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# Pulse Tube Cryocooler at 4 K: Customization for Sensitive Cryoelectronic Applications in "Dry" Low Noise Cryostats

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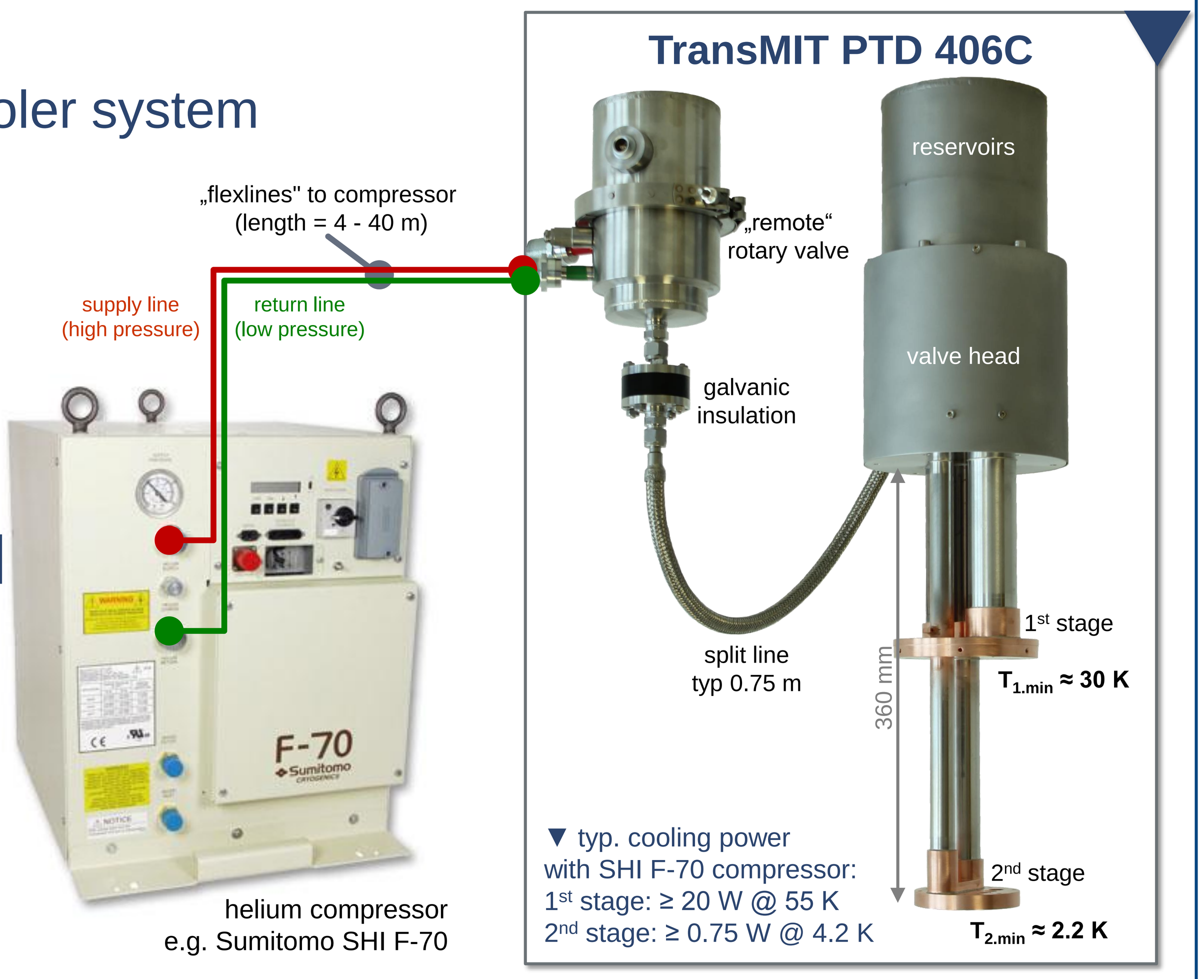
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

## ▼ Introduction

▼Pulse tube cryocooler system

- ▼Cryogen free
- ▼Closed cycle system
- ▼„Dry" cooling at liquid helium temperatures [1,2]
- ▼Remote configuration for low vibration
- ▼Galvanic insulaion against EMI




## ▼ Intrinsic Thermal and Mechanical Variations

All regenerative cryocoolers suffer from thermal and mechanical variations of the cold head due to the periodic pressure wave of compressed and expanding gas inside the tubes.

