Microcooling Developments at University of Twente

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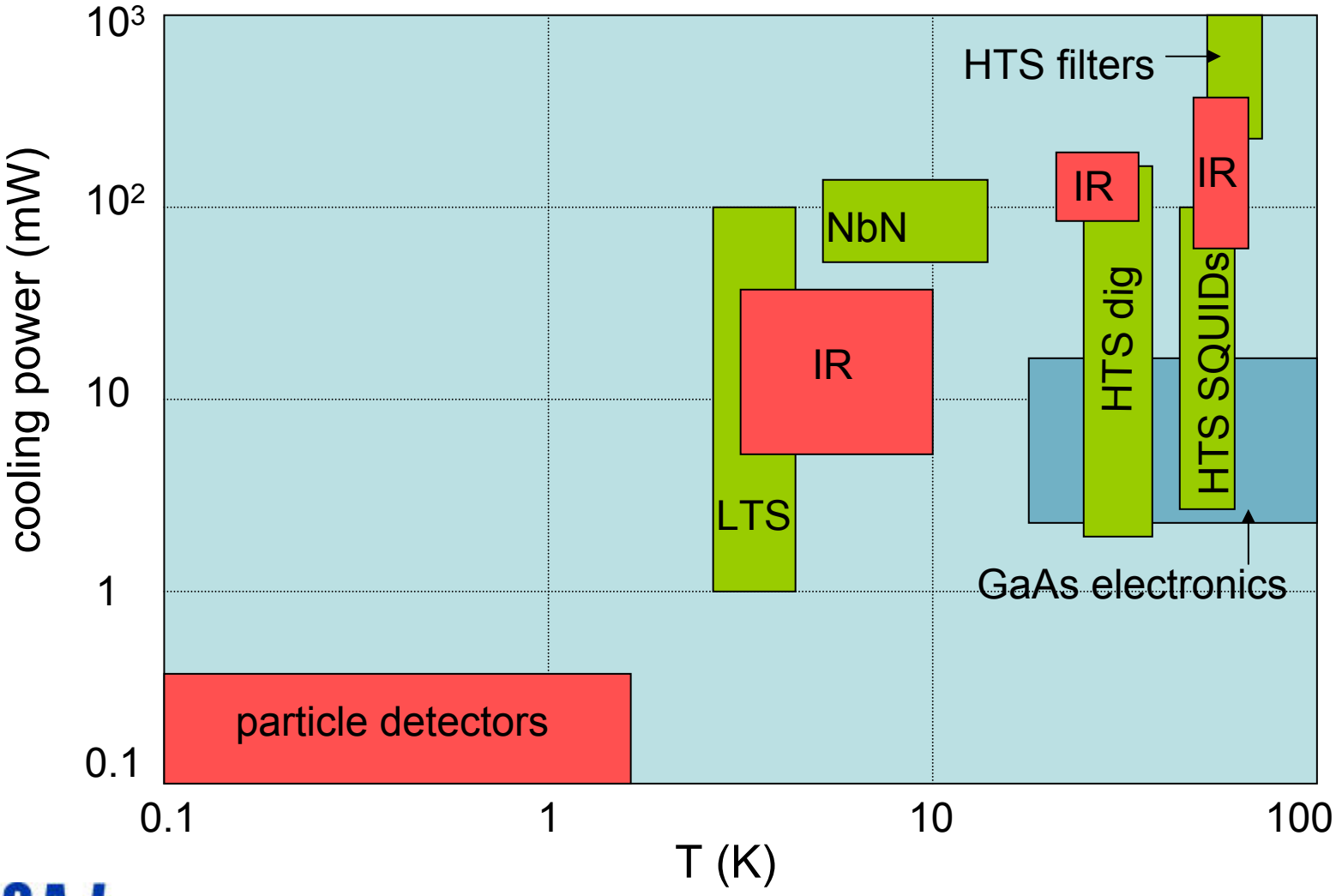
Low temperature division

Cooling needs in Space



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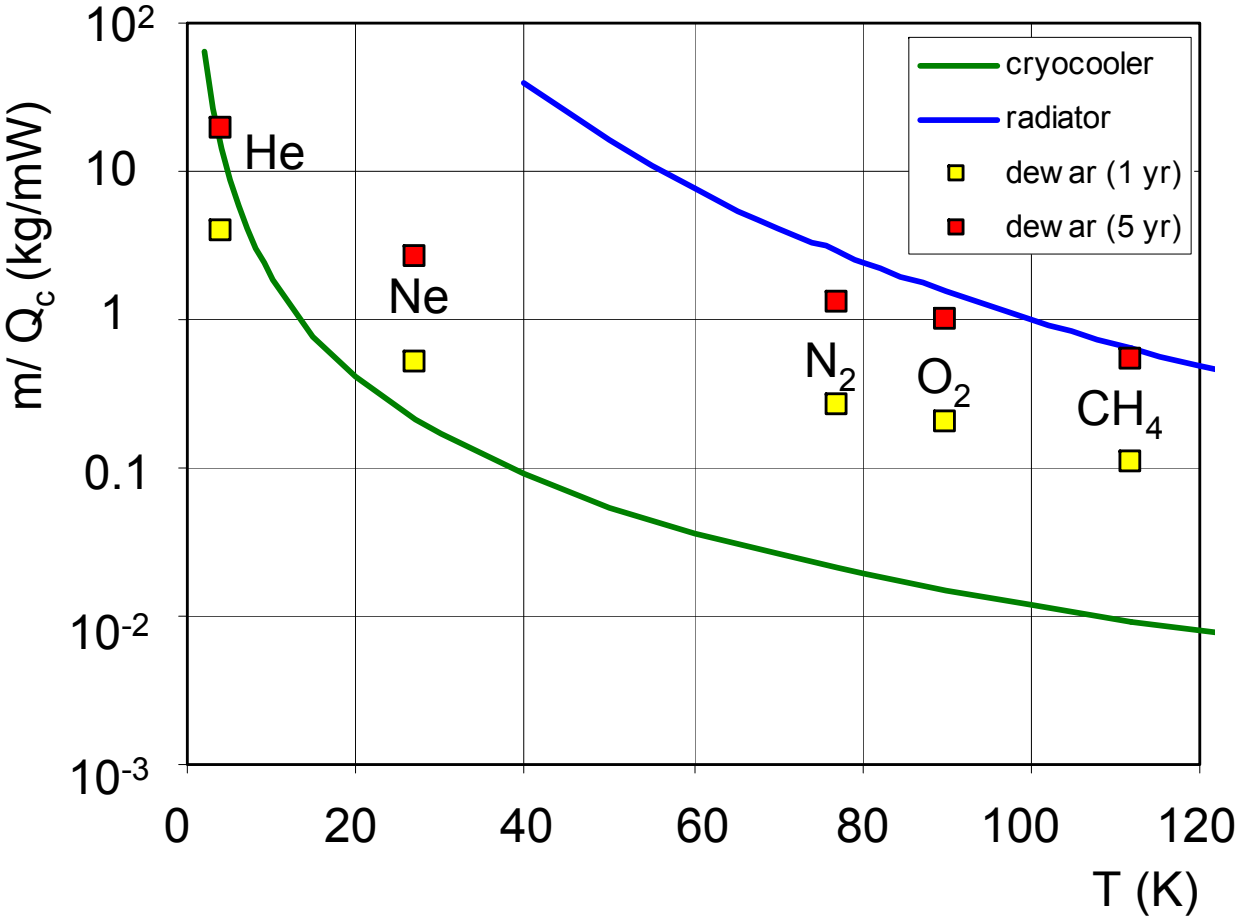
Cooling options in Space

mass per unit of cooling power (kg/mW)



