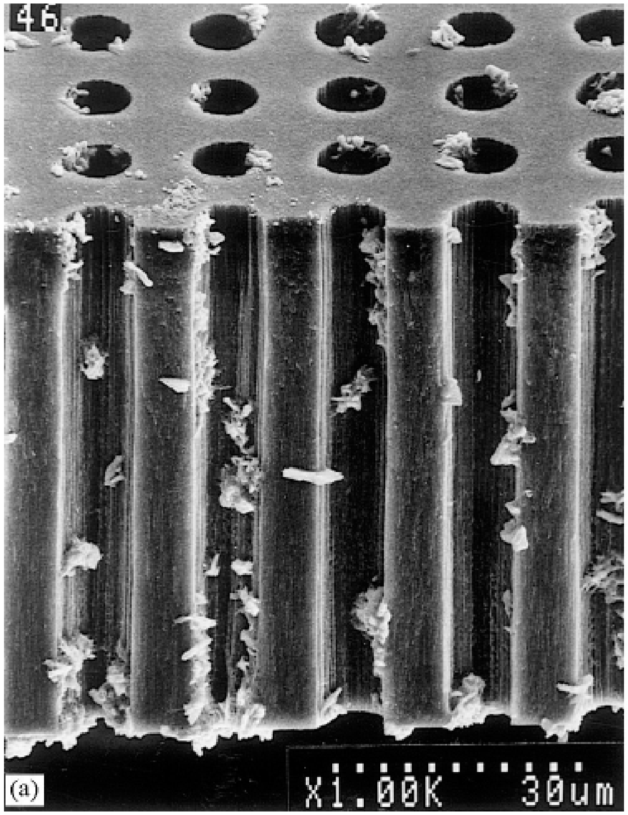
Previously tried: Anodic alumina MCPs



Sub-µm pores in
anodic alumina substrates



Lithographically etched
10 µm pores

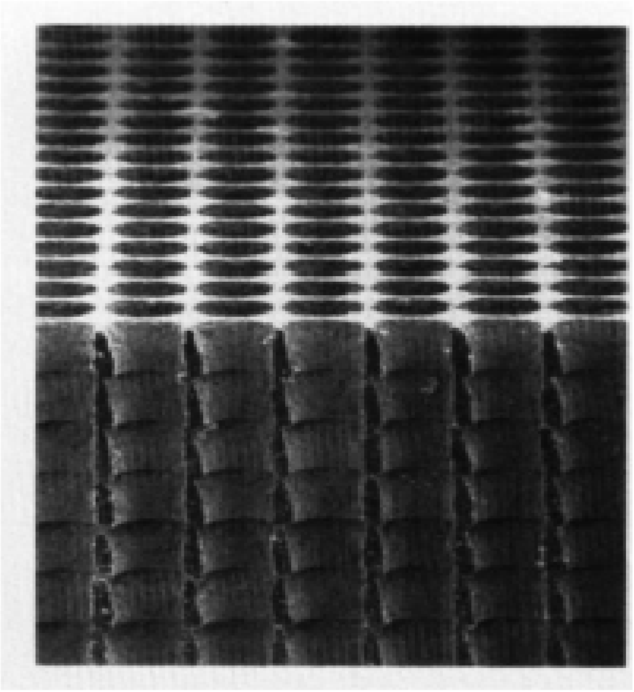


Good substrates,
no continuous films

Initial attempts did not produce conformal coating.
To date no fully functional MCP exists

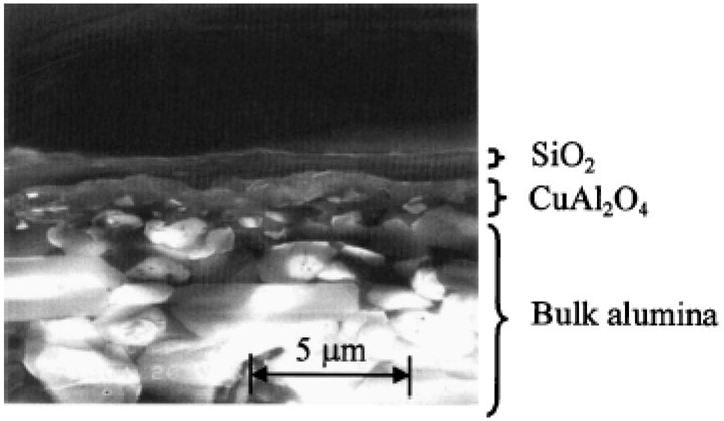
A. Govyadinov, et al., Nucl Instr. Meth. A 419 (1998) 667

