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New developments in Joule Thomson microcooling at University of Twente

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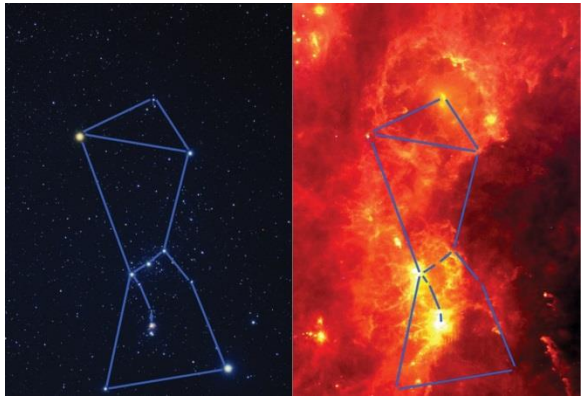
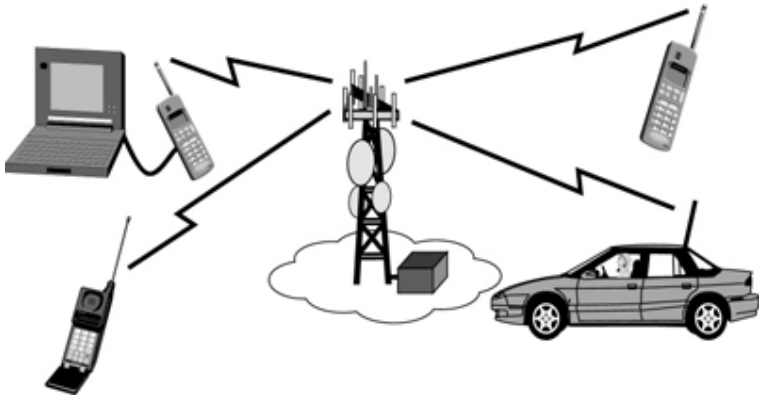
Introduction



Visible light (left) and infrared (right) images of stars.

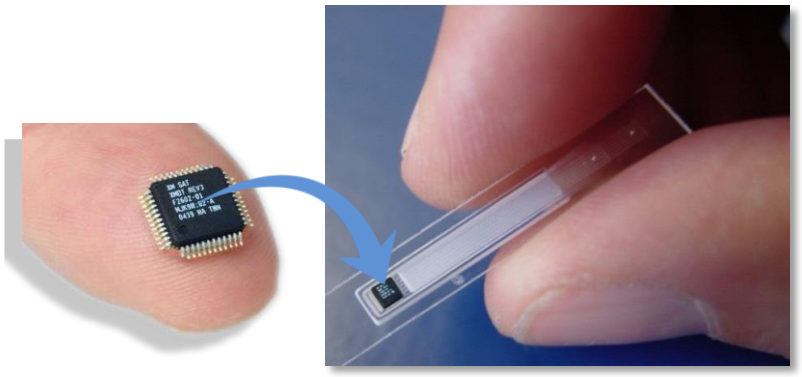
Artist's impression of a radio telescope array.

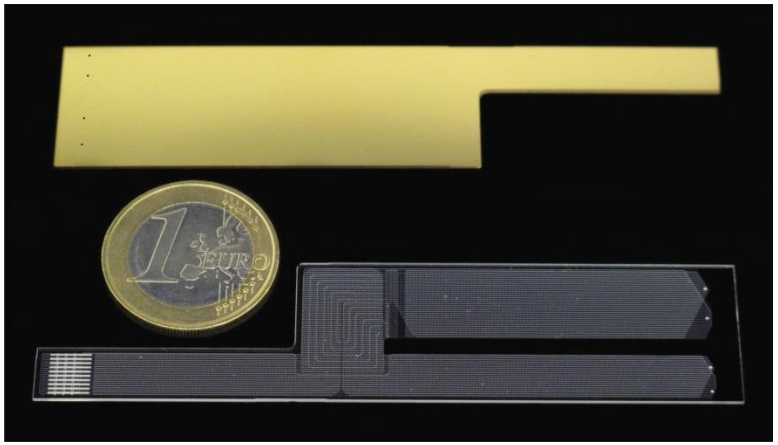
Superconductor.



Mobile communication.

Introduction





30 K two-stage microcooler.

Commercial 4 K cryocooler.

Disadvantage:

- Large size
- Mismatched cooling power

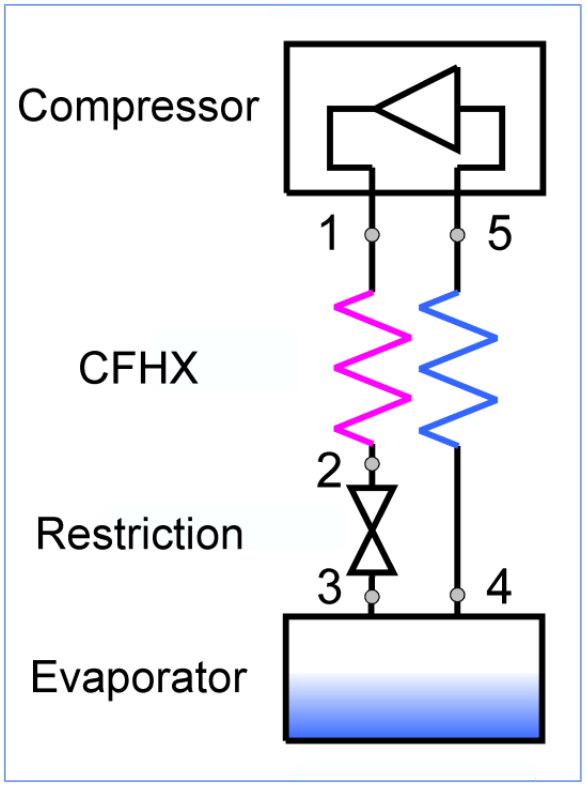
Contents

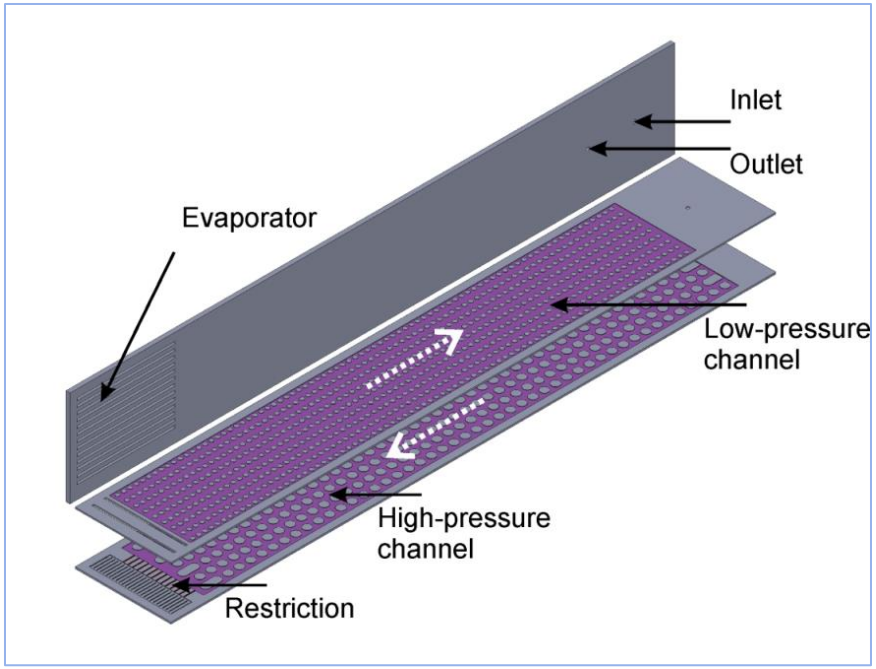
1. Microcoolers with different pillar matrices

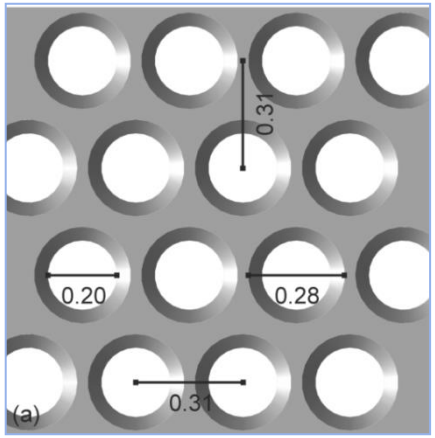
2. Microcoolers with thermoelectric precooling

3. Microcoolers with double-expansion

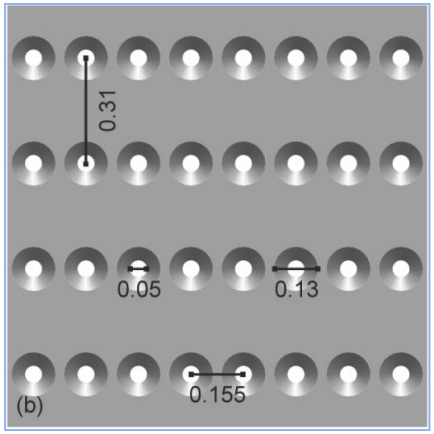
Single-stage microcooler: Thermodynamics and Geometry