→ lower T means larger cooling system

→ cryocoolers attractive because of size and weight

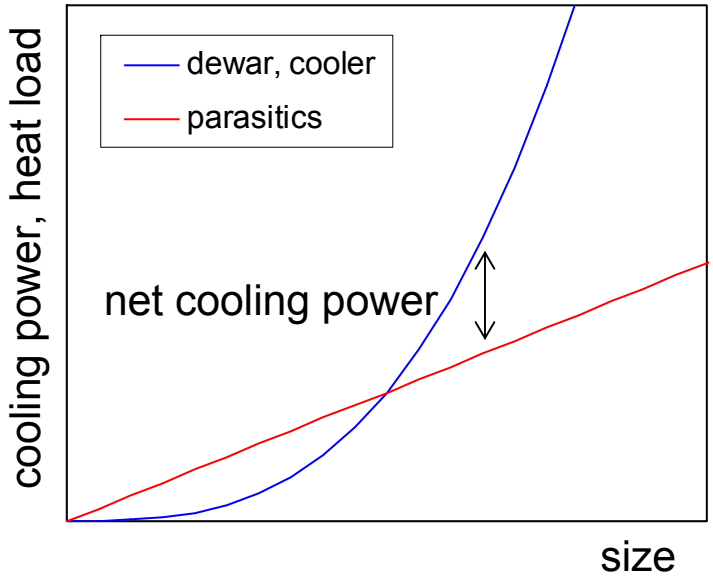
Scaling

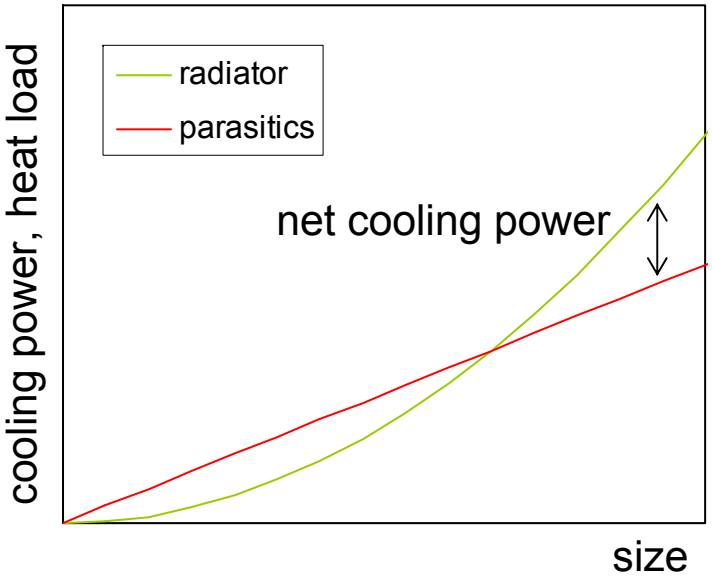
dewar cooling power: scales with volume (size^3)

cryocooler cooling power: scales with volume (size^3)

radiator cooling power: scales with area (size^2)

parasitic heat load: scales with area/length (size^1)



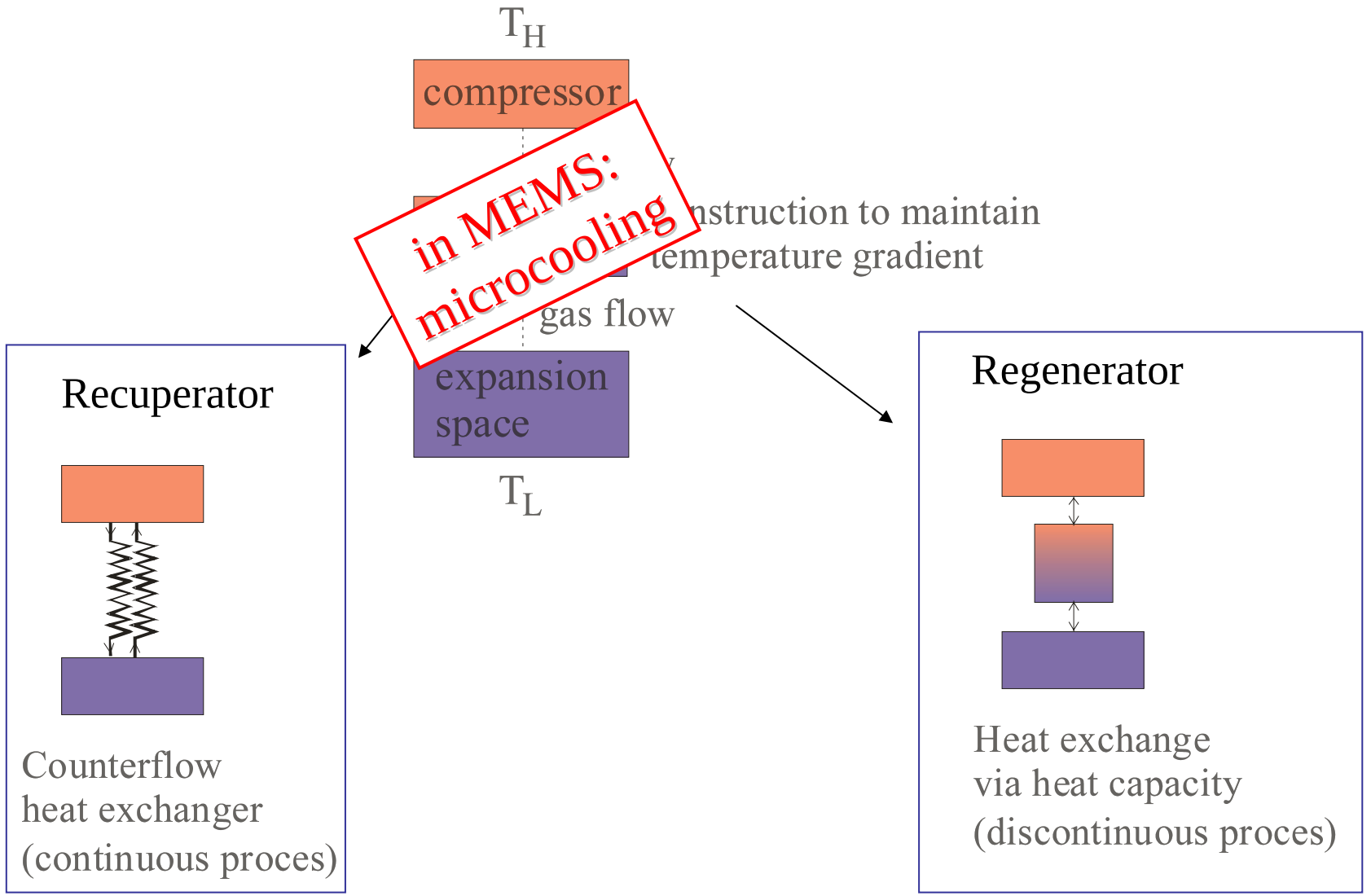


In cryocooler design the dependence of cooling power on size can be influenced

regenerative cooler: $\dot{Q}_L \sim f \times \Delta p \times V_{gas}$ ⟶ frequency f can be increased

recuperative cooler: $\dot{Q}_L = \dot{m} \times \Delta H_{gas}$ ⟶ compressor design can be used with size-independent flow (e.g. sorption)