Previously tried: Punched alumina MCPs

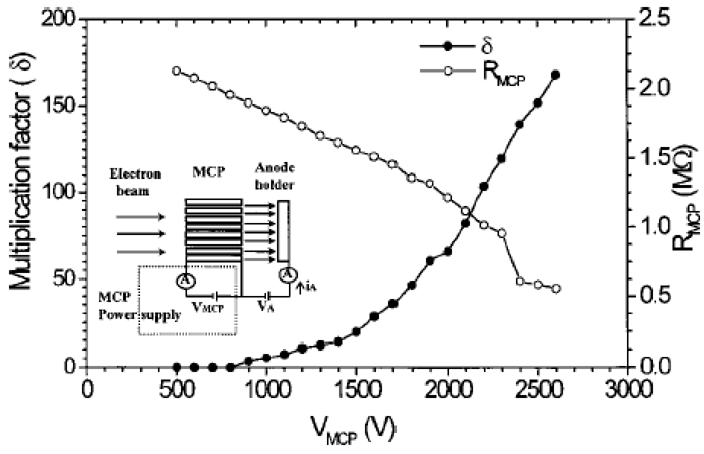


Holes are punched in thin films,
which are laminated into thick structures

Very large pore sizes.
Difficult to manufacture
(stacking many substrates).
Not suitable for imaging.



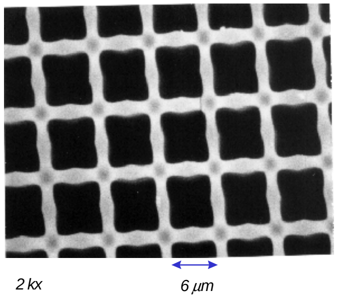
SEM image of the pore wall



Gain vs. applied bias

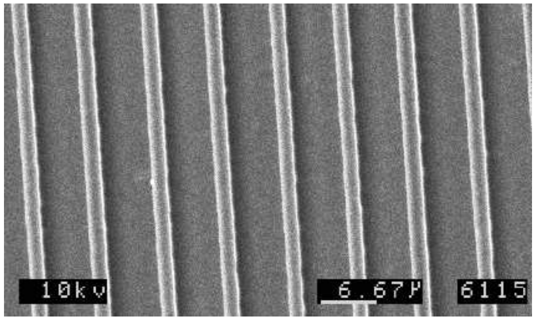
Yi Whikun, et al., Rev. Sci. Instr. 71 (2000) 4165

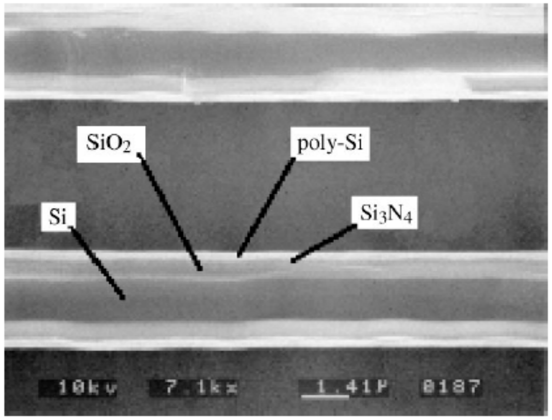
Previously tried: Silicon micromachined MCPs

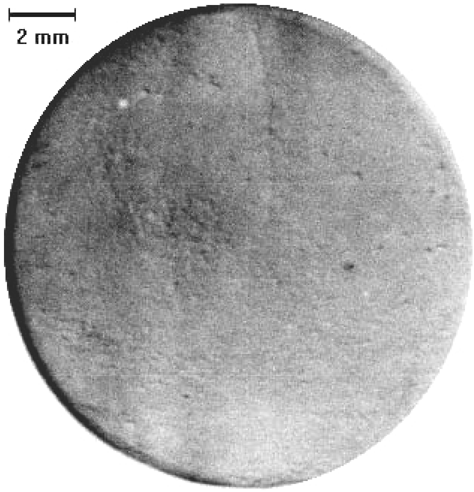


Pore pattern is set by photolithography

CVD growth of conduction layer and emission layer

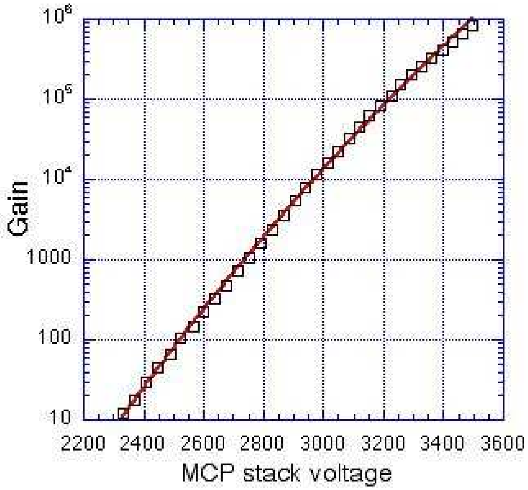






Full field UV image
(stack of 4 MCPs).
Residual distortions are seen

Relatively low gain.
No solid edge.
Long term stability.