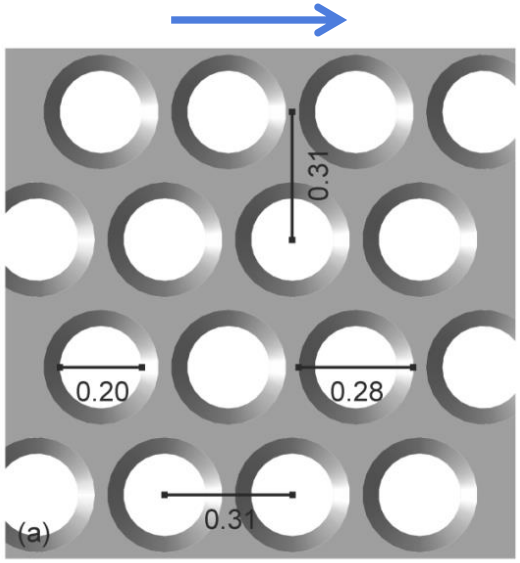


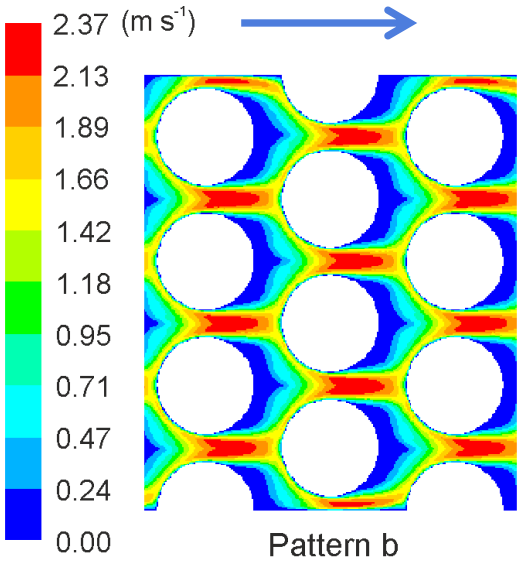
High-pressure line

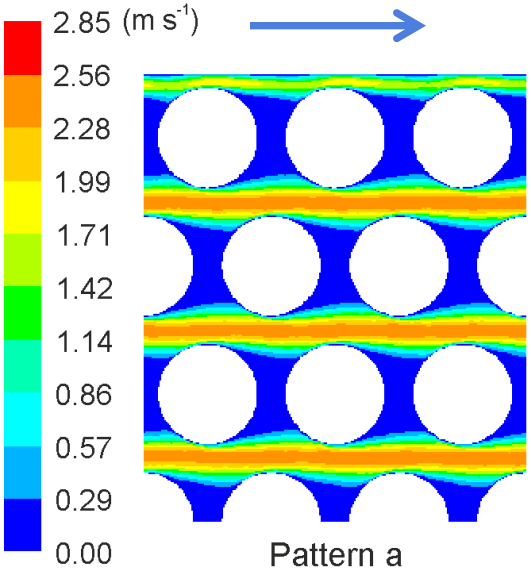


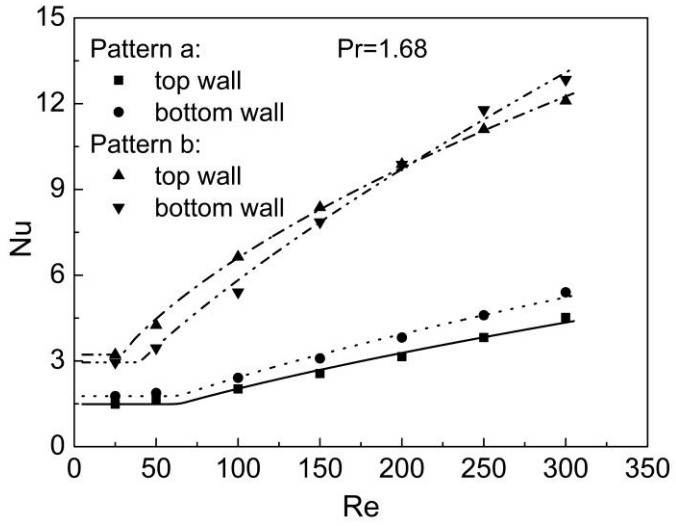
Low-pressure line

Thermal-hydraulic characteristics of high-pressure channel

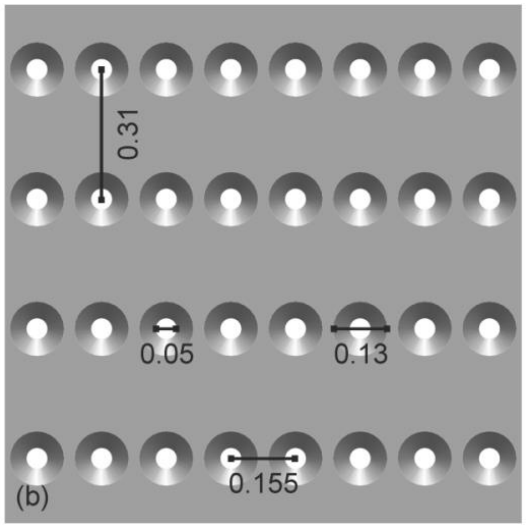


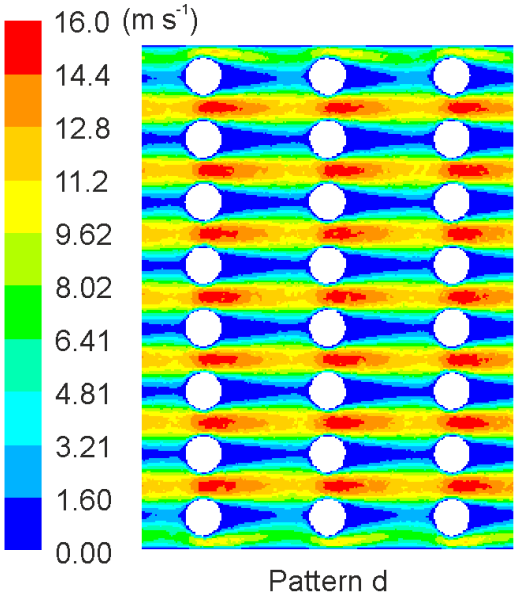




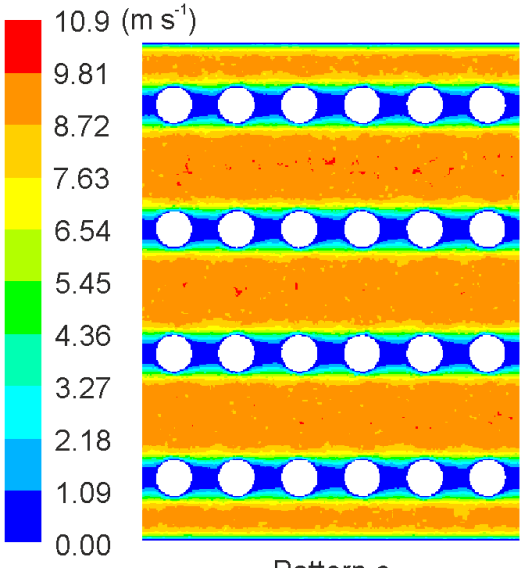


Thermal-hydraulic characteristics of low-pressure channel

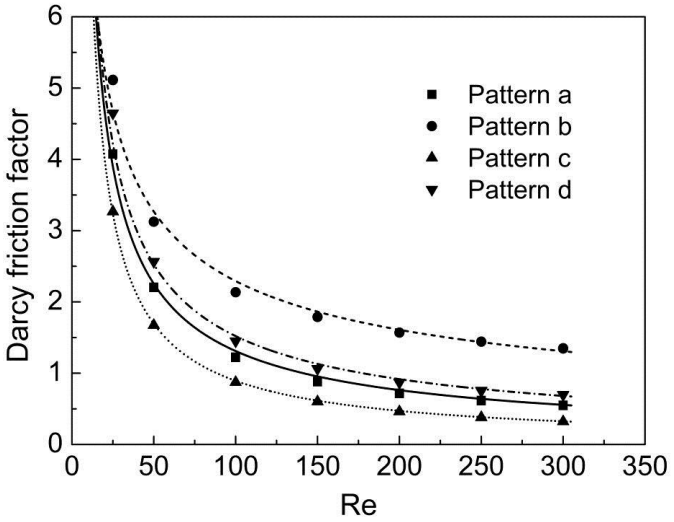




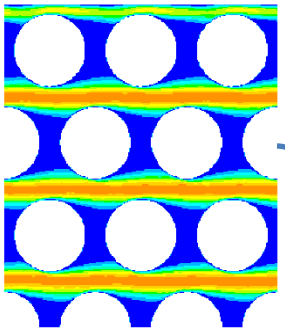
Pattern d