Cooling via expansion of compressed gas



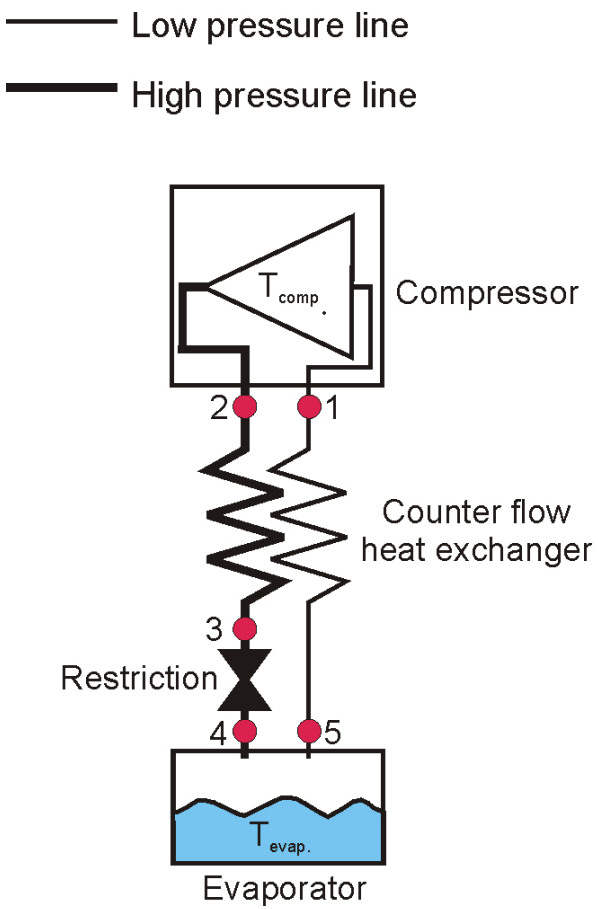
Contents:

- Microcooling research in Twente
  - micro-recuperative cooler
  - micro-regenerative cooler

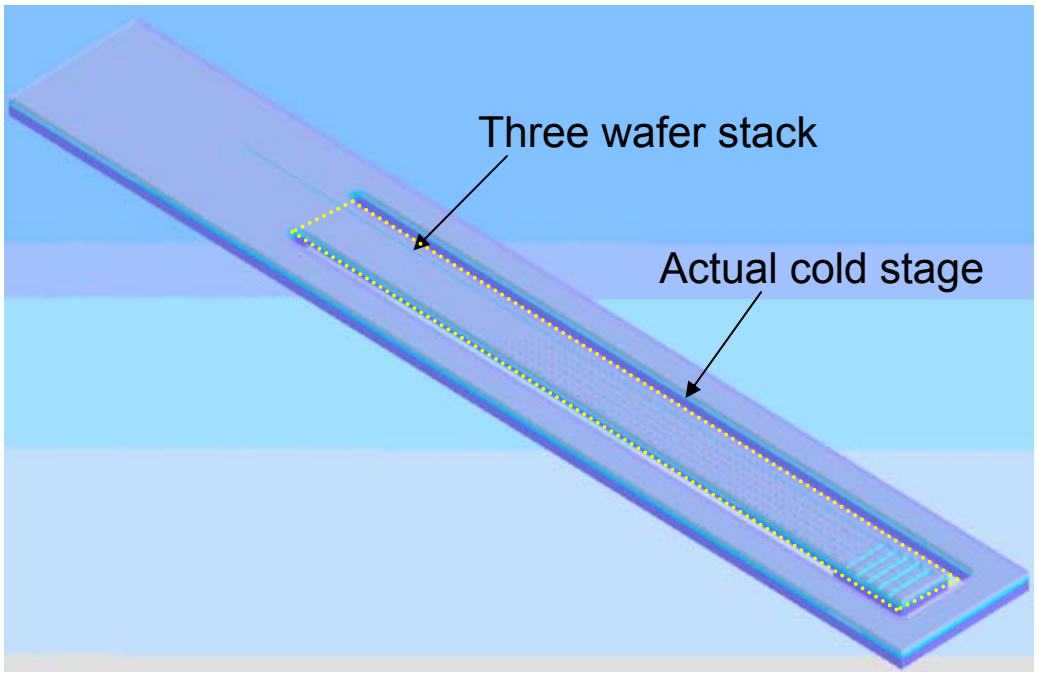
Recuperative Cooler

JT Cycle:

- Gas: N_2
- P_{high} = 80 bar
- P_{low} = 6 bar
- $T_{cold\ stage}$ = 96 K
- mflow = 1 mg/s
- P_{gross} ≈ 14 mW
- P_{net} ≈ 10 mW



