Development of a novel hydrogen liquefier prototype using the magnetocaloric effect of holmium

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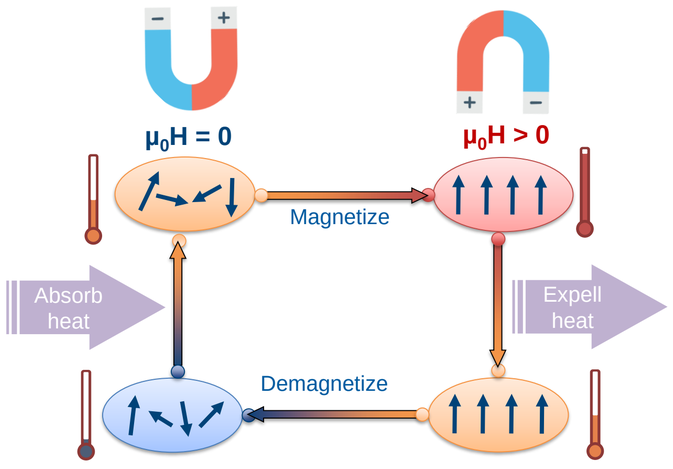
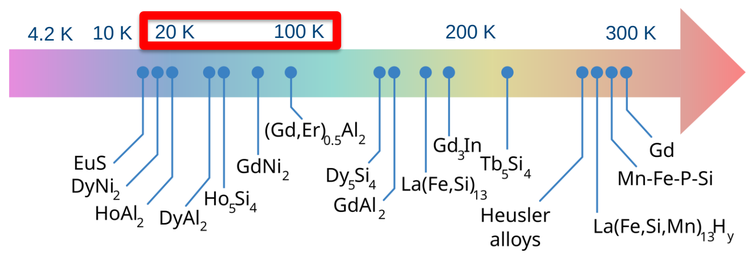
Magnetocaloric cooling



Adiabatic process:

$0 = dS_{total} \Rightarrow dS_{magnetic} = - dS_{lattice}$

- Candidates should have high magnetic entropy change and high adiabatic temperature change
- Potentially higher efficiency at very low temperatures in comparison to Hampson-Linde cycle
- Many known candidates for high and low temperatures

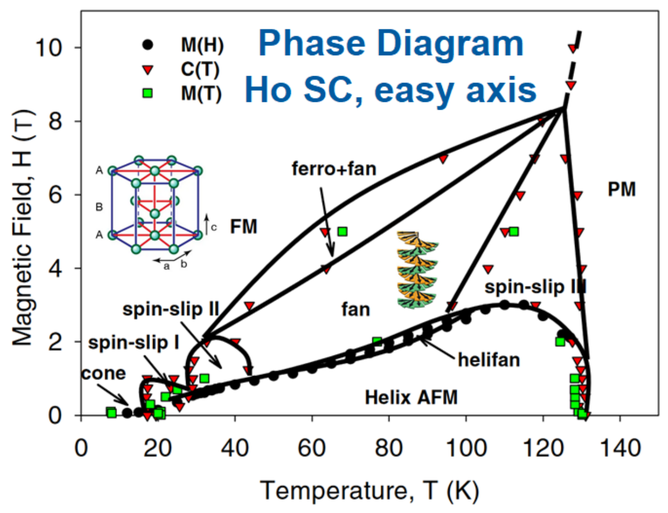


Adapted from S. Taskaev et al., Key Eng. Mater. **833**, 176 (2020)