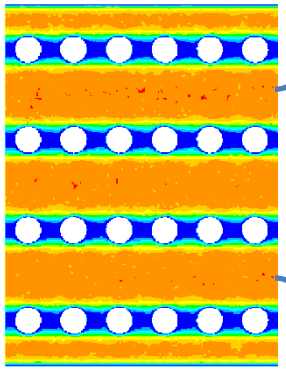
Pattern c



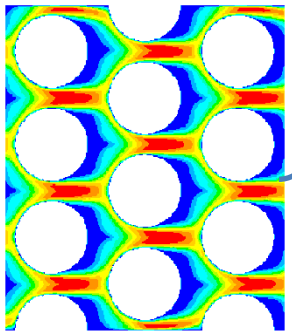
Single-stage microcooler: Performance



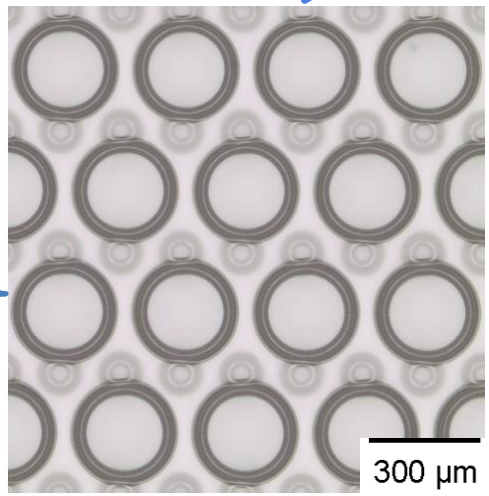
Pattern a



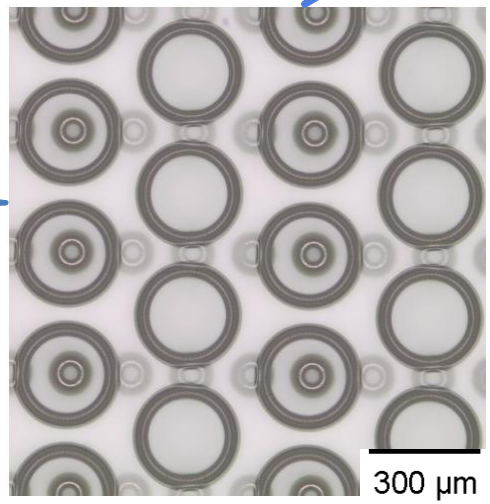
Pattern c



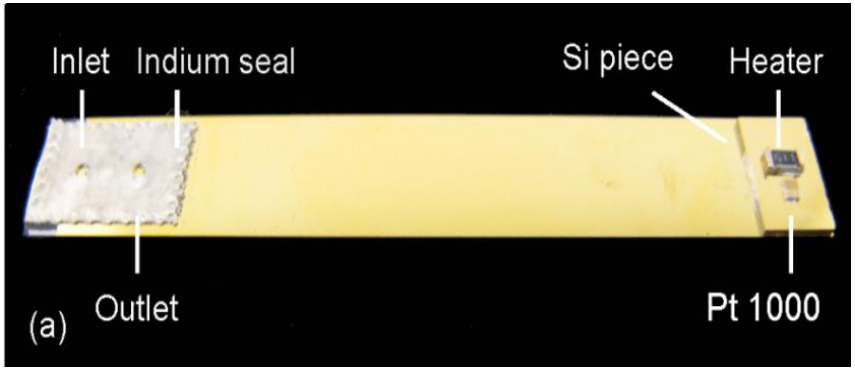
Pattern b



Pillar matrices of Cooler I



Pillar matrices of Cooler II



Operating conditions		
Working fluid	Inlet	Outlet
Nitrogen	80 bar	6 bar

	Cooler I	Cooler II
$\dot{m}$ (mg/s)	16.3	15.0
P_{gross} (mW)	250	230
P_{net}@100 K (mW)	175	180
P_{net}/P_{gross}	0.70	0.78