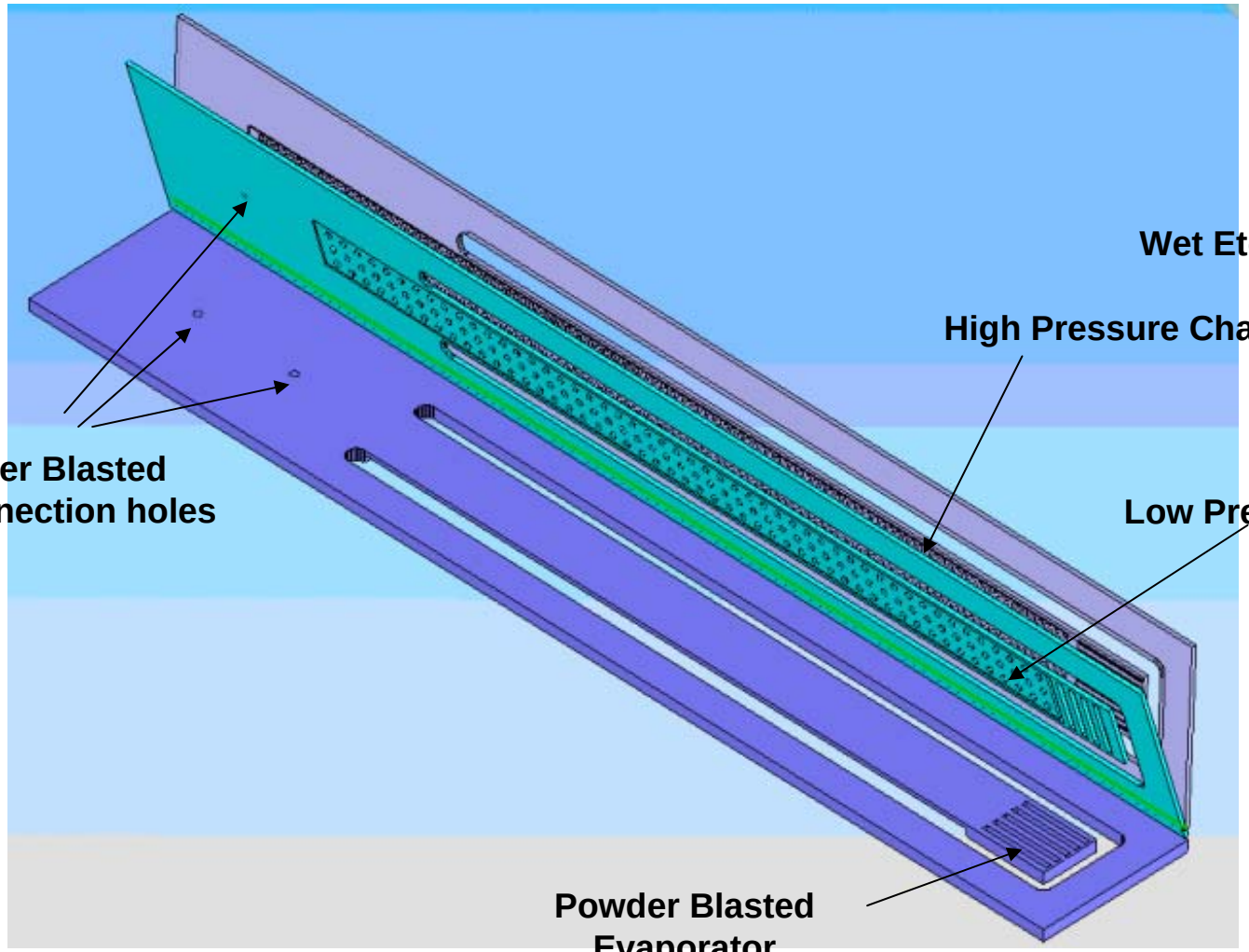
Cold-tip prototype



cold-stage length: 28 mm

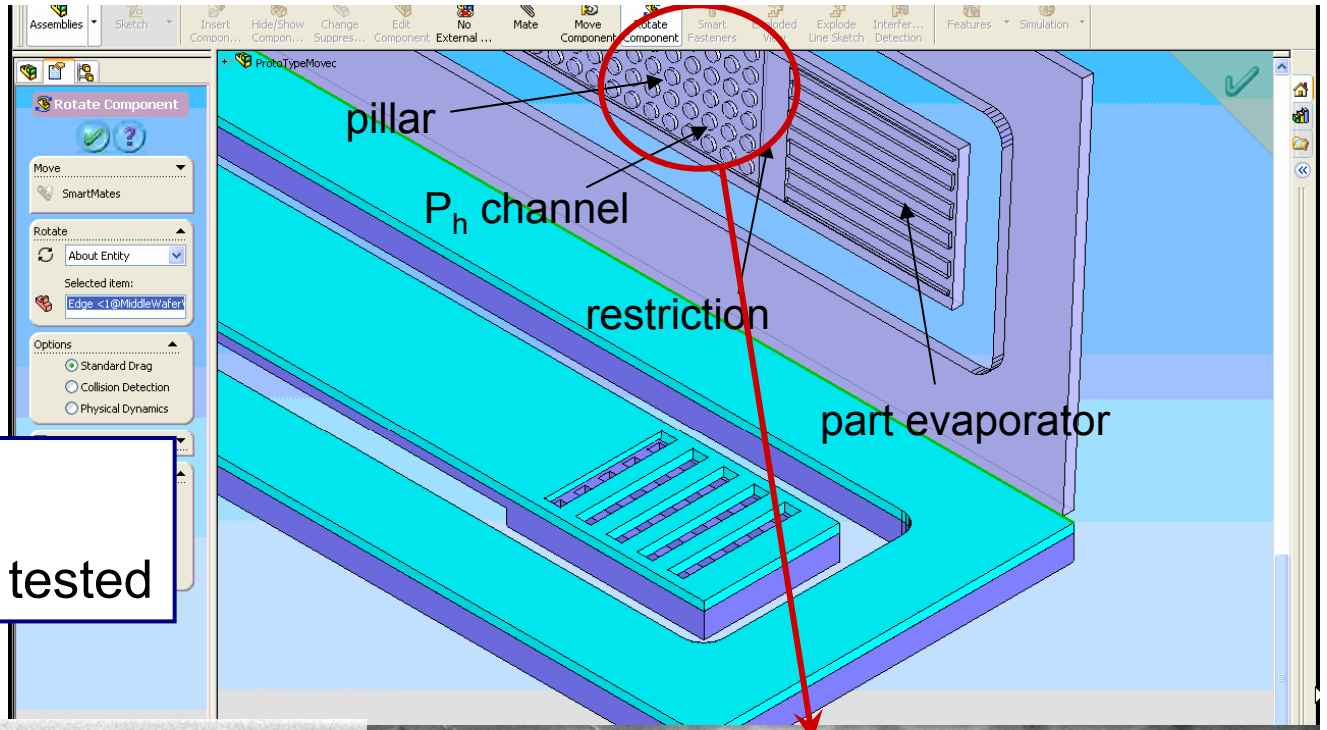
cold-stage width: 2.2 mm

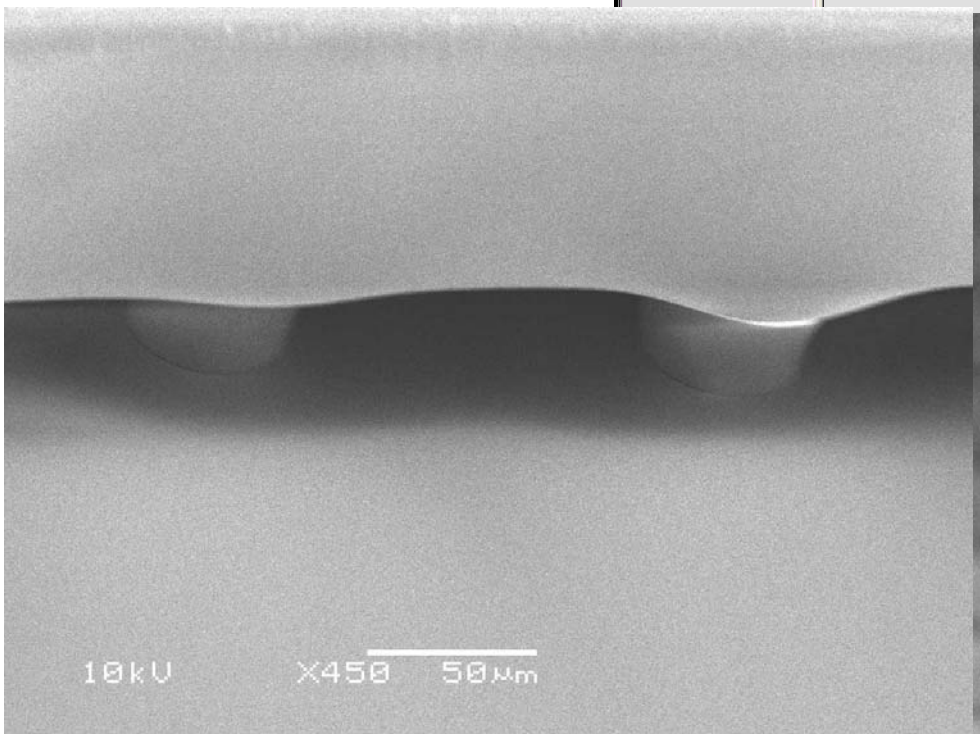
Cold-tip prototype

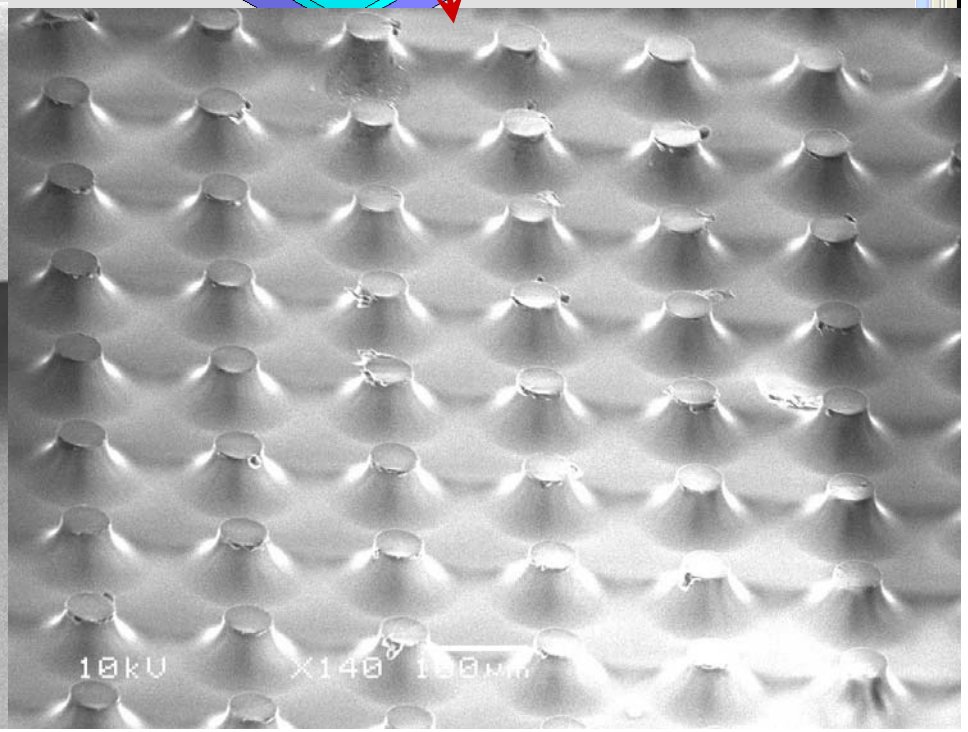


Design completed,

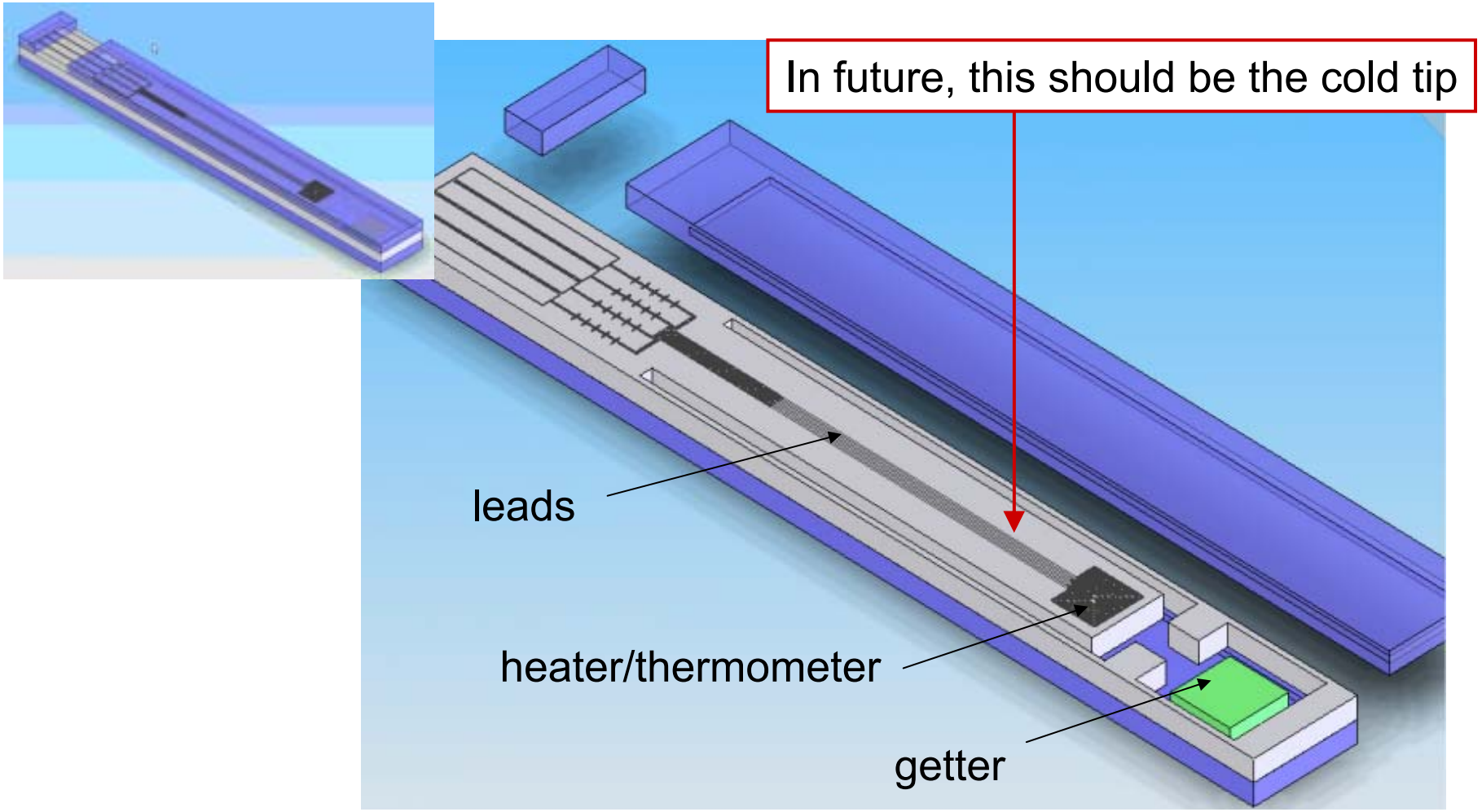
Prototypes ready to be tested