Gain of 4 MCP stack (40:1 each)

C.P. Beetz, et al., Nucl, Instr. Meth. A 442 (2000) 443

Arradiance: Improved MCP technology

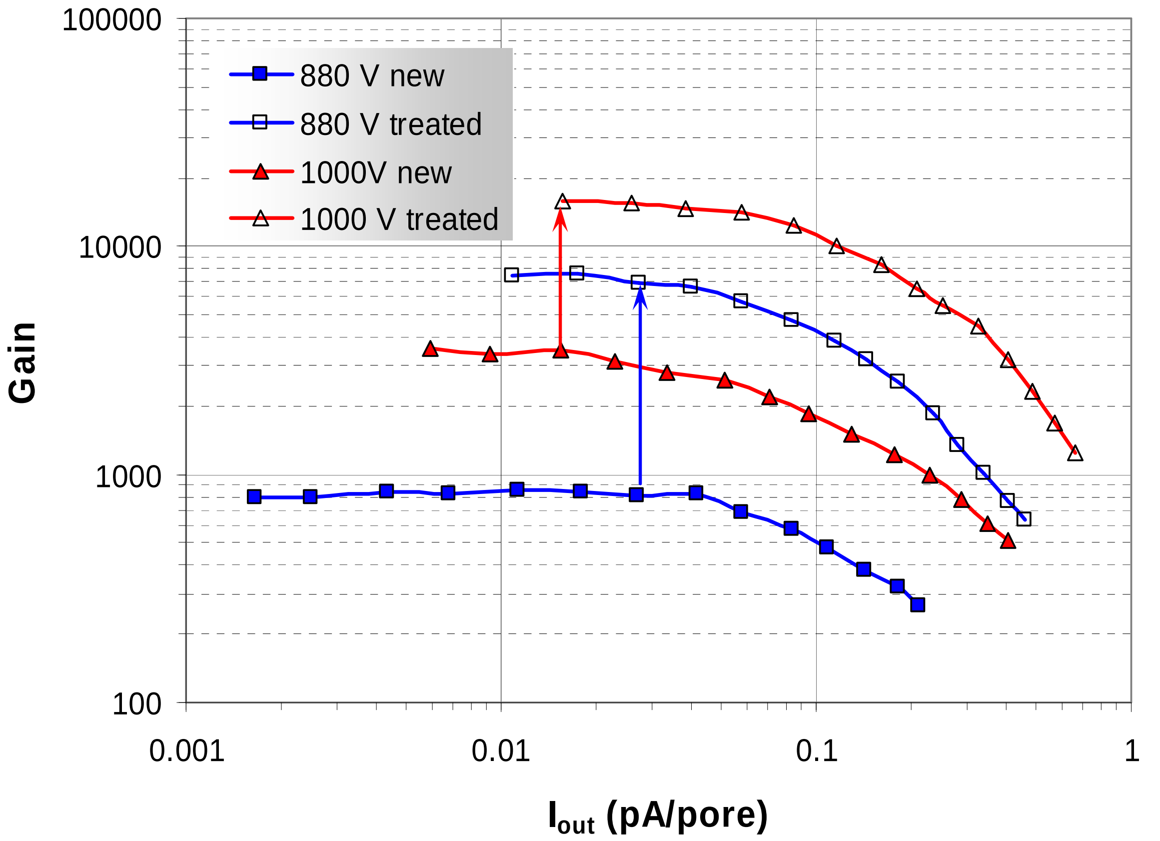
- **Improvement of the emission layer**
  - longer lifetime
  - higher gain
  - reduced ion feedback

- **Nano-engineered conduction and emission layers**
  - Novel MCP substrates (new glasses or micromachined)
  - Better uniformity / spatial resolution
  - Increased lifetime
  - Novel photocathodes / opaque mode
  - Withstand much higher processing temperature
  - Very Low noise (no radioactive traces)

Novel secondary electron emission layer

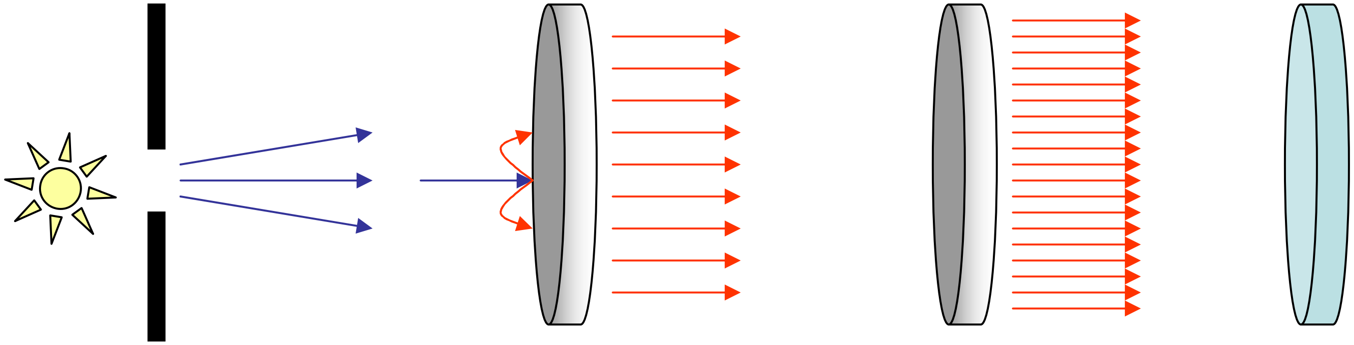
Applied over commercial glass MCPs:

50:1 L/D, 4.8 µm pores, ~250 MΩ resistance



5x-10x gain increase

Uniformity of Arradiance coating: functional test

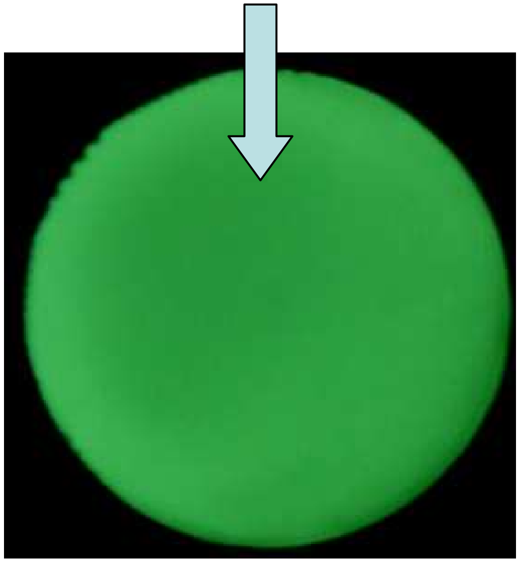


UV Light
Source
Aperture

UV Photocathode
MCP Electron
source

MCP
Under
Test

Phosphor Screen /
Anode



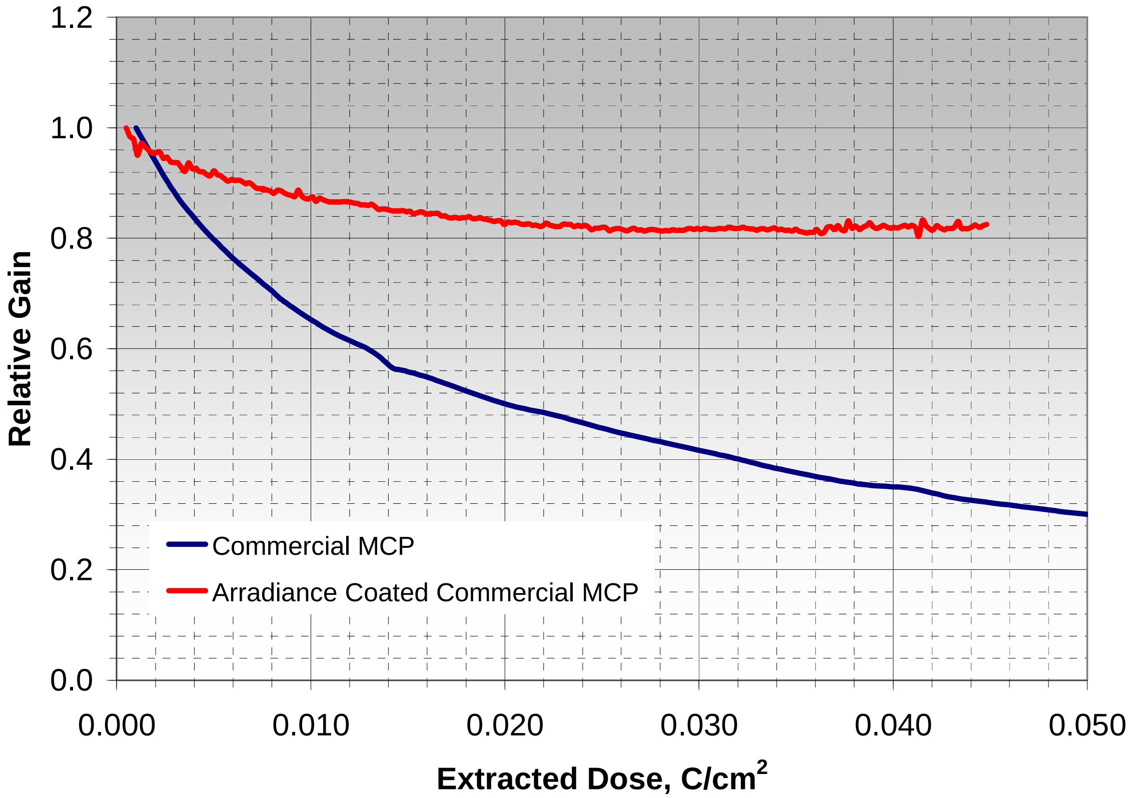
Full field illumination image.

Test MCP is irradiated by a uniform electron flux.

Photograph of the phosphor screen is shown.

