Overview of cryocooler technologies enabling accelerator science

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4 K Cryocoolers reliability & developments

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‘Wet’ versus ‘Dry’ Cryogenics - personal experience

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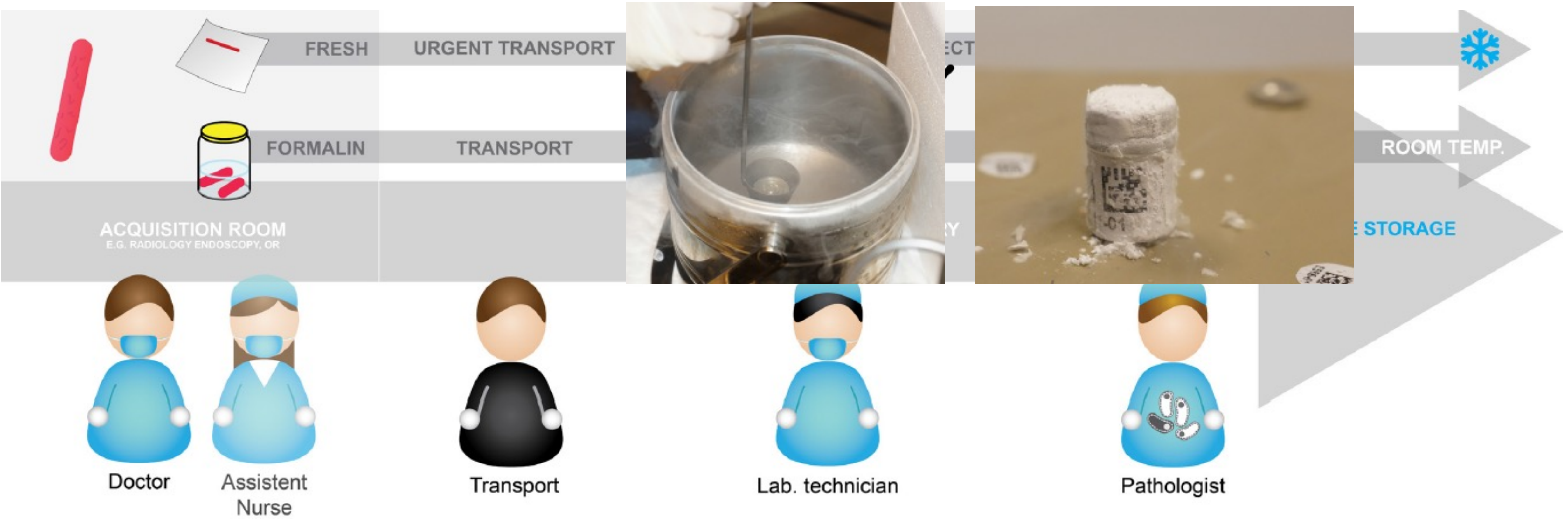

Courtesy: Theo van der Leij, Pamgene B.V.