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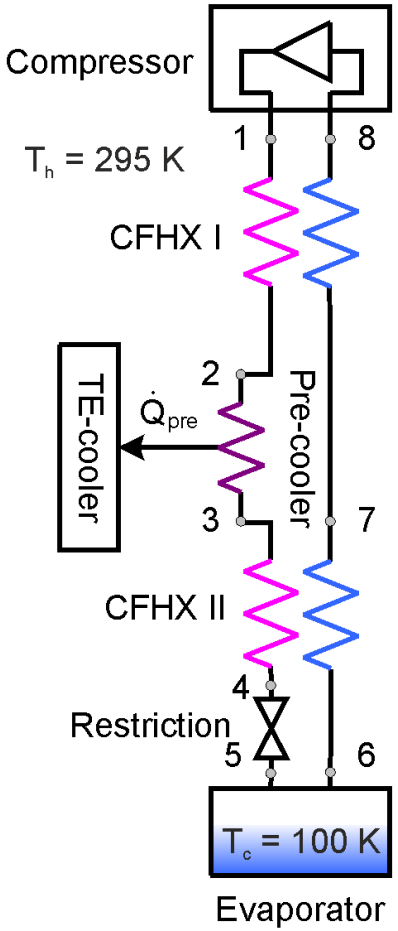
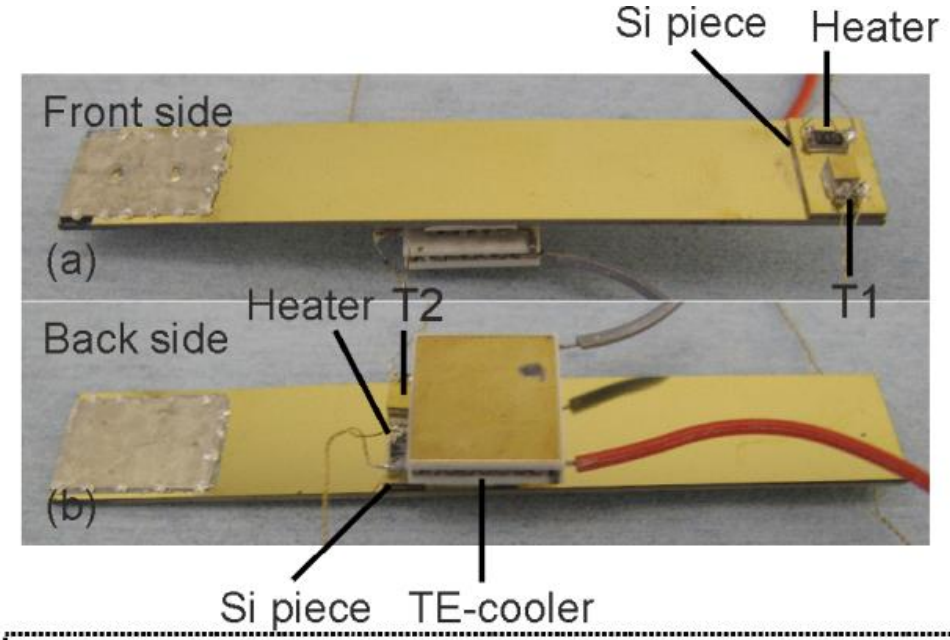
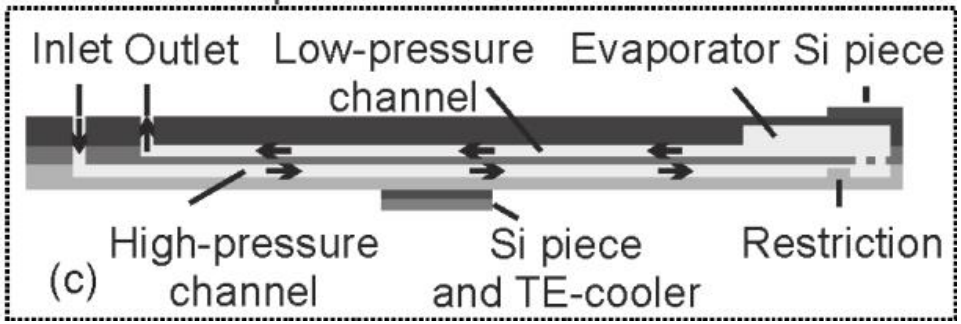
Microcooler with thermoelectric precooling: Thermodynamics