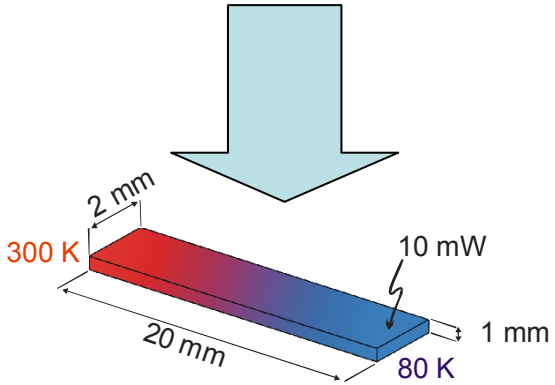


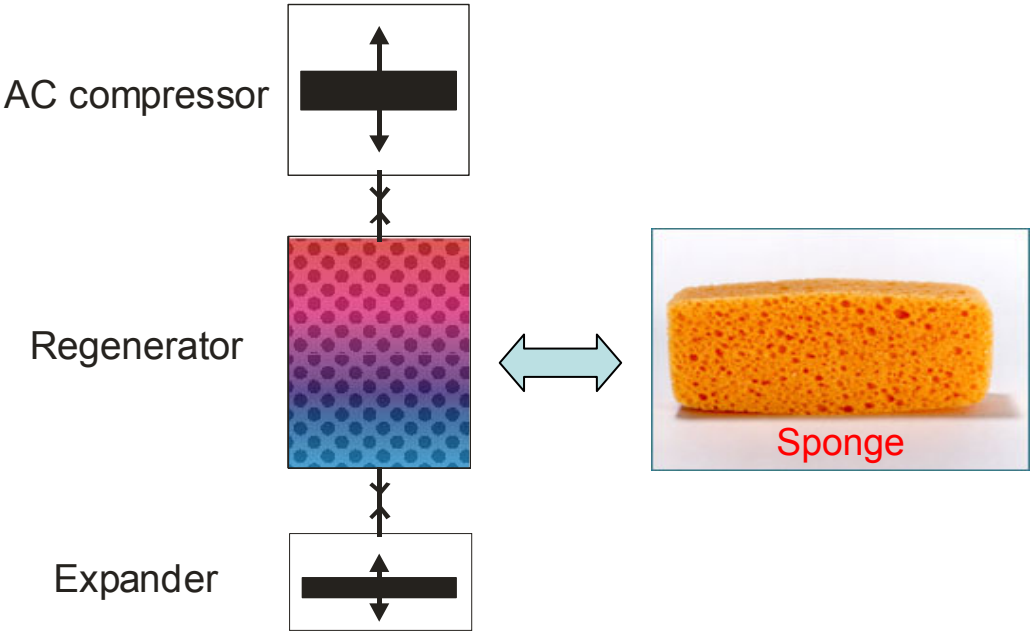
Micro vacuum chamber



→ test chamber under construction: gas pressure to be monitored via thermal conductivity (Pirani-principle)

Micro-regenerative cooling:





Regenerator exchanges heat alternately with gas

Regenerator is critical element