Amsterdam UMC
University Medical Centers

ATS

‘Dry’ cryogenic system

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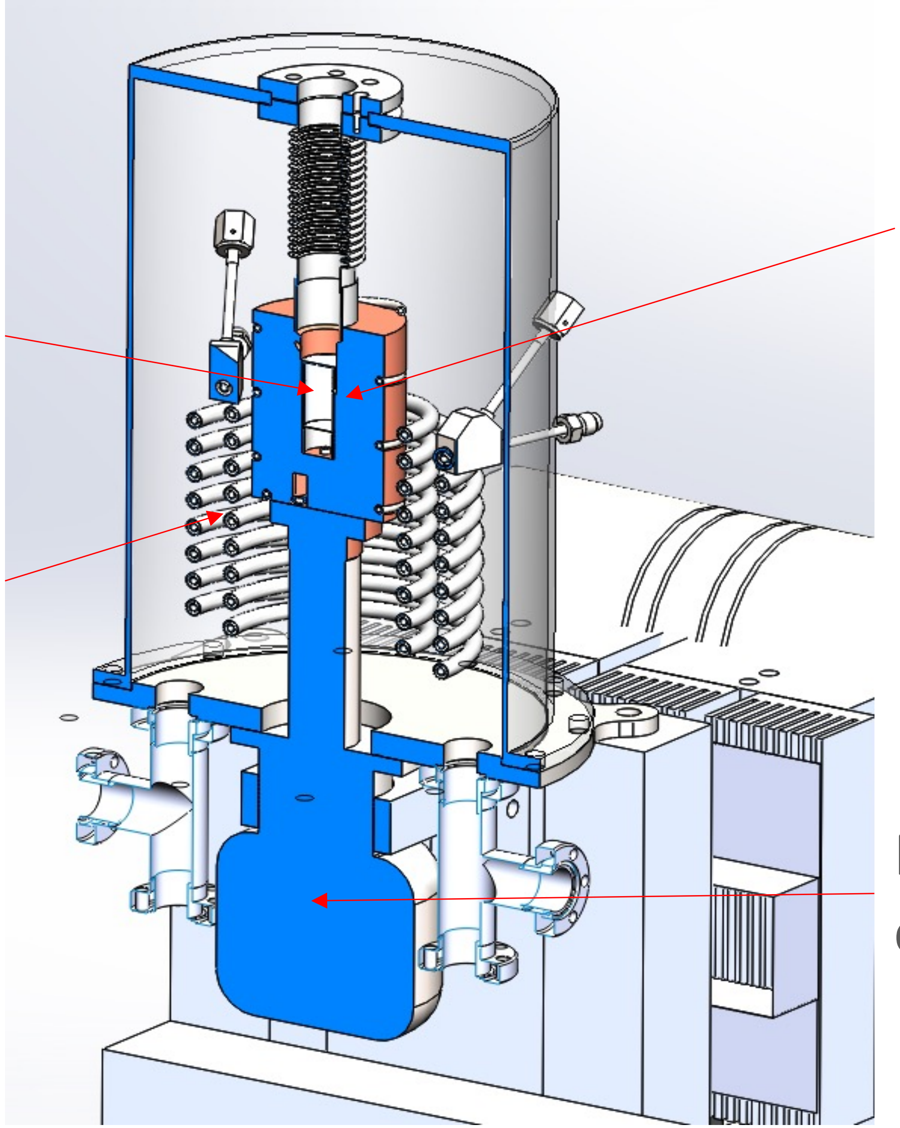
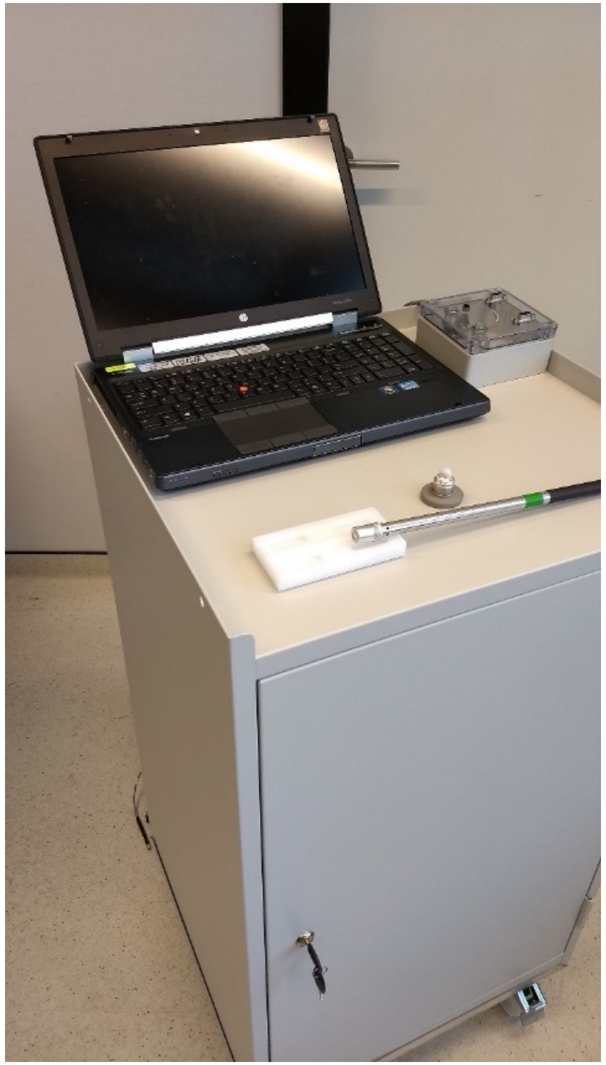
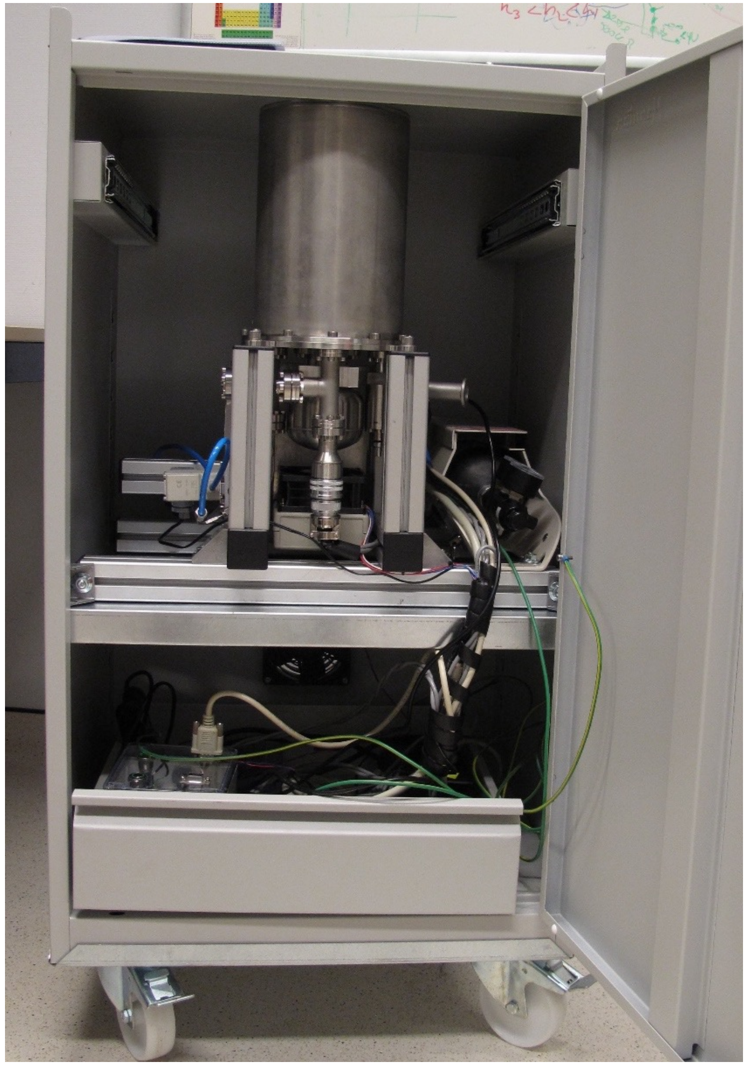
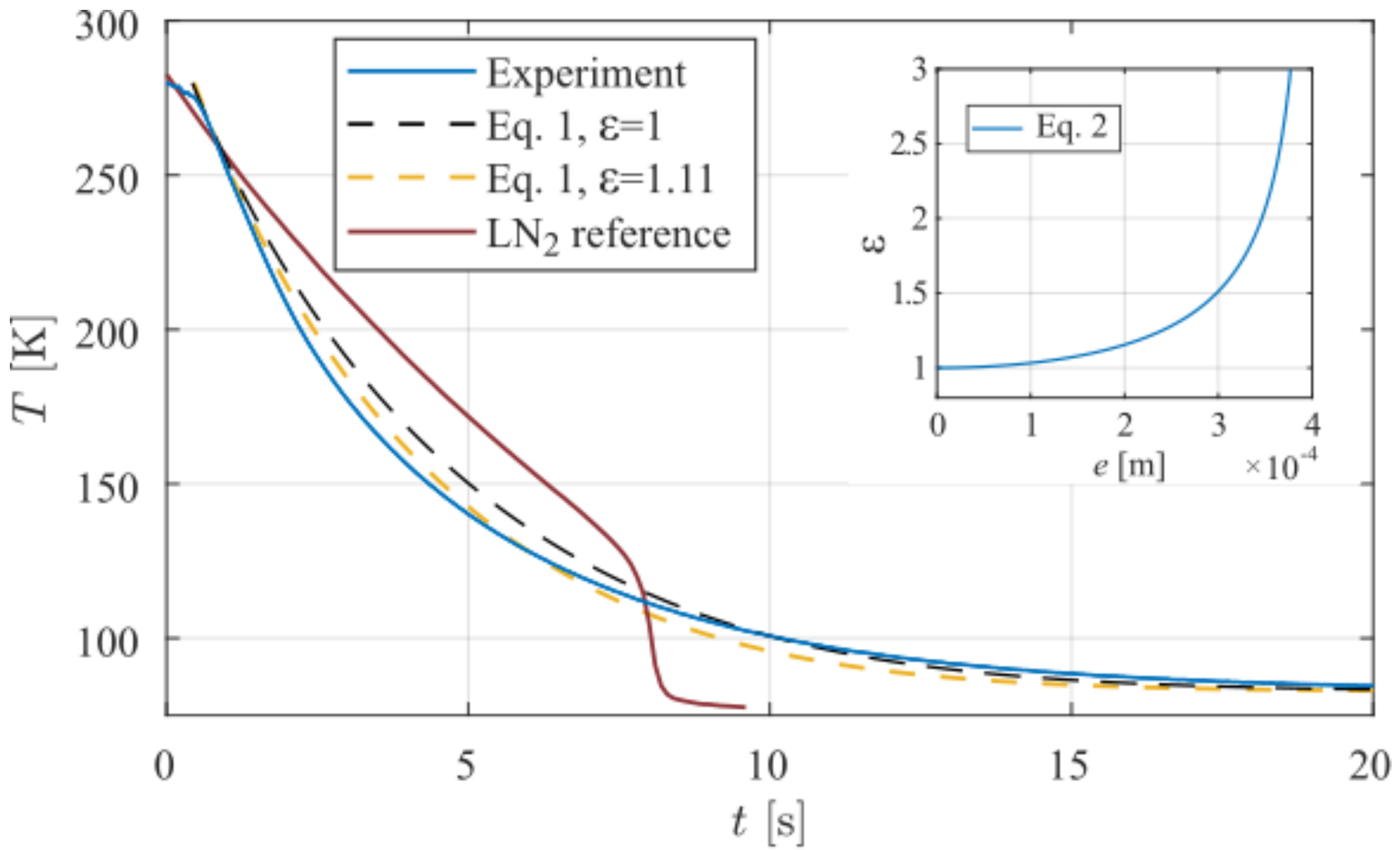