### ▼ mechanical vibrations

periodic elastic deformation („breathing") of the thin-walled tube with the pressure oscillation (s: wall thickness; d: diameter)

$$\frac{\Delta L}{L} = E^{-1}\frac{d}{2s}\Delta p$$

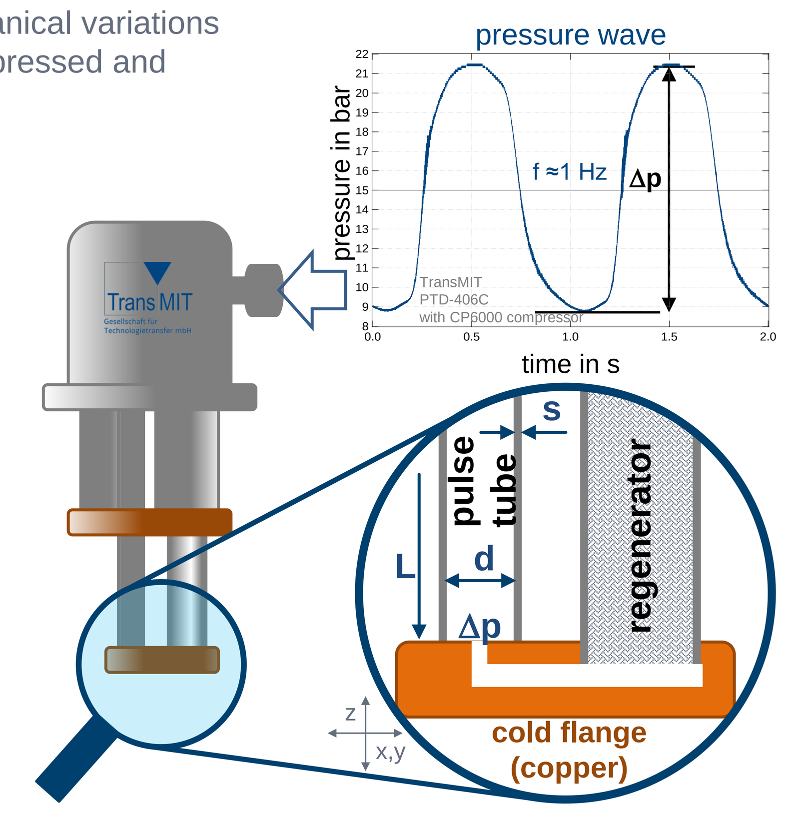
(E: Young's modulus)

### ▼ temperature variations

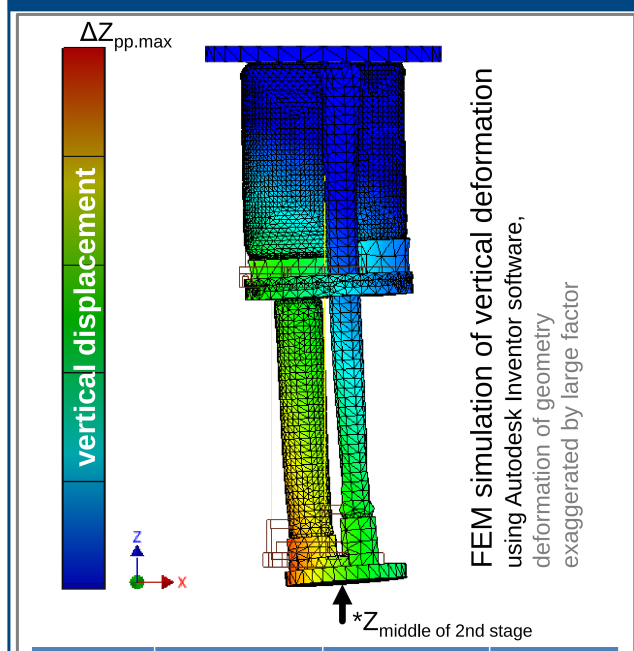
from periodic expansion (*adiabatic*) of the working fluid (He)