Example:

Cooling Power 30 mW @ 100K

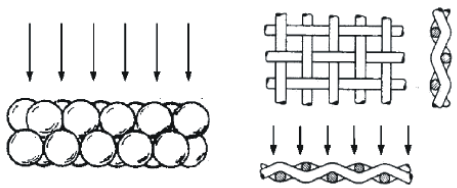
Stored Heat flux in Regenerator

$$\dot{Q}_{reg} = \dot{m} C_{p,g} (T_{amb} - T_{cold}) \approx \mathbf{400\,mW}$$

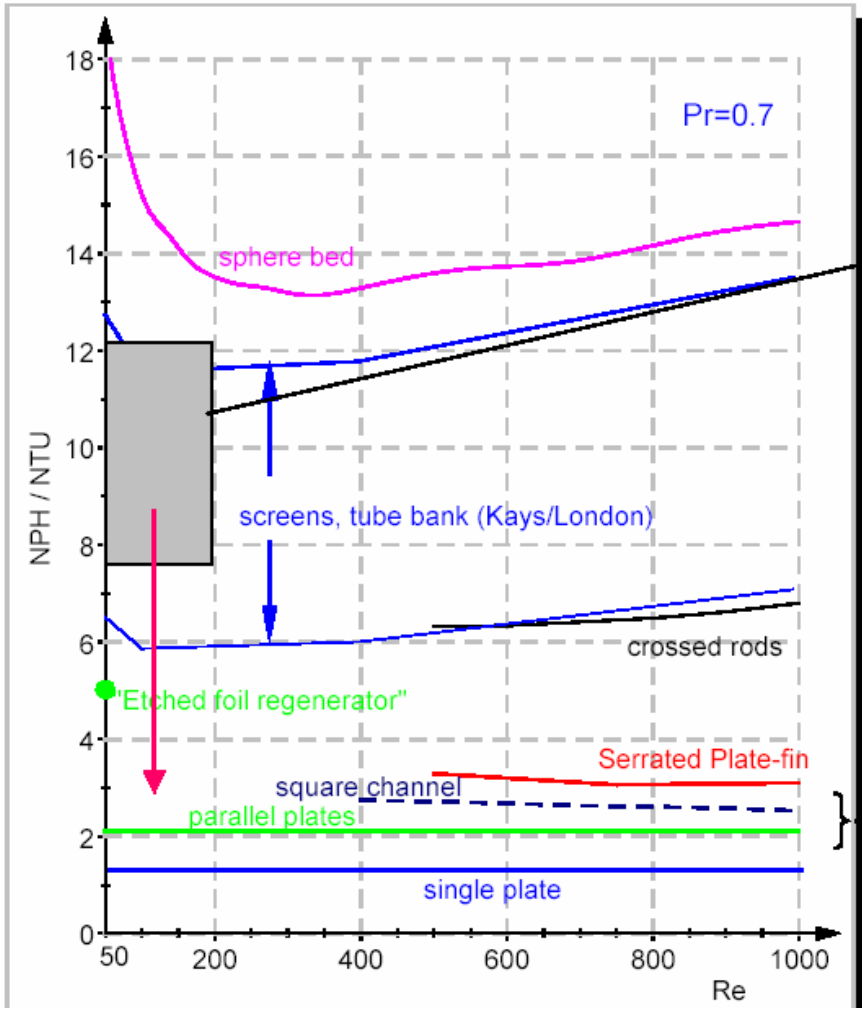
If we accept **loss** of **2%**, →**8 mW** lost from cooling power

Optimization of Regenerator is critical!!