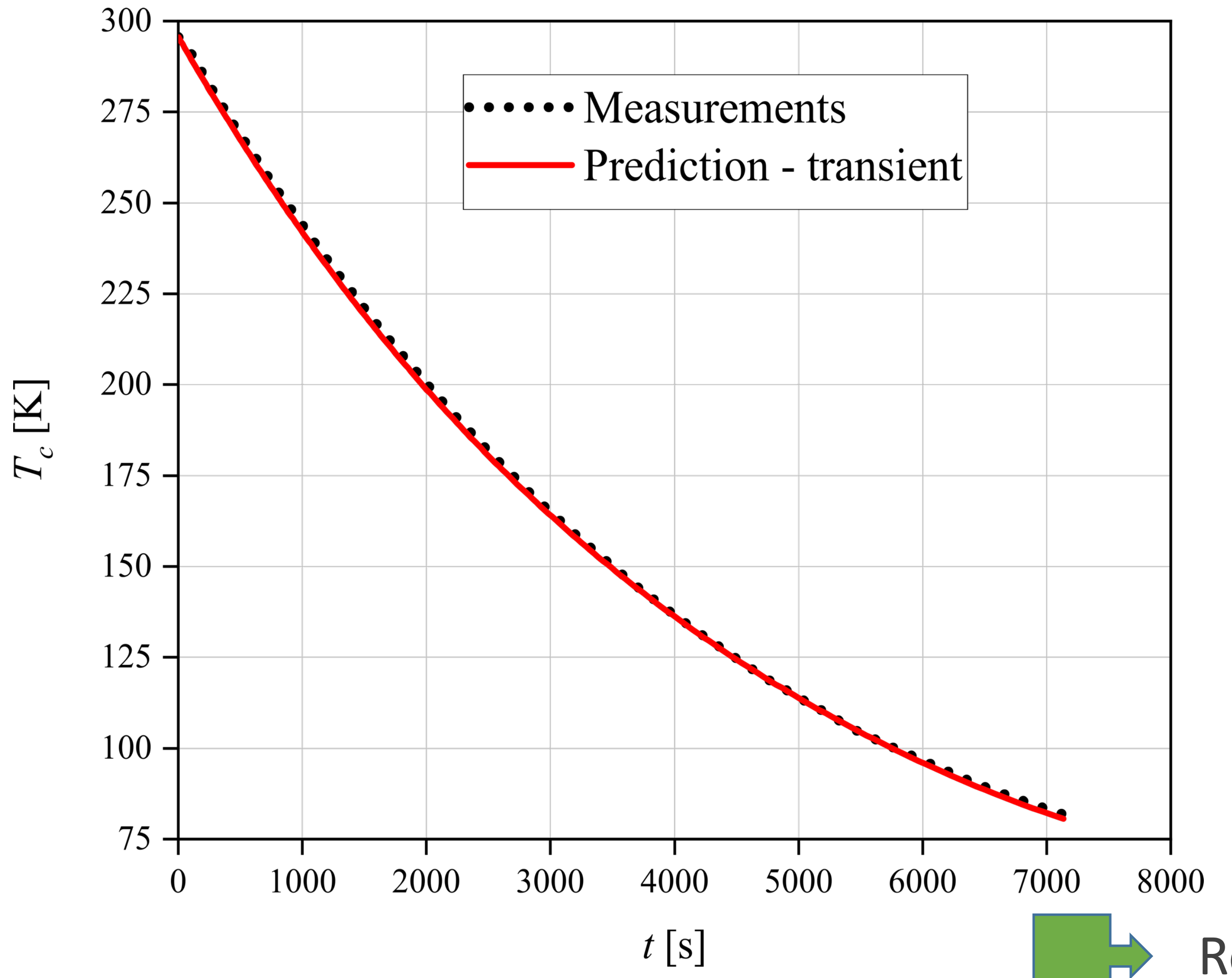
Performance of the snapfreezer



$$\epsilon = \frac{S(e)}{S(0)} = \frac{\cosh^{-1}\left(\frac{R^2+(R+d)^2}{2R(R+d)}\right)}{\cosh^{-1}\left(\frac{R^2+(R+d)^2-e^2}{2R(R+d)}\right)}$$

PhD Thesis: Sahil Jagga, University of Twente

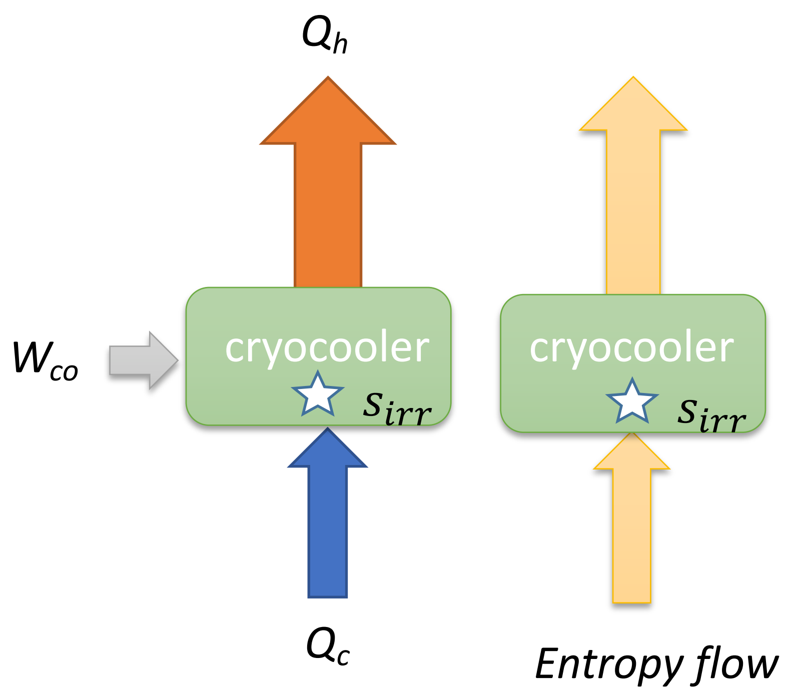
Preparation time



- Unlike cryogenic fluids where the cooling speed can be tuned, cryocooler systems have an inherently large lead time.
- Proper thermal design is a must to reduce parasitic heat loads
- The cooler need to cool itself first, important consideration for small loads.