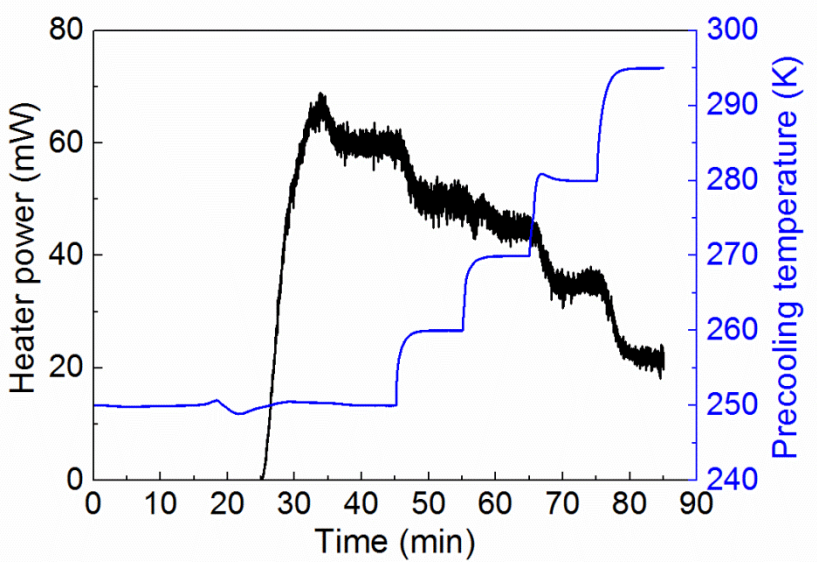


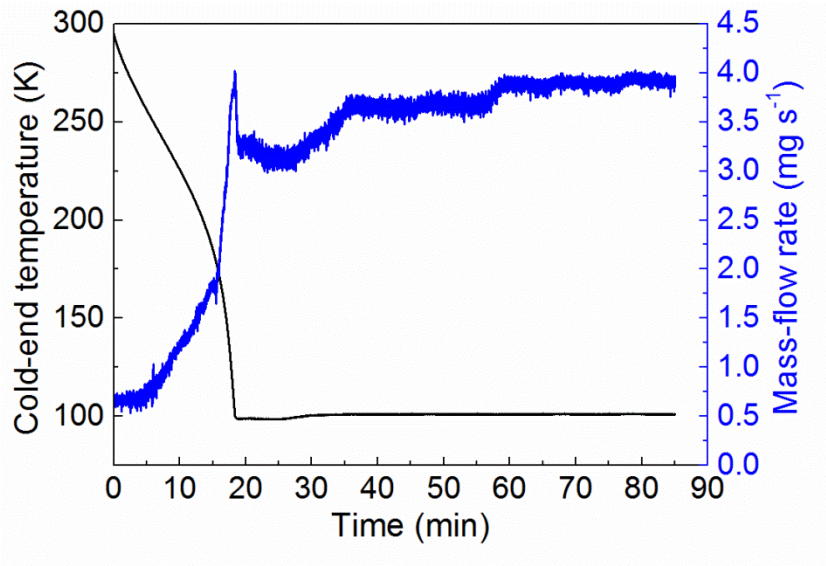


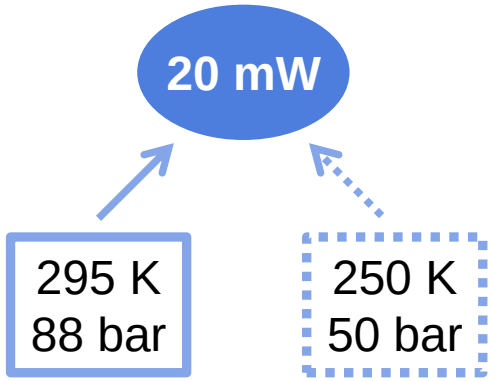


Microcooler with thermoelectric precooling: Performance

Operating conditions		
Working fluid	Inlet	Outlet
Nitrogen	88 bar	6 bar