$$\Delta T = \frac{\alpha_V T}{\rho C_p}\Delta p$$

Volume expansion coefficient: $\alpha_V = 1/V\,(dV/dT)_p$

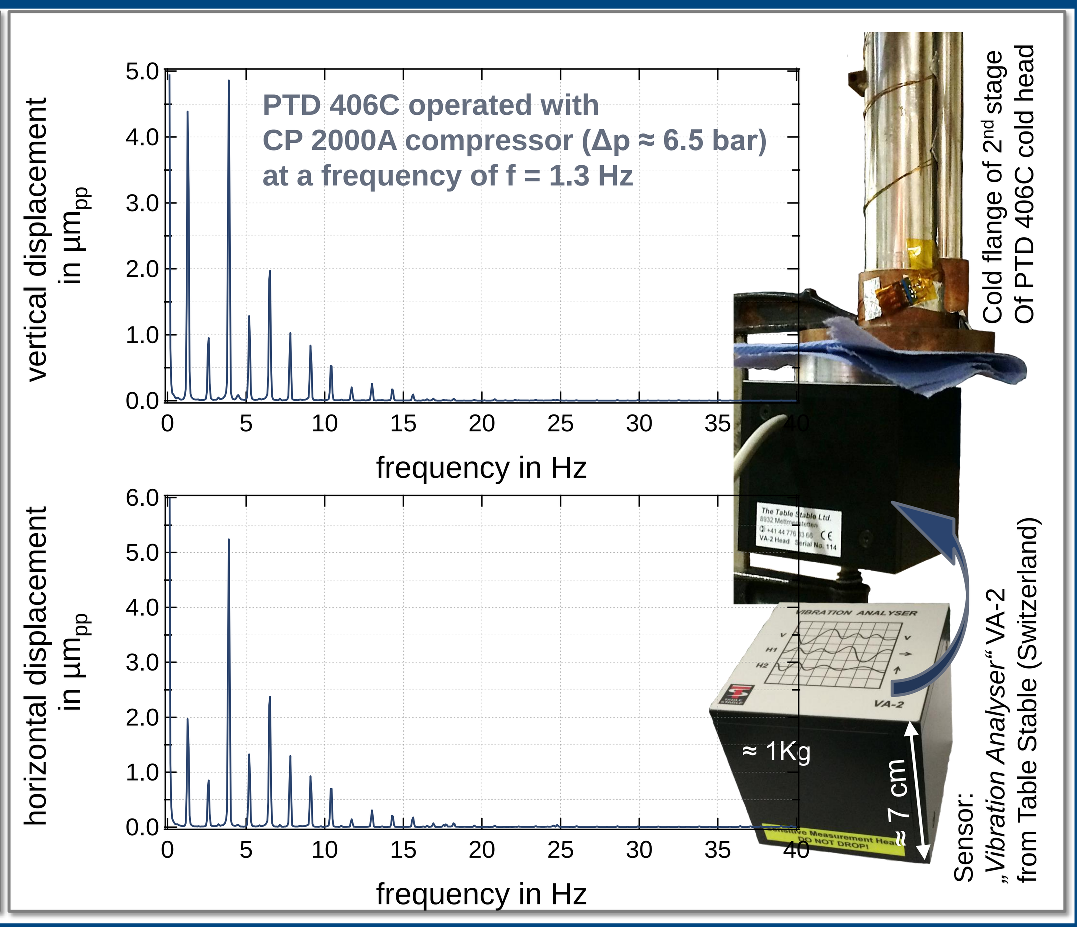



## ▼ Mechanical Vibration of PTD 406 C in Measurement and Simulation

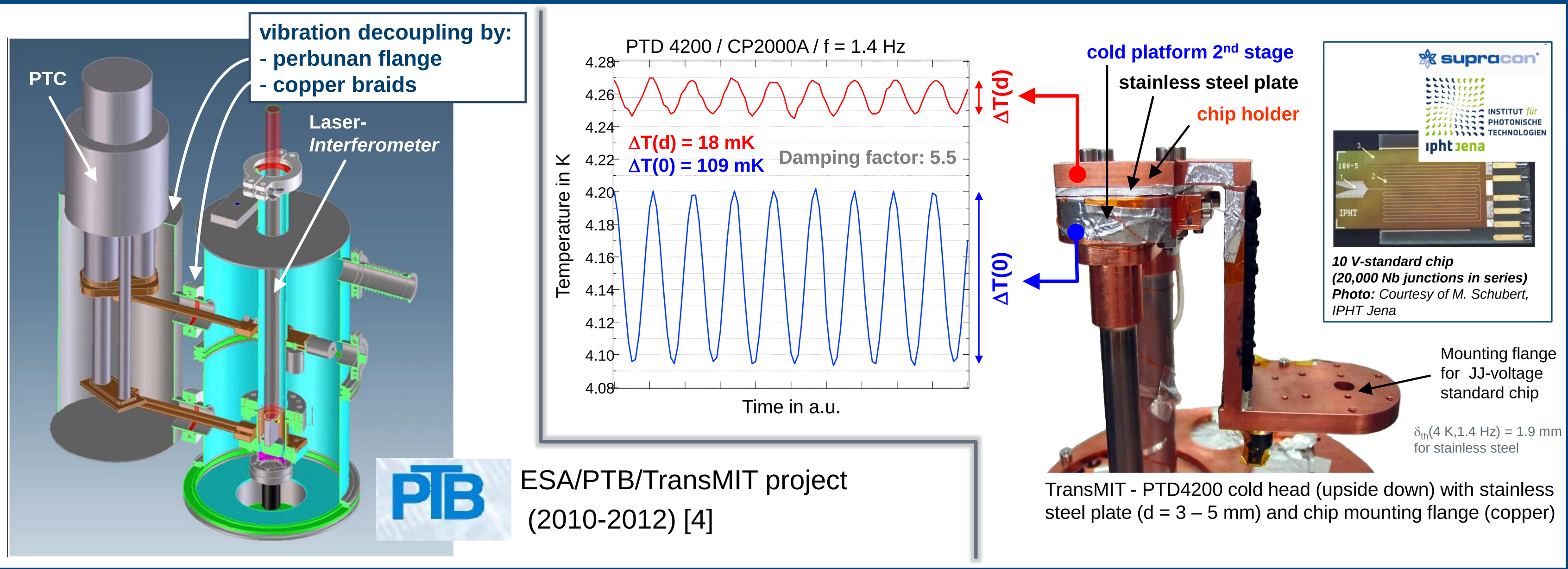



| Pressure ΔP | Compressor e.g. | $\Delta Z_{pp}$ middle of 2nd stage | $\Delta Z_{pp,max}$ |
|---|---|---|---|
| 6.5 bar | CP 2000 A | 8.06 µm | (11.05µm) |
| 9.3 bar | CP 4000 | 12.02 µm | (15.8 µm) |
| 13 bar | CP 6000 | 16.8 µm | (22.1 µm) |

cf. Cryomech PT4-05: z-displacement ≈ 25 µm with 5 kW compressor (CP 950) [3]