Ready for application

Heat rejection at the warm end



Heat rejection at the warm end

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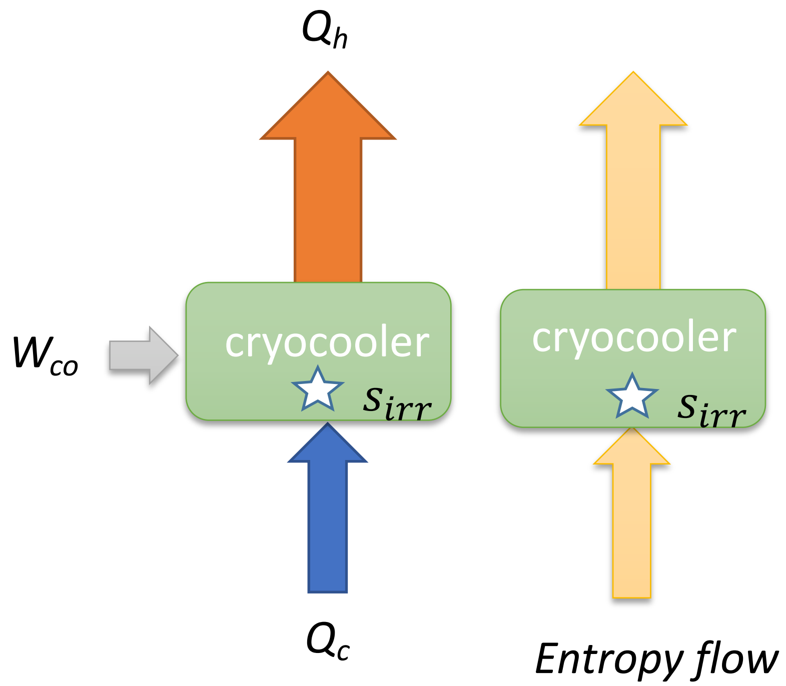
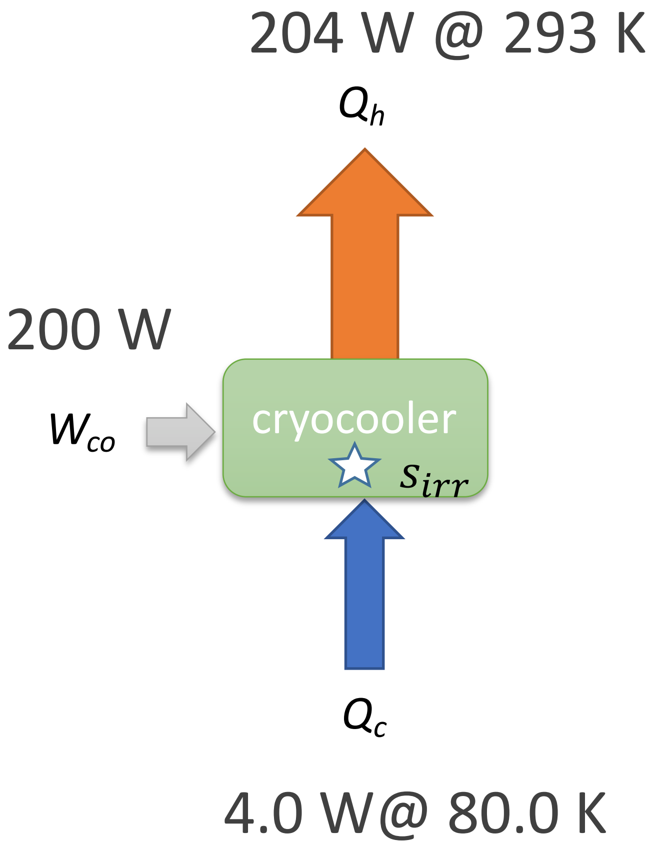


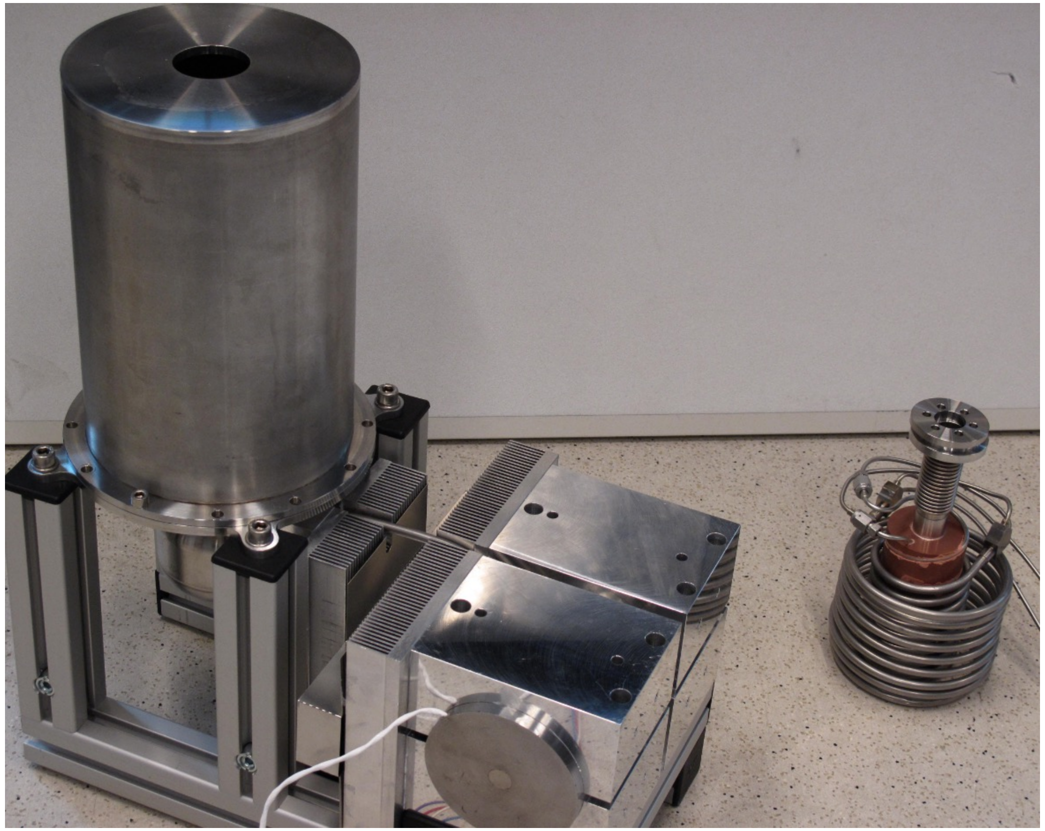
Heat rejected (water cooled):?