Novel secondary electron emission layer

Improved lifetime, Relaxed detector preconditioning



50:1 L/D

Bias 880 V

18 mm active area

4.8 µm pores

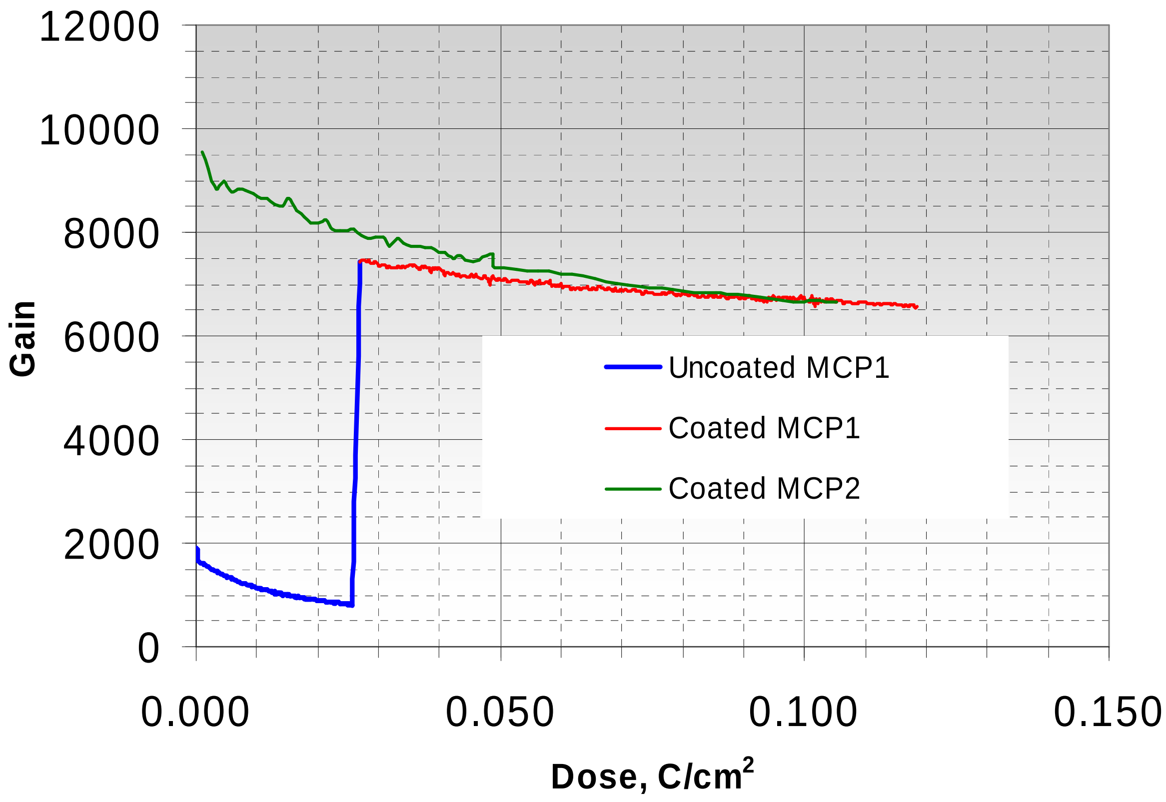
R ~ 100-200 MΩ

I_{out} ~ 10-20% I_{strip}

Applied over commercial glass MCPs

Novel secondary electron emission layer

Revive aged MCP to high gain values



50:1 L/D

Bias 880 V

18 mm active area

4.8 µm pores

R ~ 100-200 MΩ

I_{out} ~ 10-20% I_{strip}

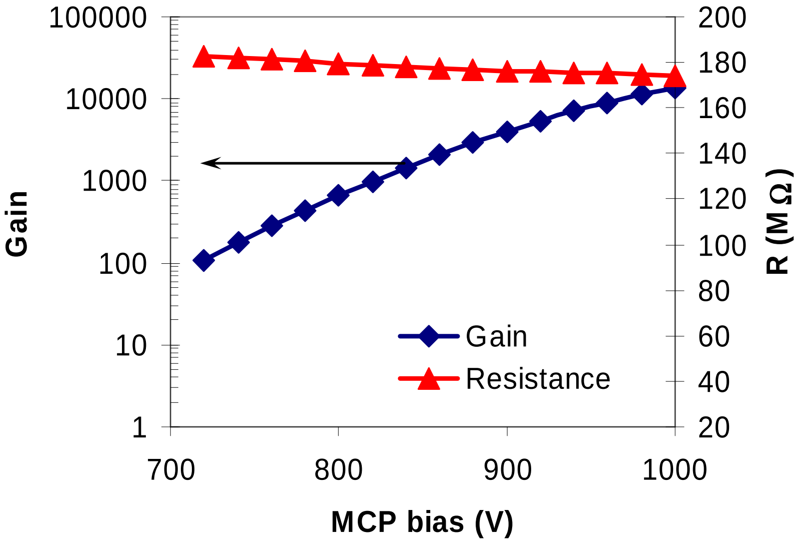
Applied over commercial glass MCPs

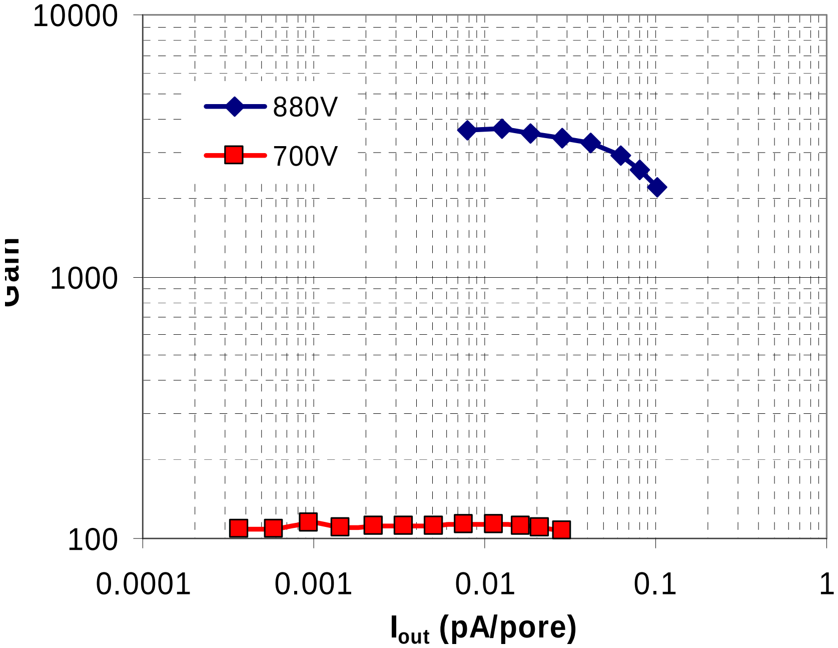