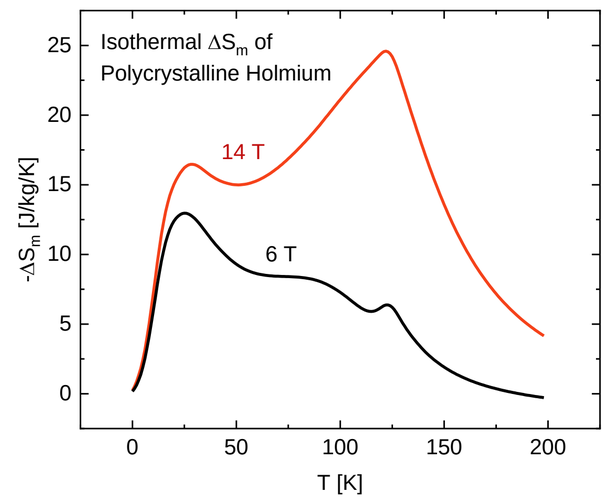
Magnetocaloric effect in Holmium

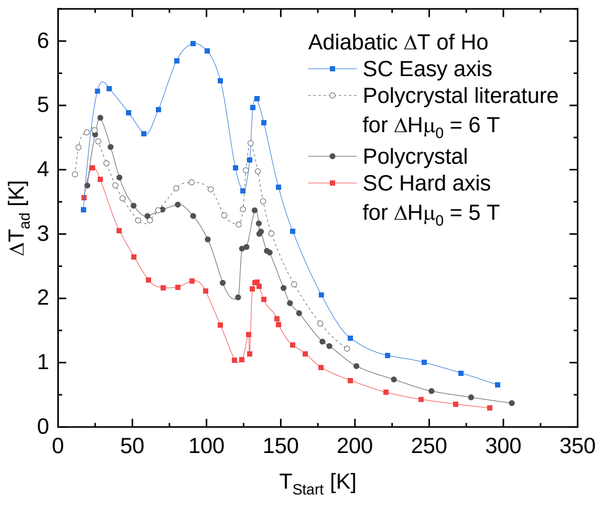
Why Holmium?

- Huge magnetocaloric effect at low temperatures
- Covers the relevant range of 20…80 K with “plateau” of magnetocaloric effect due to several magnetic transitions
- Complex magnetic phase diagram of the easy axis in the single crystal (SC) contributes most of the magnetocaloric effect to the investigated polycrystal

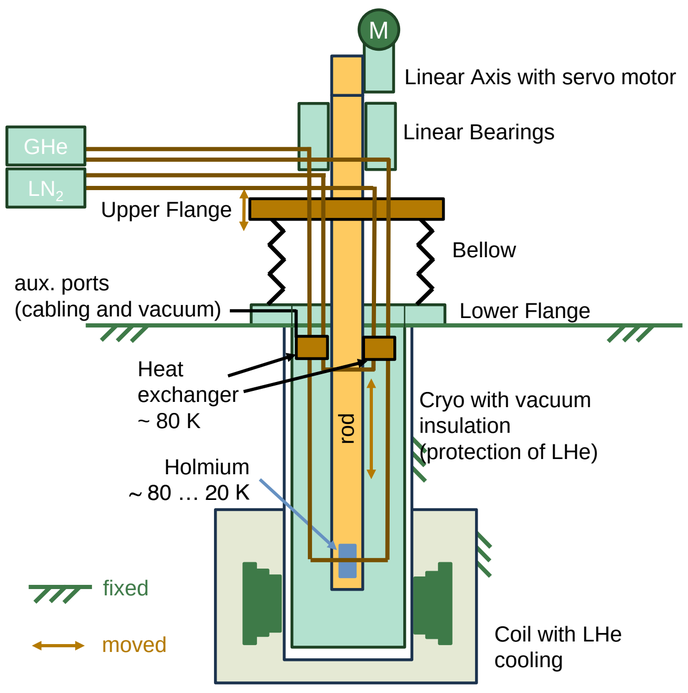


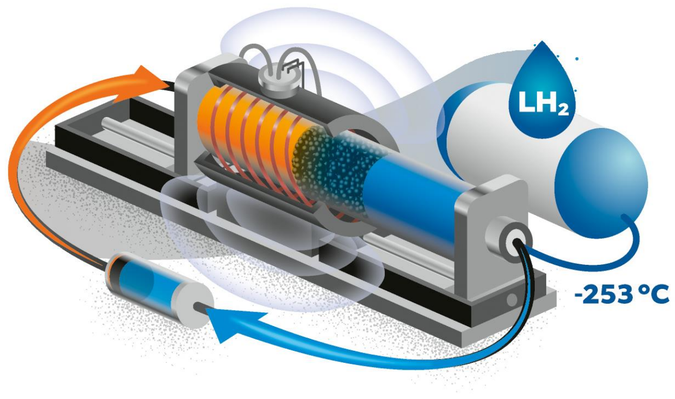
V. I. Zverev et al., J. Magn. Magn. Mater **524**, 167593 (2021); Crystal structure from © Encyclopedia Britannica, Inc. (2012)