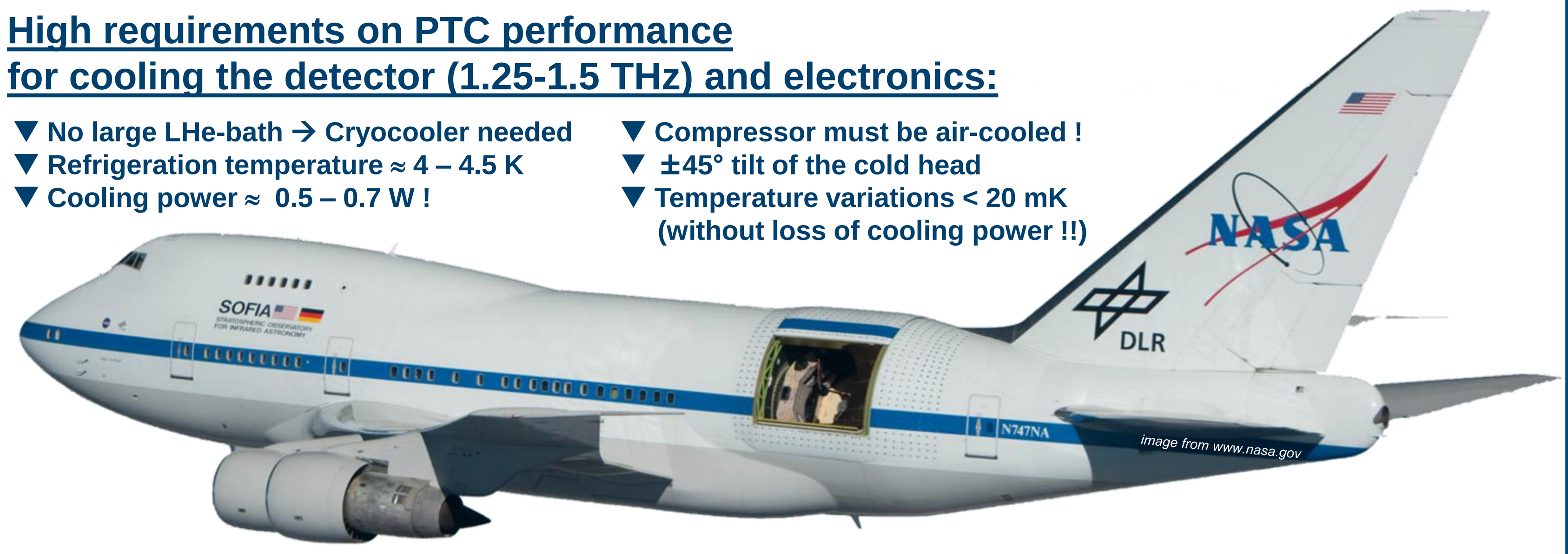

## ▼ Mechanical and Thermal Decoupling [5] from Application




## ▼ Cooling THz-Detectors in Radio Astronomy (SOFIA) [6]

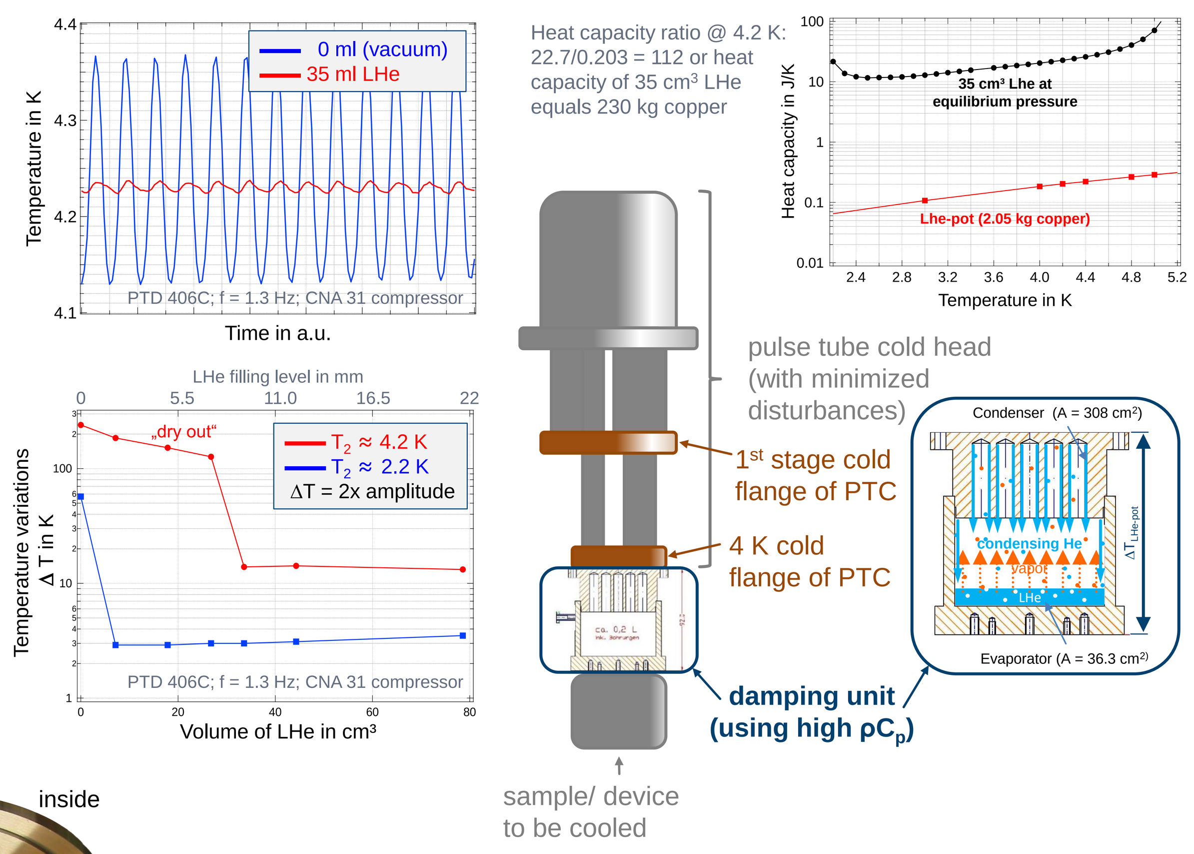
**High requirements on PTC performance for cooling the detector (1.25-1.5 THz) and electronics:**