Nano-engineered conduction and emission films

- Can be applied to any substrate sustaining ~200^{o}C
- Conformal coating / large aspect ratio
- Micromachinned substrates
- No radioactive traces
- Separate control of conduction and emission properties
- Reduced ion emission / long life photocathodes

Nano-engineered conduction and emission films

4.8 µm pore substrate, 50:1 L/D, R~170 MΩ,
gain under electron bombardment

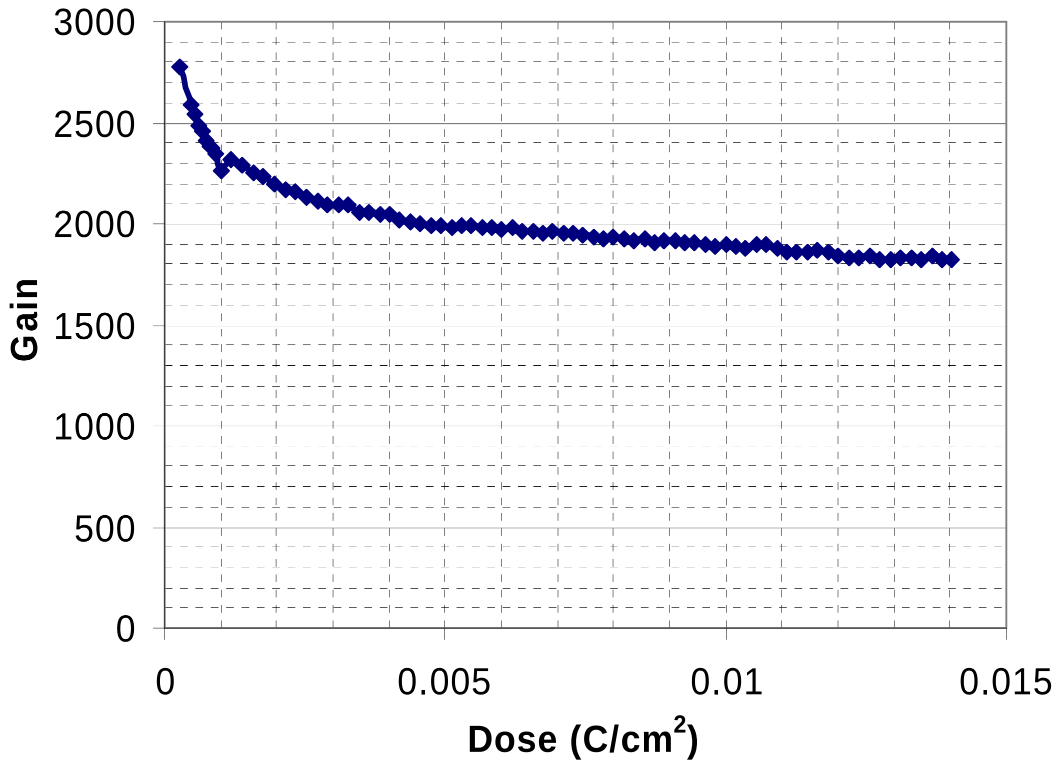




- Stable resistance
- Typical exponential gain increase with bias
- Good gain ~ 14000 at 1000V
- Good TCR (comparable to glass MCP values)