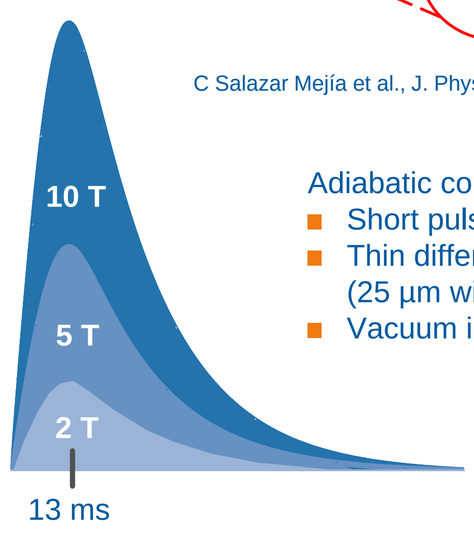
ΔT_{ad} literature data from Nikitin, S. A. et al., Phys. Met. Metallogr. **60**, 56 (1985)





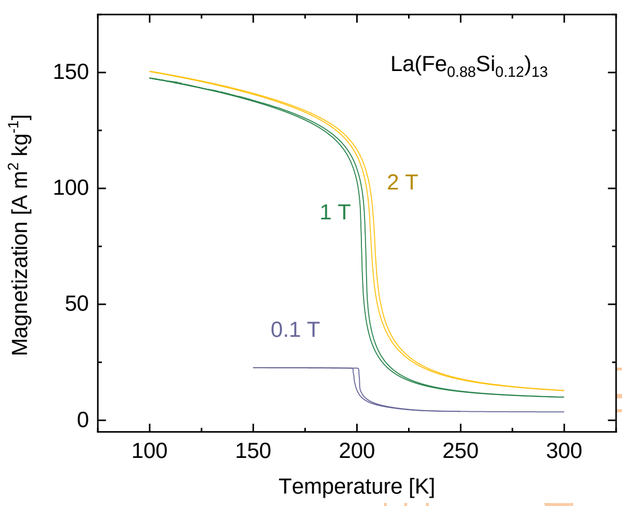
Direct measurements of ΔT_{ad} in pulsed fields

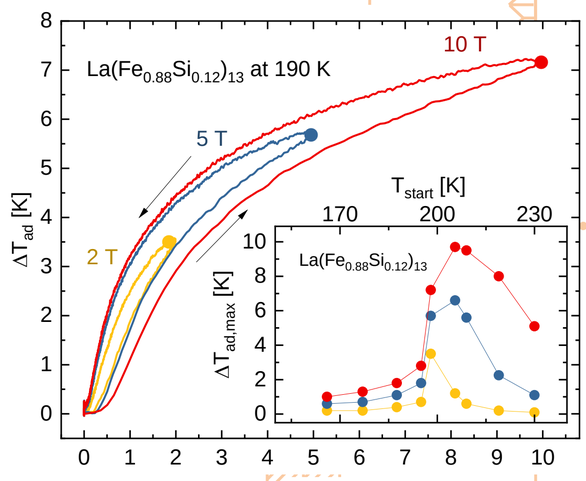
C Salazar Mejía et al., J. Phys. Energy **5**, 034006 (2023)

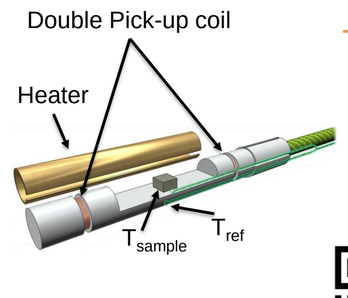


Adiabatic conditions:

- Short pulse (13 ms rise time)
- Thin differential thermocouple (25 µm wire thickness)
- Vacuum insulation







Thanks to Timo for the visuals!

Virtual Lab Tour:

Conclusion

- Investigated holmium for hydrogen liquefaction
- Investigated fluid dynamics of gases through a packed bed
- Started designing a cryogenic magnetocaloric-cooling device

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