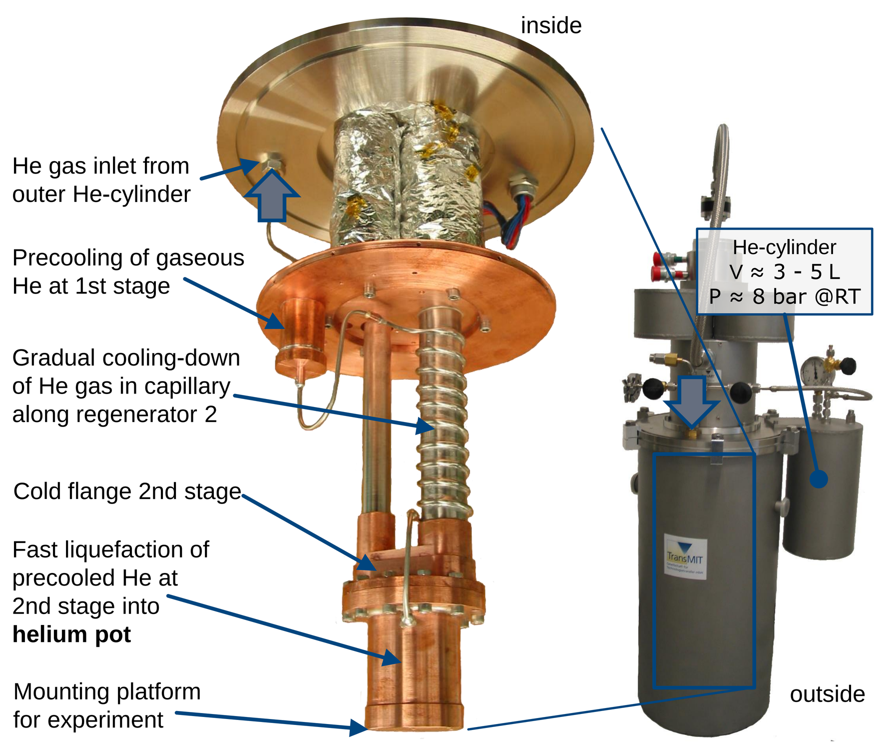
- ▼ No large LHe-bath → Cryocooler needed
- ▼ Refrigeration temperature ≈ 4 – 4.5 K
- ▼ Cooling power ≈ 0.5 – 0.7 W !
- ▼ Compressor must be air-cooled !
- ▼ ±45° tilt of the cold head
- ▼ Temperature variations < 20 mK (without loss of cooling power !!)