Nano-engineered conduction and emission films

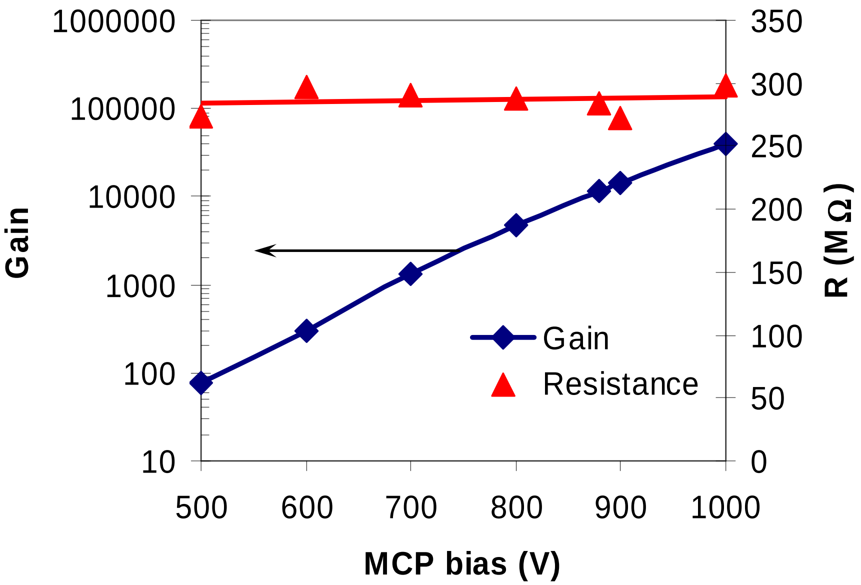
4.8 µm pore substrate, 50:1 L/D, Bias = 880V,
I_{out}~0.07 pA/pore, gain under electron bombardment

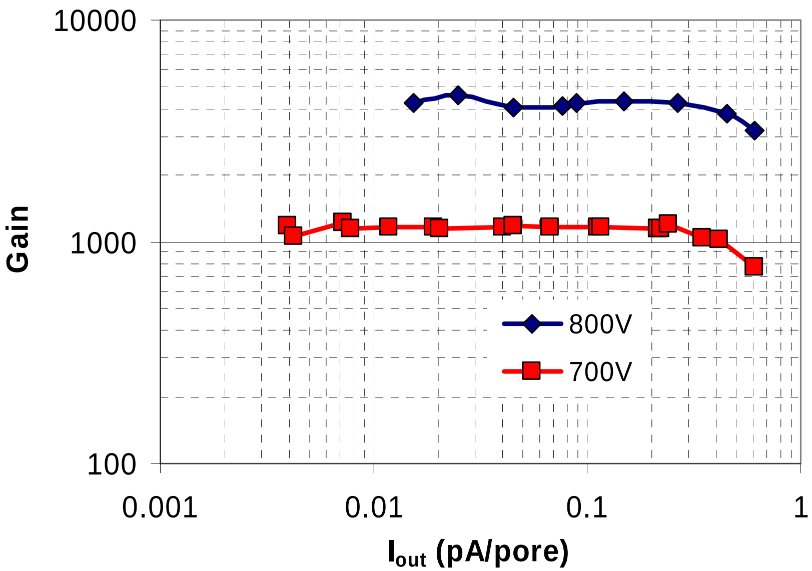


Quickly reaches stable gain

Nano-engineered conduction and emission films

10 μm pore NO LEAD glass substrate, 40:1 L/D, R~280 MΩ,
gain under electron bombardment