Power Consumption 50Hz (Input Power):7.9 kW

1.0 W@ 4.2 K with
40.0 W@ 45.0 K

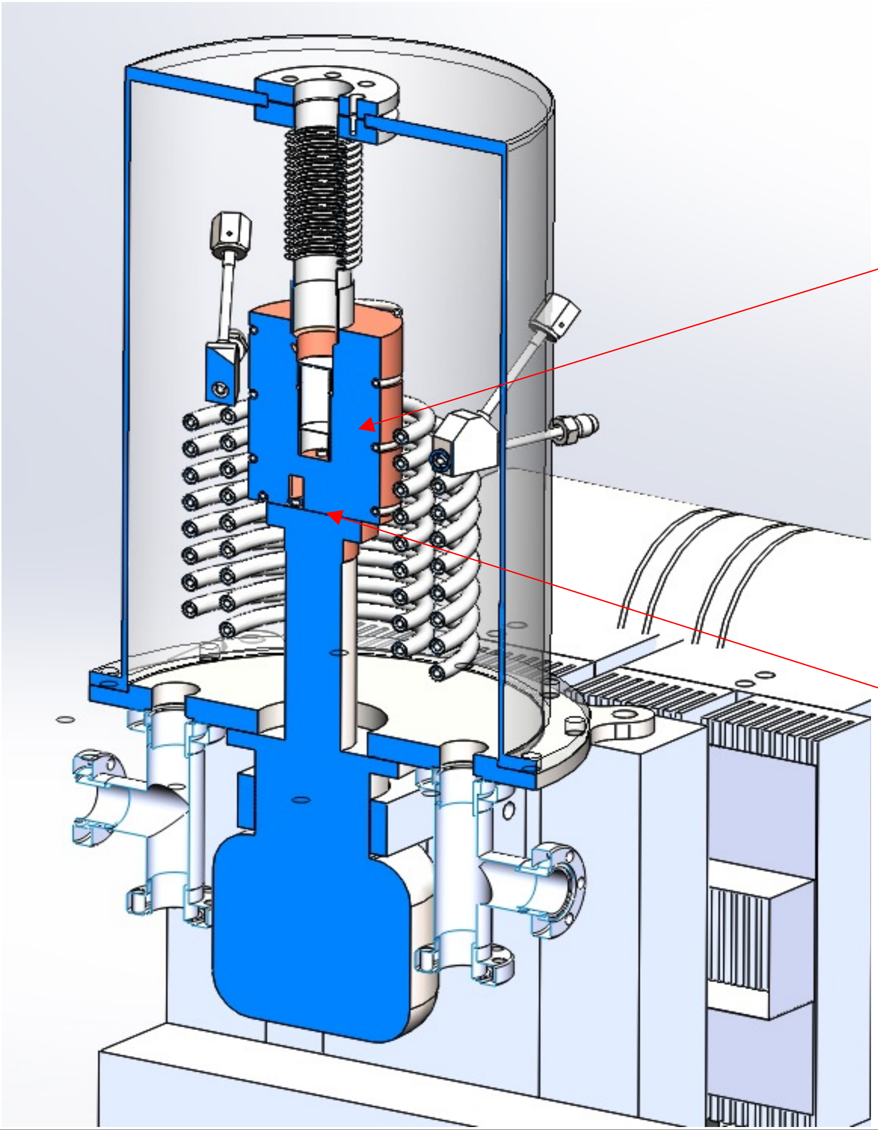
Heat rejection at the warm end





- Air cooled; Fans are noisy
- Fanned Pulse tube cryocooler (Oxymoron)

Other topics



➢ Limited thermal diffusion of materials;

PhD thesis: '*Rick Spijkers*' on two phase heat spreaders

CryoSponge – Physics of imbibition and evaporation of cryogenic liquids in porous materials

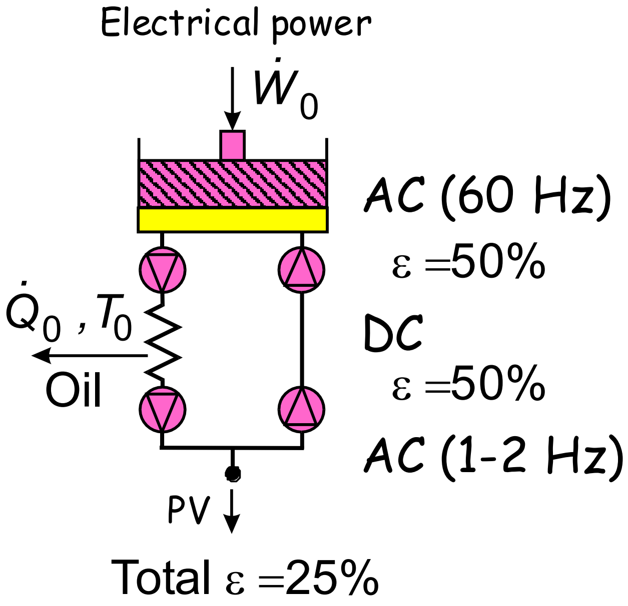
➢ Thermal contact between solid surfaces