MEMS enables regenerator matrix optimization



Sphere bed Stacked screens



Working area of stacked screens in cryocoolers

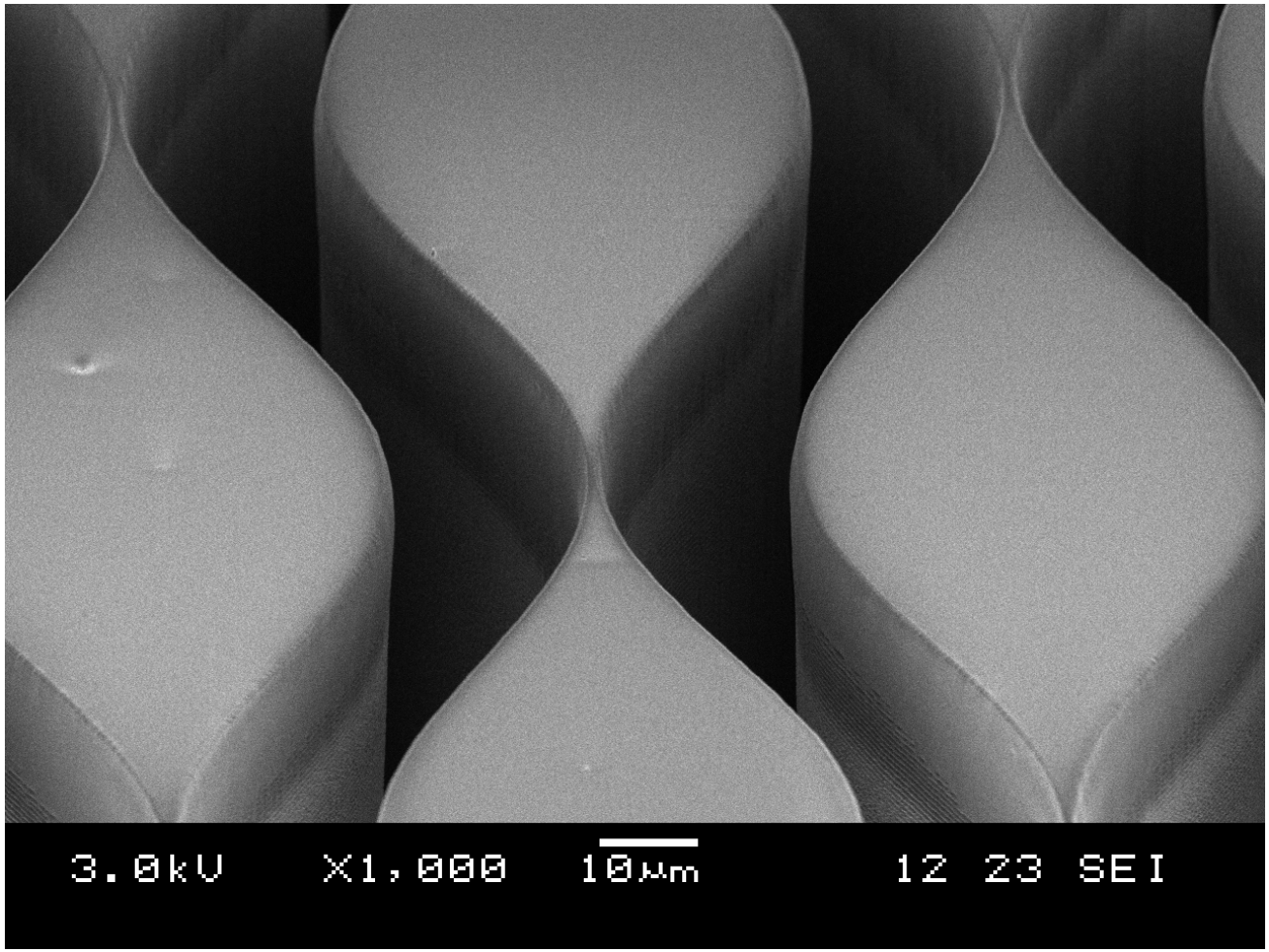
Potential for improvement:

factor 4

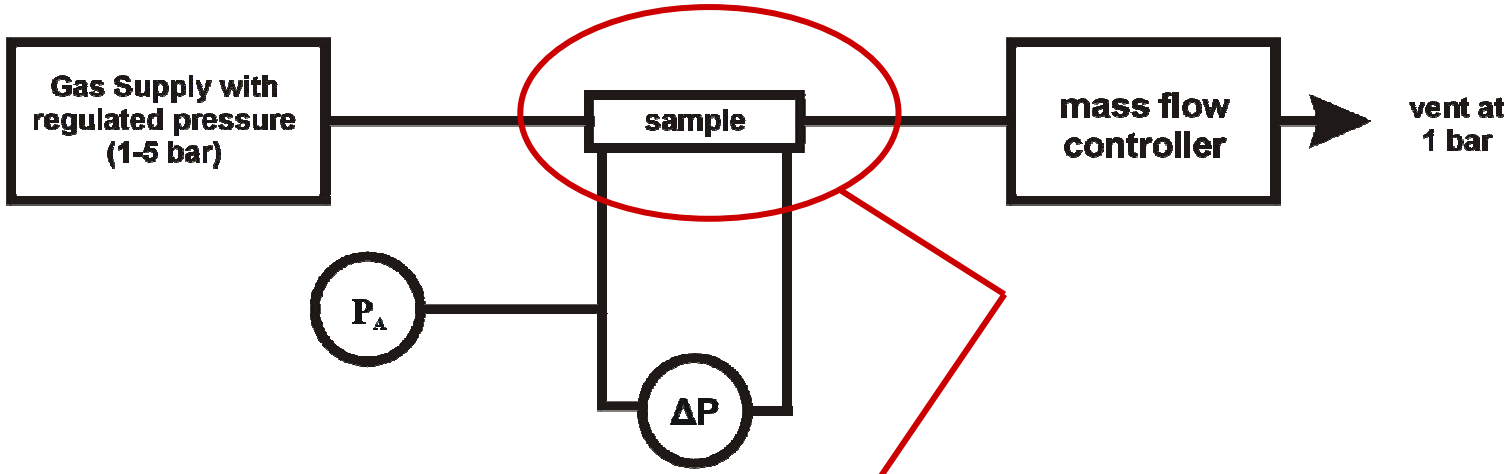
Analytical solutions

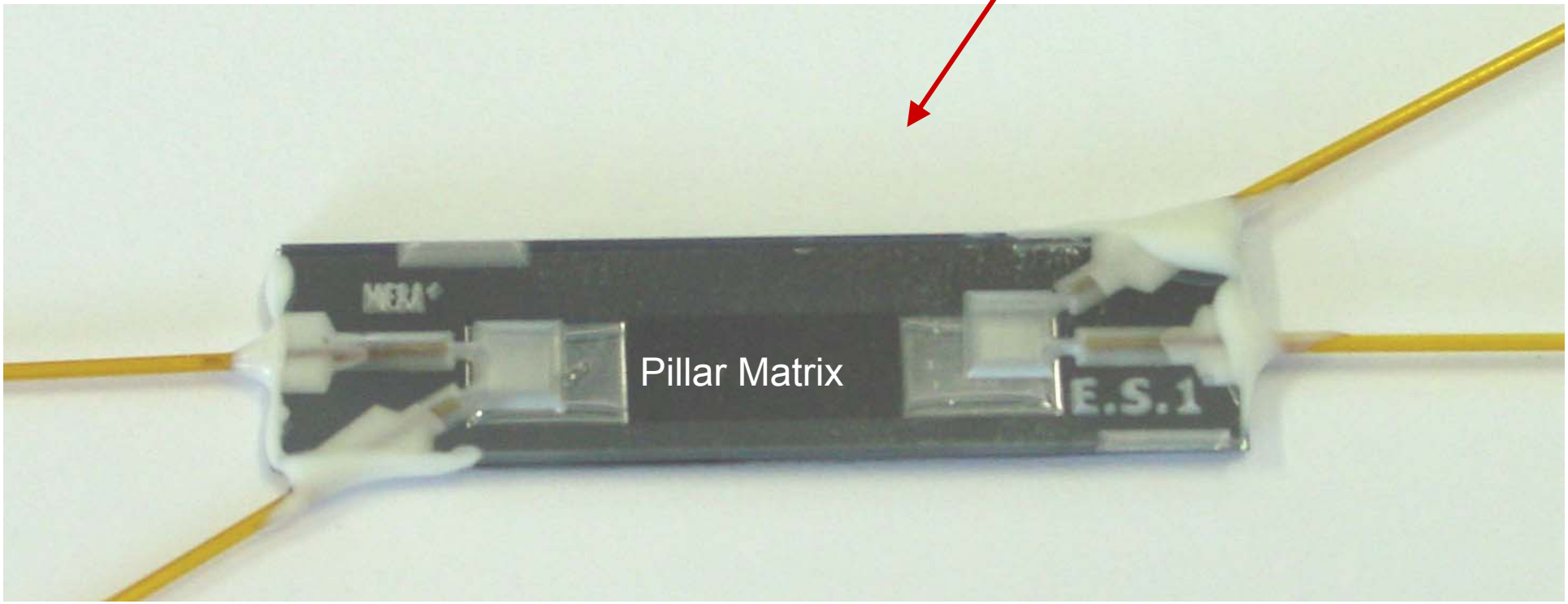
Fabrication

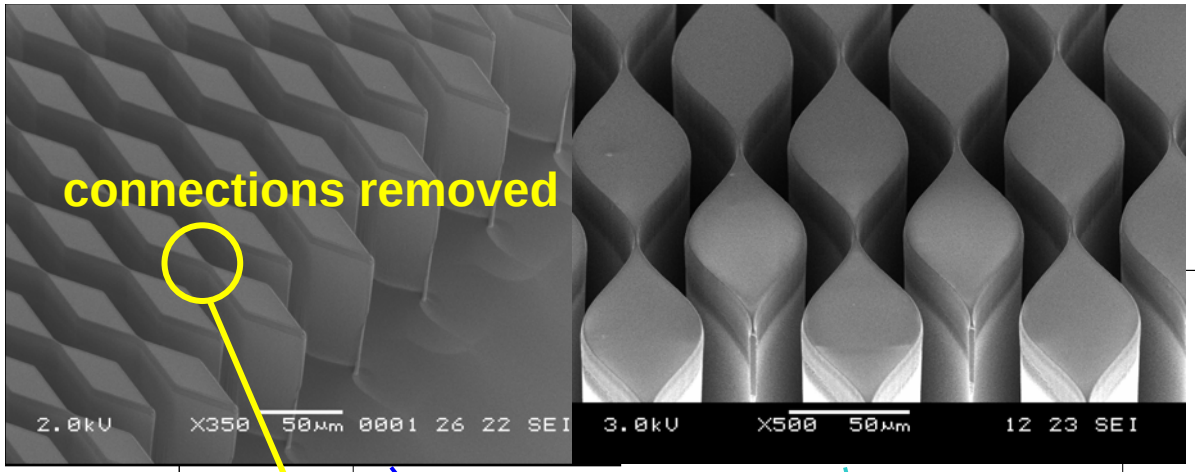
Regenerator Pillar Matrix – Optimized Bosch Process

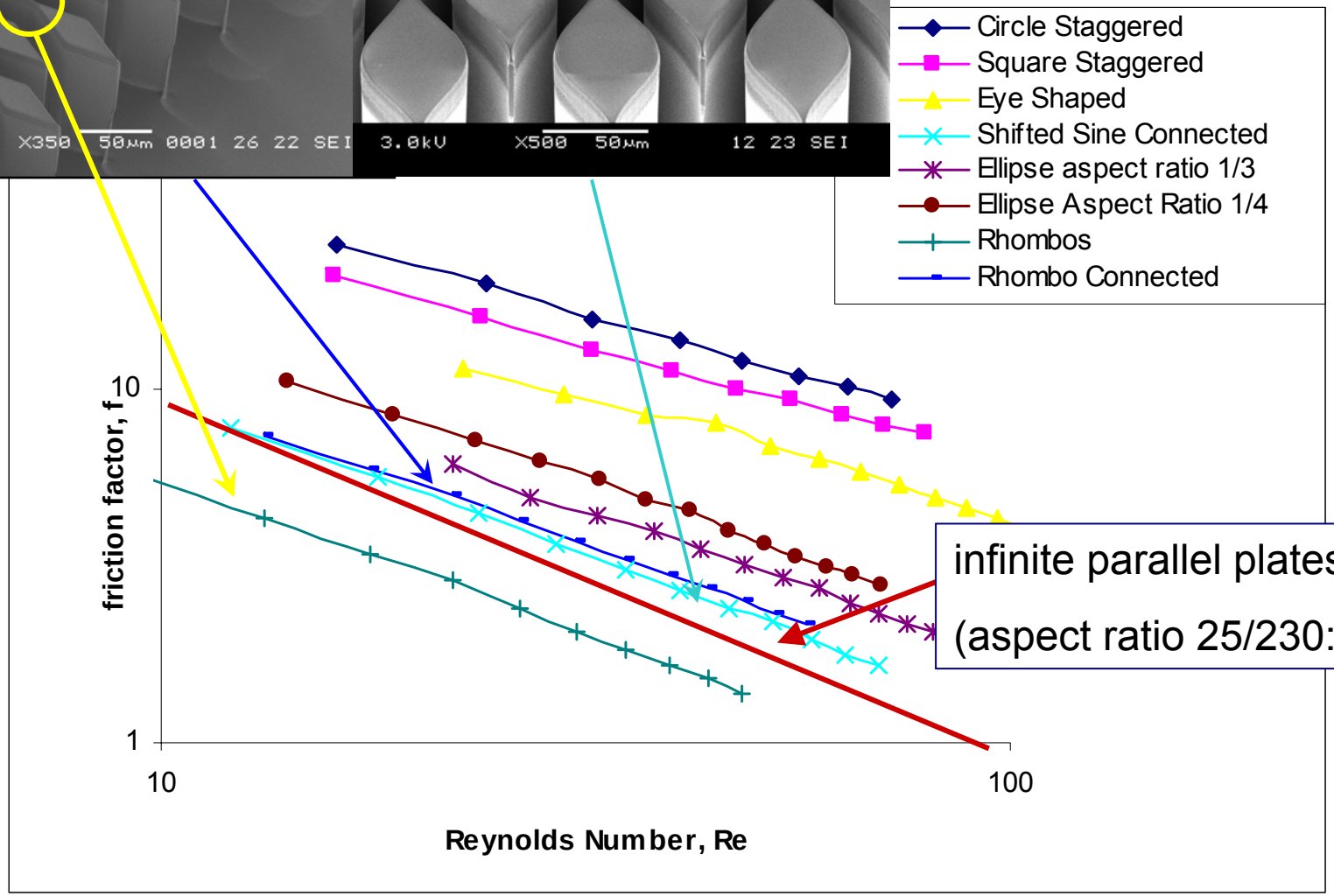


Pressure drop measurements









infinite parallel plates: fRe=96

(aspect ratio 25/230: fRe = 84)

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Status - Outlook

- Micro cryocooler has high potential for space applications
- The total volume of the cold stage << 1 cm^3, 10 mW @ 96 K
- Total integration of cold stage, device, vacuum chamber and compressor

Micro-recuperative cooling

- Optimal design of counter flow heat exchanger is complete,
- First prototypes are ready to be tested.
- Multi staging: 5 mW @ 27 K

Micro-regenerative cooling

- Various micro regenerator geometries were fabricated.
- Hydraulic and Thermal characterization of different geometries is done.

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