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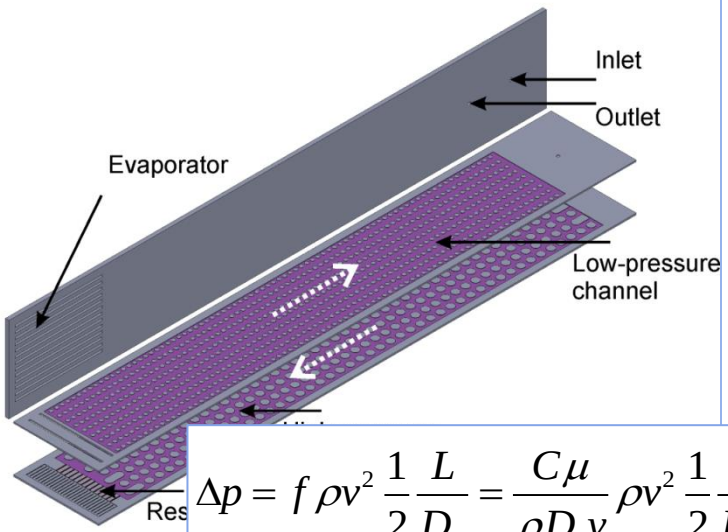
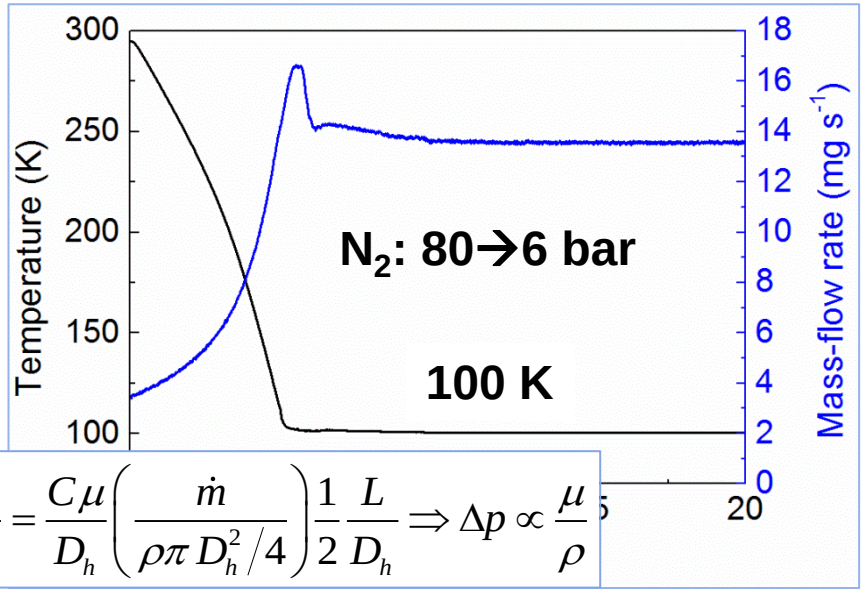
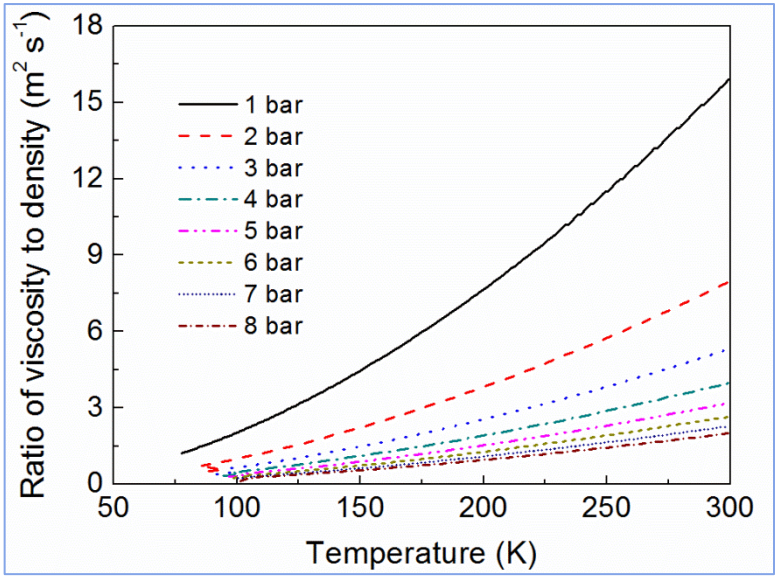
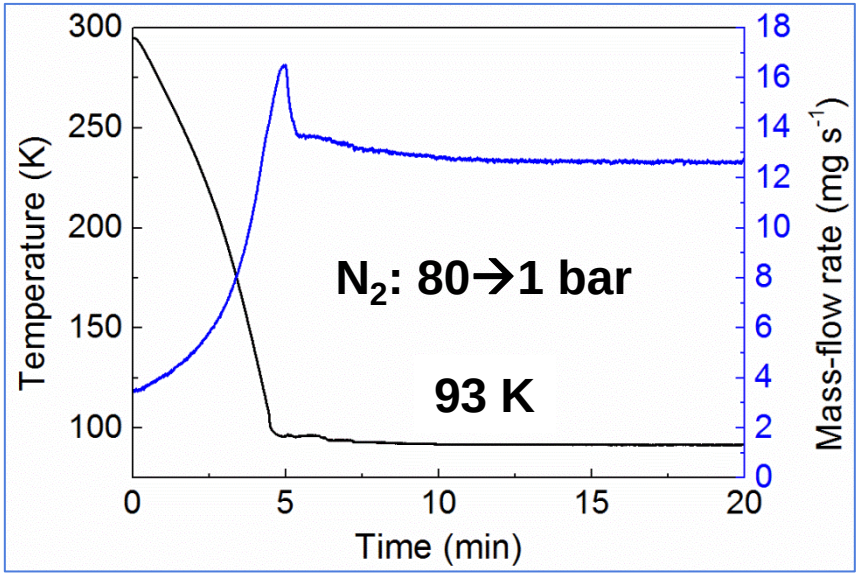
Single-stage microcooler