Ram Dhuley – Fermi lab

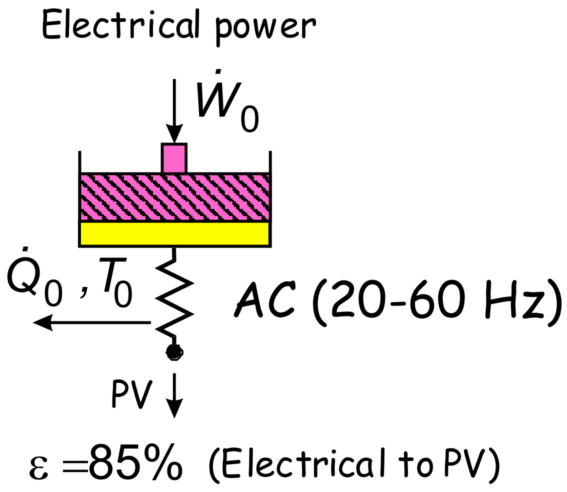
Contents

4K work horse

- Gifford-McMahon cryocooler
- Low frequency pulse tube cryocooler



Valved compressor



High frequency valveless compressor

Valveless cryocooler developments

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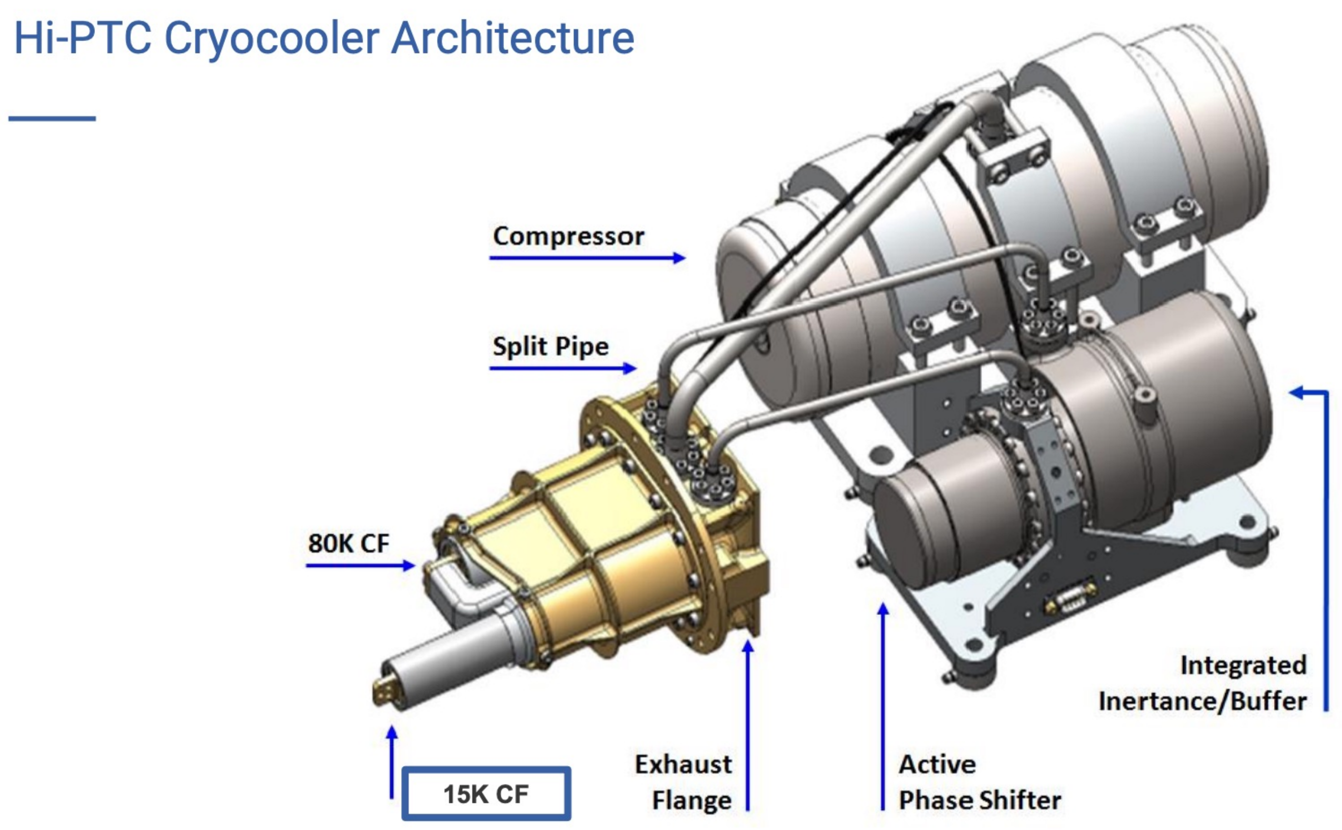
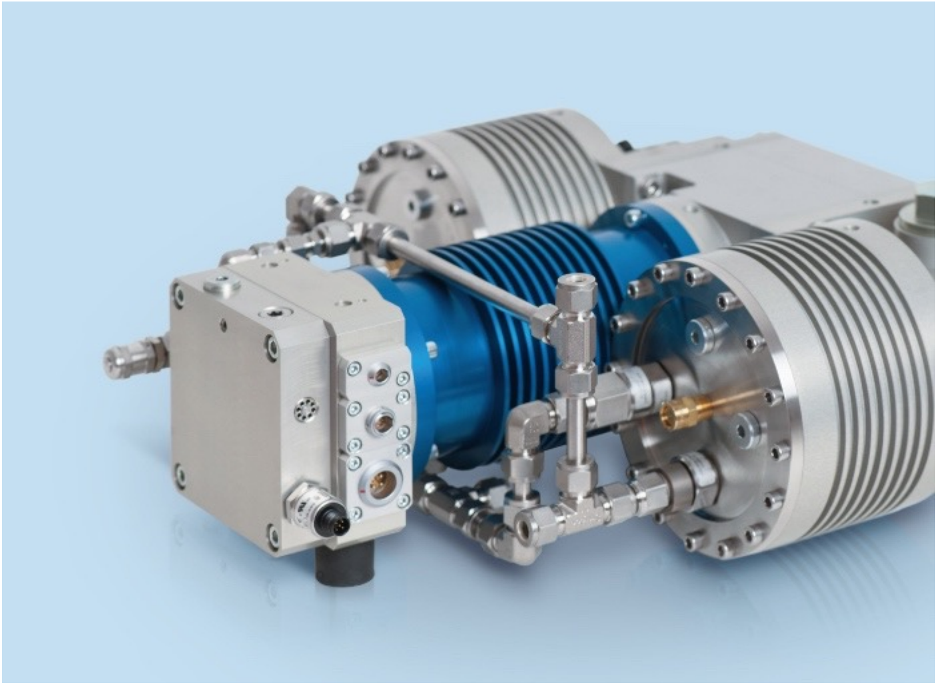


Air Liquide & Thales cryogenics

Picture from EASISchool Grenoble (available online)

550 W input power
30 mW at 4.2 K
Perfect for detector cooling



Pressurewave.de

Hybrid concepts for 4 K

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- RAL cryocooler [Stirling + JT]
- Gas circulator [Several]
- Northrop Grumman (Pulse tube + JT)
- Ball aerospace (Stirling + JT)
- Lockheed Martin (Pulse tube with inertance tube)

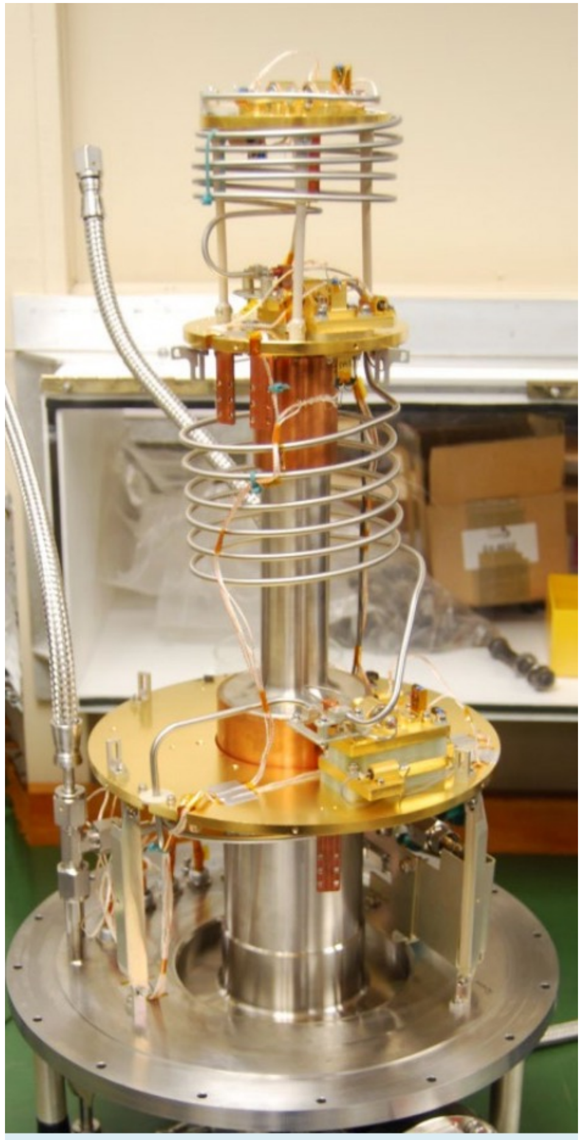

Image: Martin Crook, STFC, UK

1kW input - Free piston Stirling cooler

- University of Twente in cooperation with Microgen Engine Cooperation
- 1 kW compressor performance varies between 77 – 85 % (Electrical to mechanical power)
- 3.5 kW compressor - to be developed