## ▼ Temperature stabilization unit for „upGREAT"-detectors suitable for high cooling powers

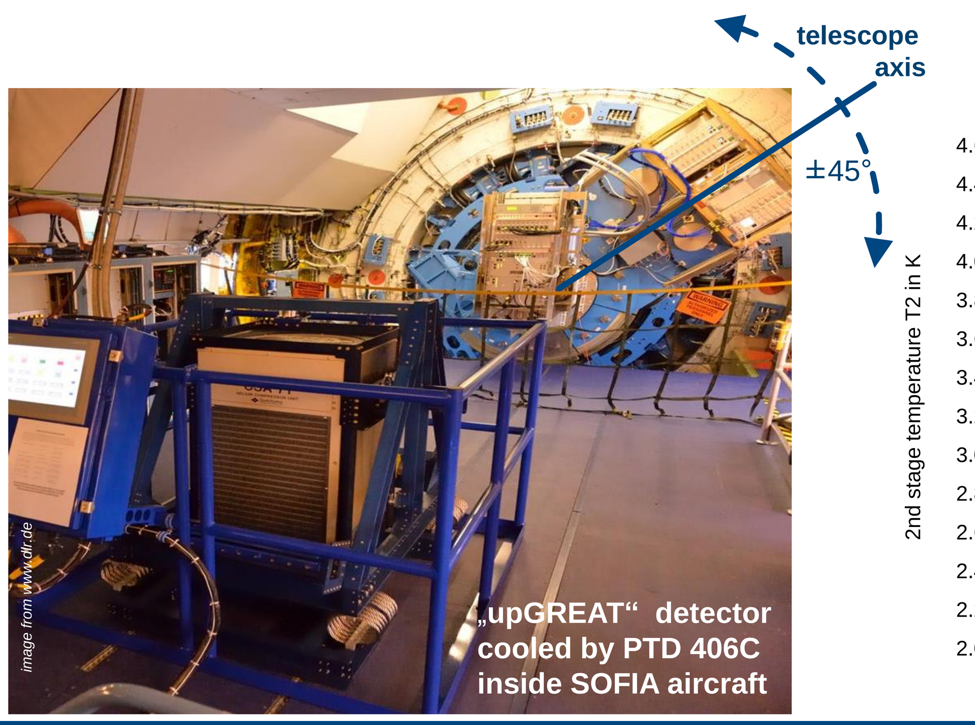
Applications as cooling of THz detectors in radio astronomy require high temperature stability at large cooling loads (e.g. ΔT < 20 mK @ 4.2 K with cooling power of 500mW @ 4.2K). Here, a reservoir filled with liquid helium can be used to stabilize the temperature variations of a cryocooler. Especially at cryogenic temperatures, the heat capacity of LHe is two orders of magnitude higher than the heat capacity of copper. The LHe-system works in a closed cycle and can be integrated in the dry cryostat. It works autonomously and remains maintainance free.



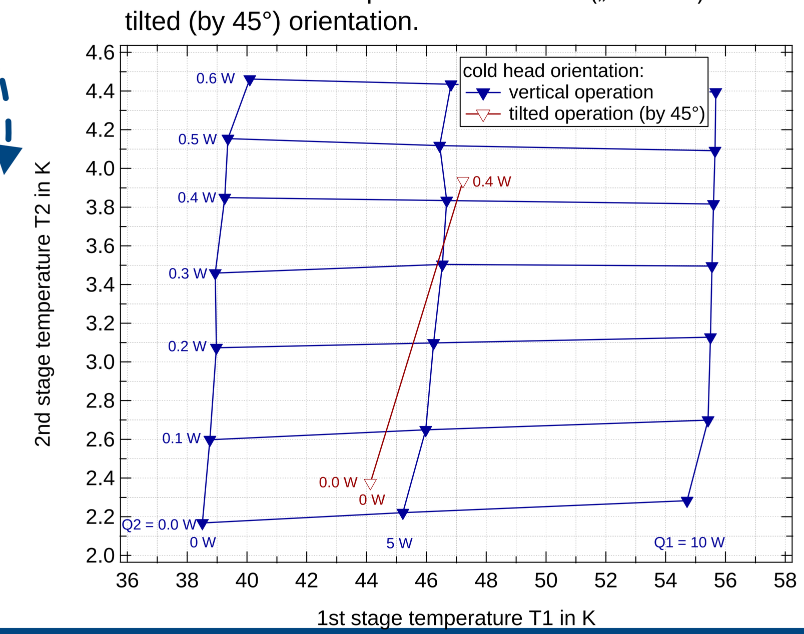




Depending on the heat load, the damping effect sets in when the filling level of LHe exceeds the „dry-out" effect. Once the reservoir is filled with LHe, the temperature oscillation is reduced to about ΔT = 13 mK at 4.2 K transducing a cooling load of about 500 mW. Such large power transitions are possible without a recognisable loss in cooling power (cf. identical mean temperature of dampened and undampened T-variations ). The two phase (liquid and gaseous) He in the reservoir works as a thermo-syphon wherein the power is transported by the vapor of He in the evaporator at the bottom of the reservoir and the recondensing of He in the condenser.

## ▼ Cooling power of PTC in non-vertical operation




Loadmap of the simultaniously available cooling power of both stages of a PTD 406C cold head operated with a SHI CNA-31A compressor in vertical („normal") and tilted (by 45°) orientation.




## ▼ References & Acknowledgments

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