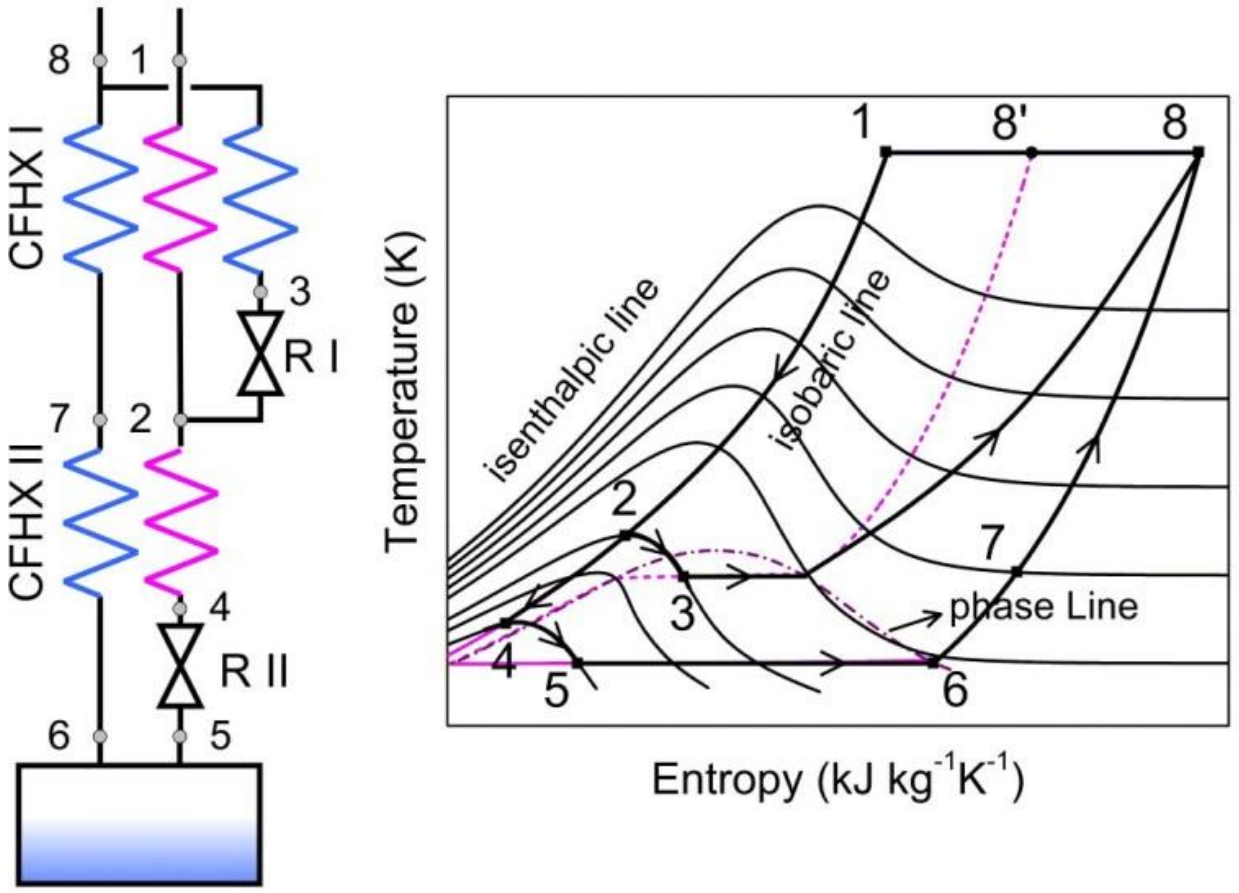


$$\Delta p = f\,\rho v^2\,\frac{1}{2}\,\frac{L}{D_h} = \frac{C\mu}{\rho D_h v}\,\rho v^2\,\frac{1}{2}\,\frac{L}{D_h} = \frac{C\mu}{D_h}\left(\frac{\dot{m}}{\rho\pi D_h^2/4}\right)\frac{1}{2}\,\frac{L}{D_h} \Rightarrow \Delta p \propto \frac{\mu}{\rho}$$





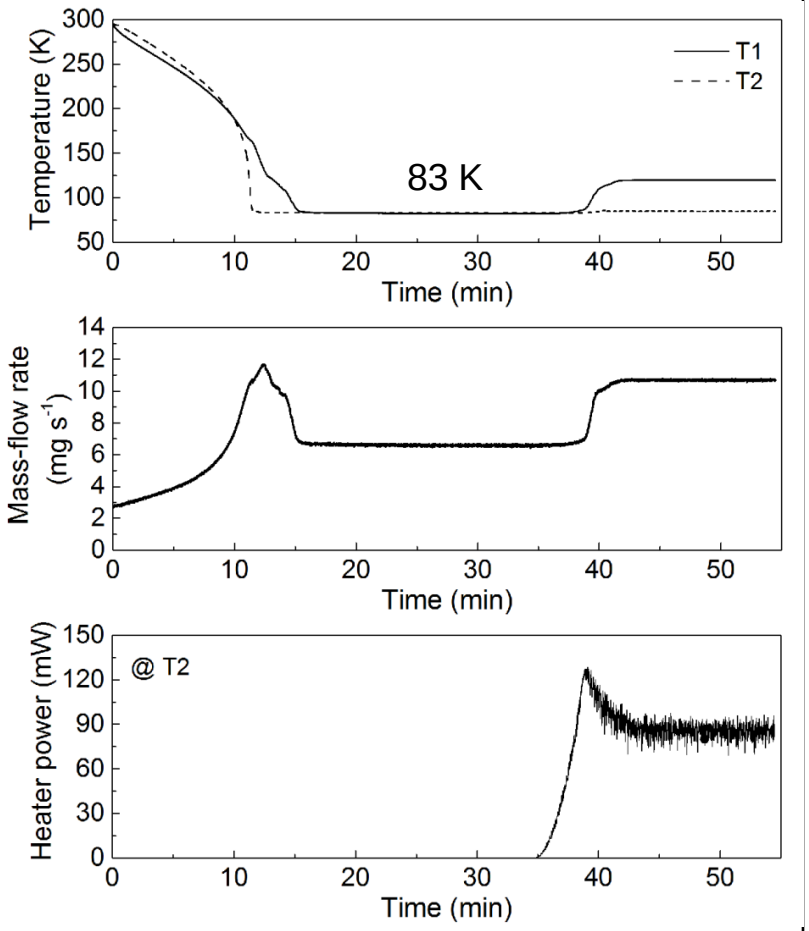
Double-expansion microcooler: Thermodynamics



Schematic of the Linde-Hampson cooling cycle with double JT expansion and the gas cycle drawn in the T-s diagram.

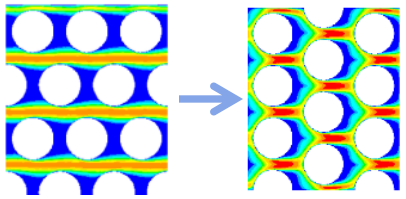
Double-expansion microcooler: Performance

Operating conditions		
Working fluid	Inlet	Outlet
Nitrogen	80 bar	1 bar



Conclusions

- Microcooler with different pillar matrices



P_{net}/P_{gross} increases from 0.70 to 0.78.

- Microcooler with thermoelectric precooling

- Double-expansion microcooler

Cold-end temperature: 83 K;

Cooling power: 90 mW@85 K.

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Thanks for your attention!