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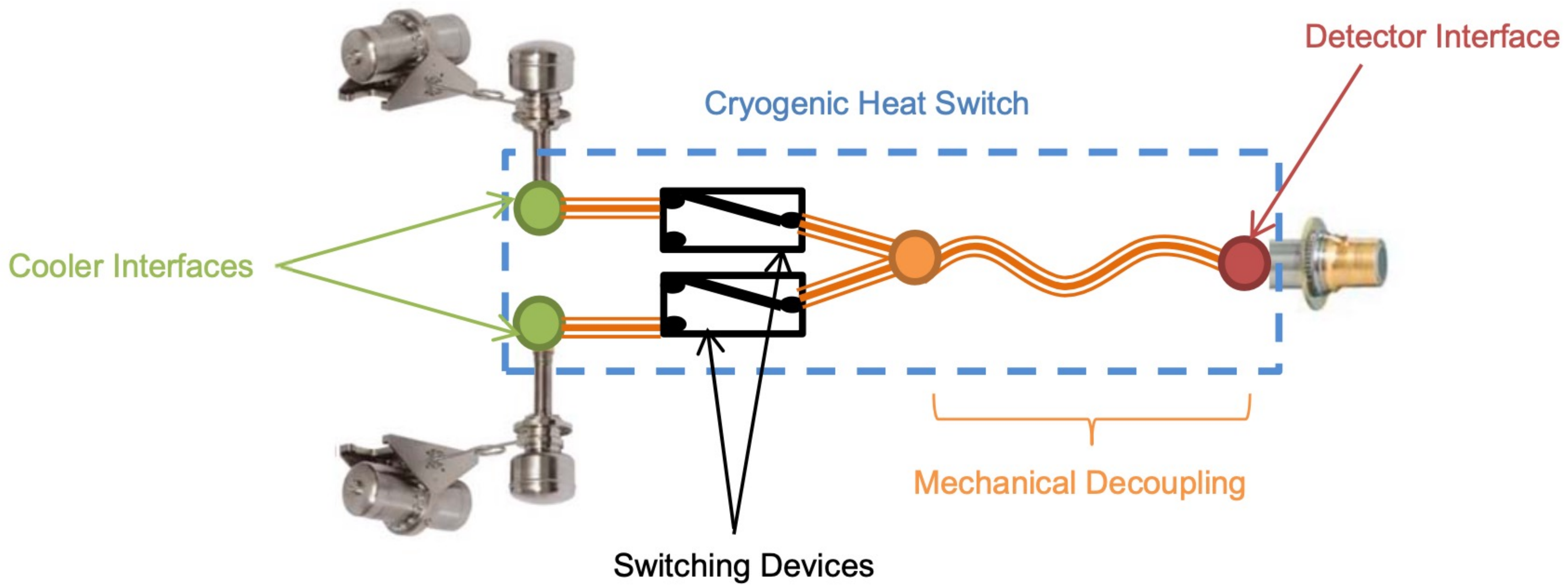
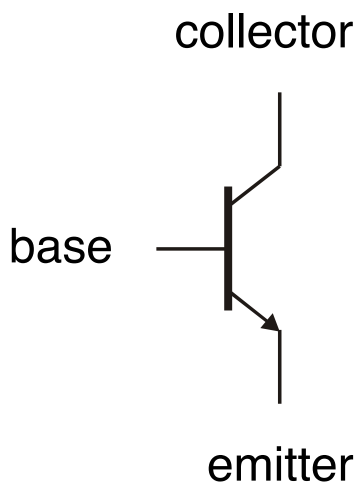
Redundancy