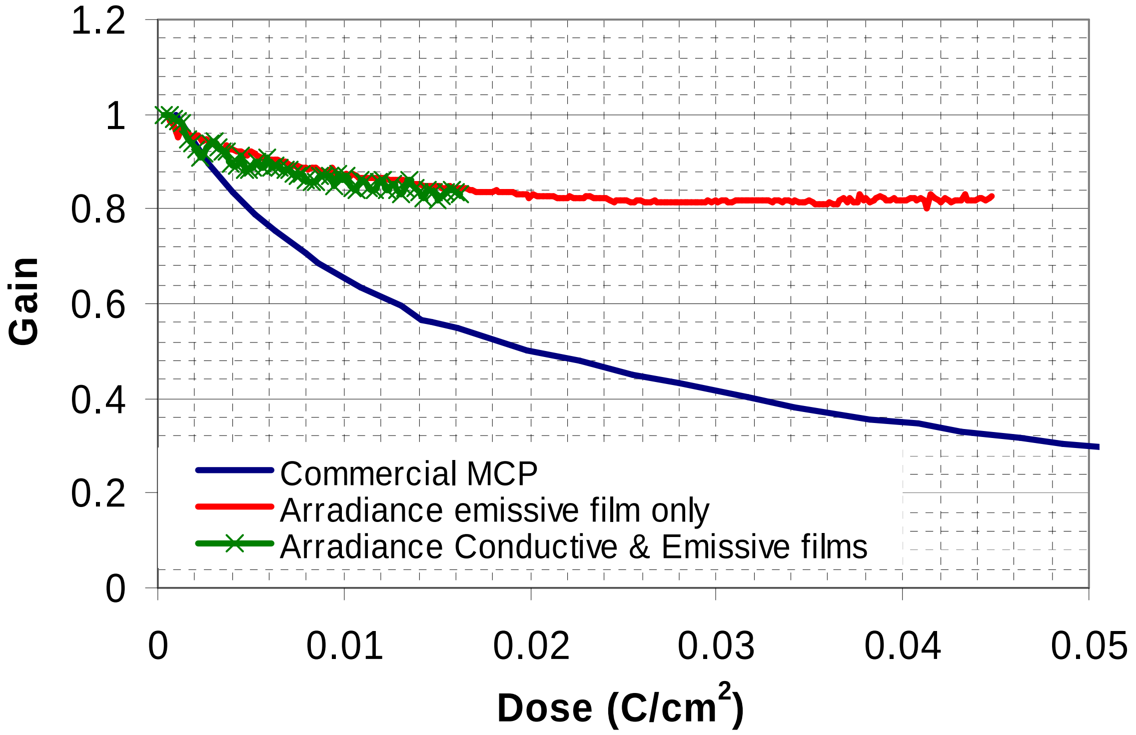




- Stable resistance
- Typical exponential gain increase with bias
- Good gain ~ 40000 at 1000V bias
- Good TCR (comparable to glass MCP values)

Nano-engineered conduction and emission films

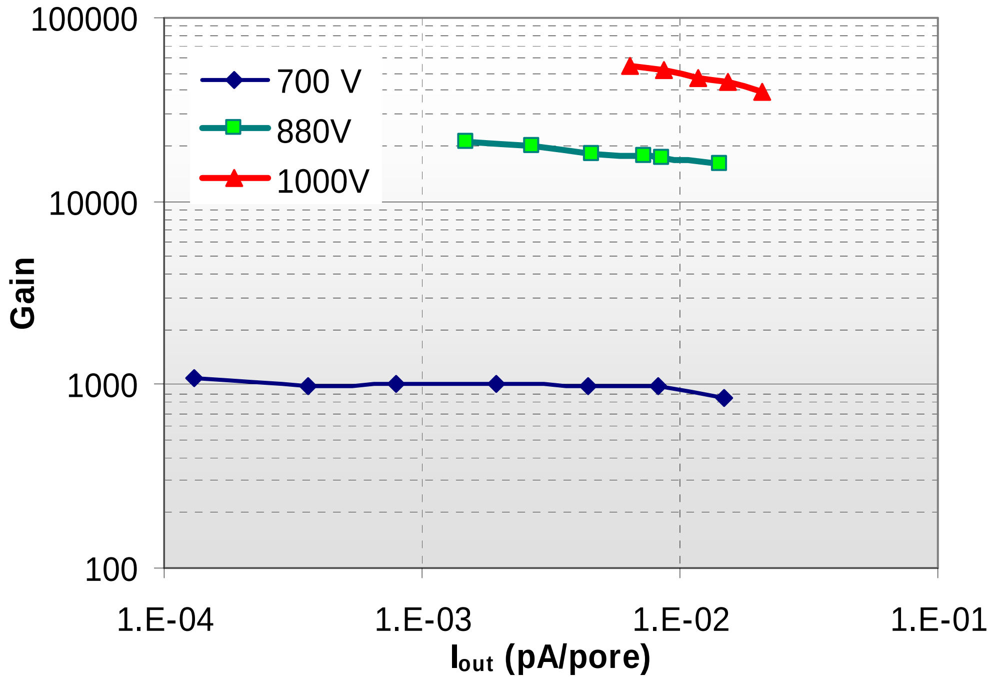
10 µm pore NO LEAD glass substrate, 40:1 L/D, Bias = 880V, I_{out}~0.4 pA/pore, gain under electron bombardment



Quickly reaches stable gain

Nano-engineered conduction and emission films

4.8 µm pore substrates, 50:1 L/D,
gain under electron bombardment



Typical count rate saturation at output
equal to ~10% of strip current

Summary

- Novel emission and conduction layers for MCP technology have been developed
- Emission layer improves the performance of glass MCPs
    - High gain
    - Longer lifetime
    - Reduced outgassing
- Substrate independent conduction and emission films open new possibilities
    - Micromachinned substrates
    - high T compatible
    - Novel photocathode materials/configurations
    - Low noise – no radioactive traces
    - Better uniformity / reproducibility / spatial resolution