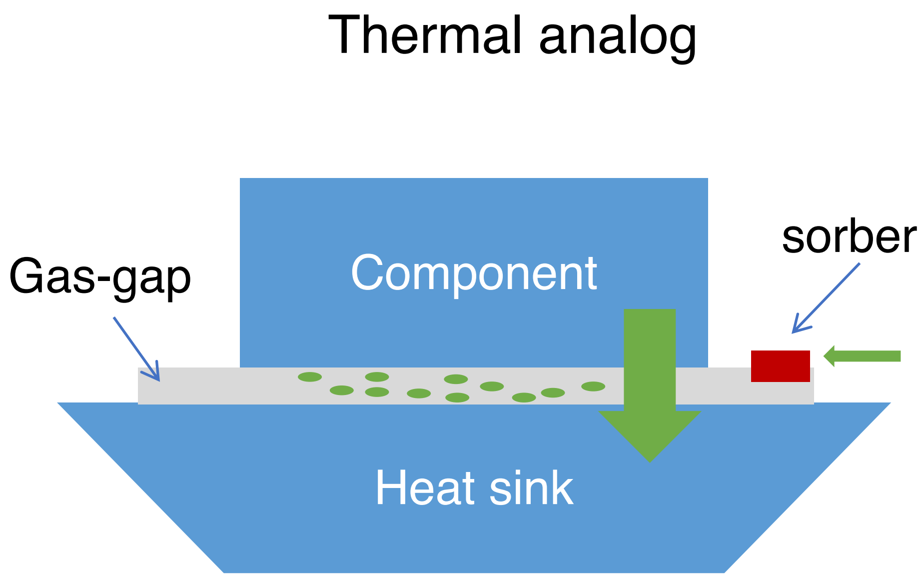


SOW ESA 30 – 80 K Heat Switch

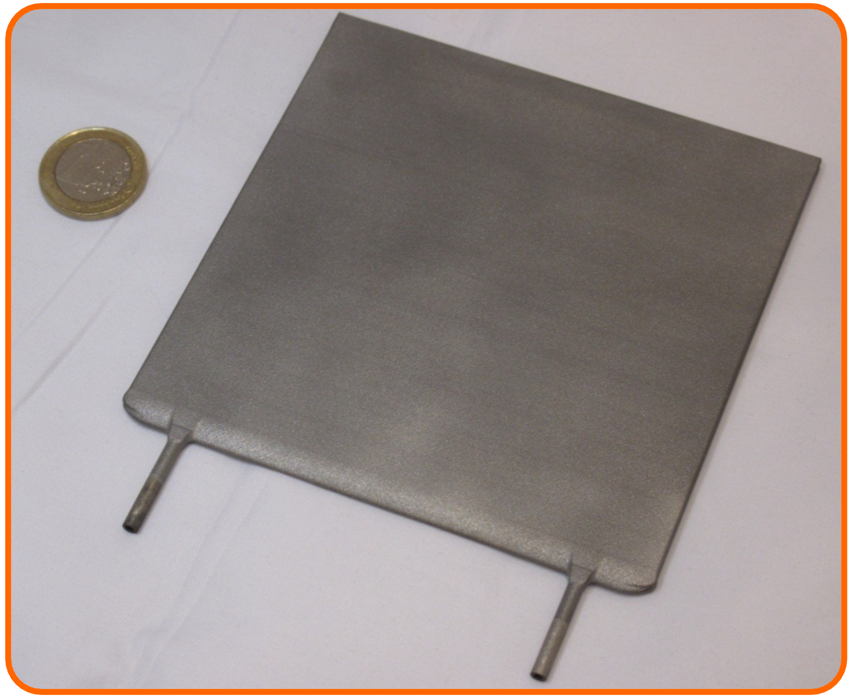
Flat-panel gas-gap heat switch

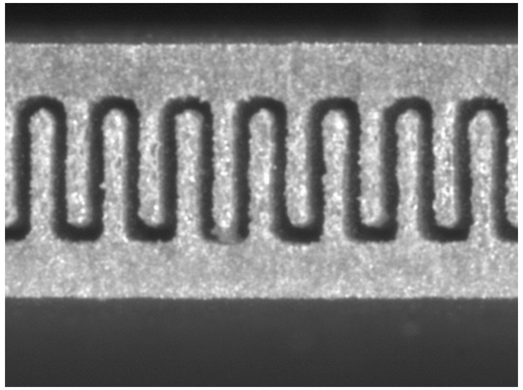


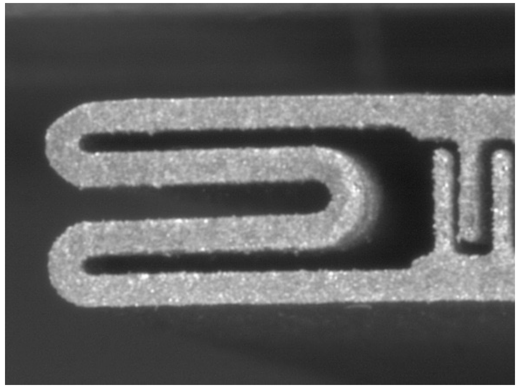
Control large current from collector to emitter with small base current!



Flat-panel gas-gap heat switch







Flat-panel gas-gap heat switch

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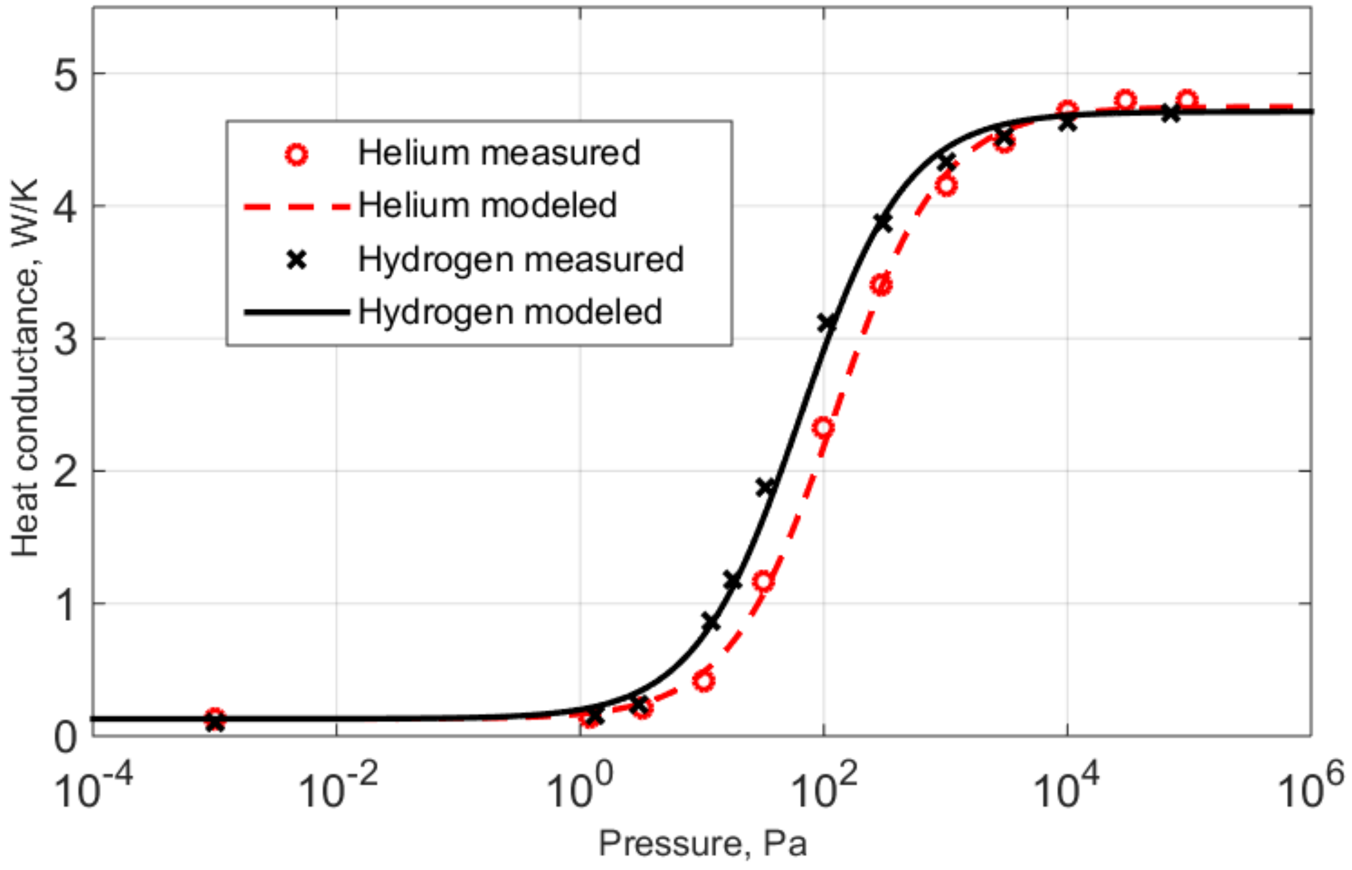

U_{off} = 0.13 W/K
P_{off} <= 0.01 mbar

U_{on} = 4.71 W/K
P_{off} >= 100 mbar

On/Off ratio ~ 35

imagination at work

An efficient liquid helium gas-gap switch allowing rapidly servicing low-temperature dynamic nuclear polarisation systems

ICEC27-ICMC 2018
27th International Cryogenic Engineering Conference
International Cryogenic Materials Conference 2018
September 3-7 2018 Oxford England

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[2]GE Research Circle Technology Inc, Healthcare Imaging, Cambridge, UK

Summary

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- Cryocooler based cryogenic systems architecture is significantly different compared to cryo-fluids
- Several architectures for detector cooling are investigated for space applications
- Cryocoolers are inefficient (in terms of energy conversion metric)
- Cost effective in some applications
- Helium reliquification infrastructure is not required.