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Measurements of thermal conductivity at cryogenic temperatures

Academia & Industry in Space Projects
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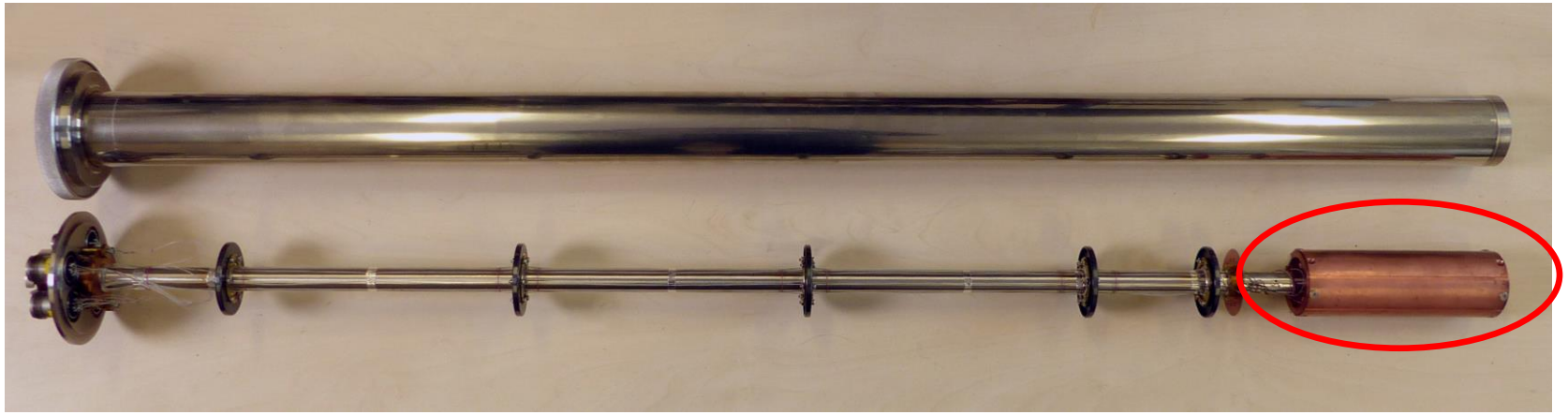
Institute of Scientific Instruments of the CAS

Brno, Czech Republic

Apparatus for testing thermal conductivity (λ) at low temperatures

Apparatus designed and developed earlier at ISI Brno: λ of metals:
Hanzelka et al. Thermal conductivity of a CuCrZr alloy from 5 K to room temperatures Cryogenics. 2010, vol. 50 (11-12), pp. 737-742.



Standard measuring process:

- Sample preparation, fixing in meas. chamber.
- Evacuation of Stainless-Steel casing with the apparatus, placing into LHe.
- *T* monitoring and setpoints using temperature controller Lake Shore 340.

Measurement of thermal conductivity – apparatus

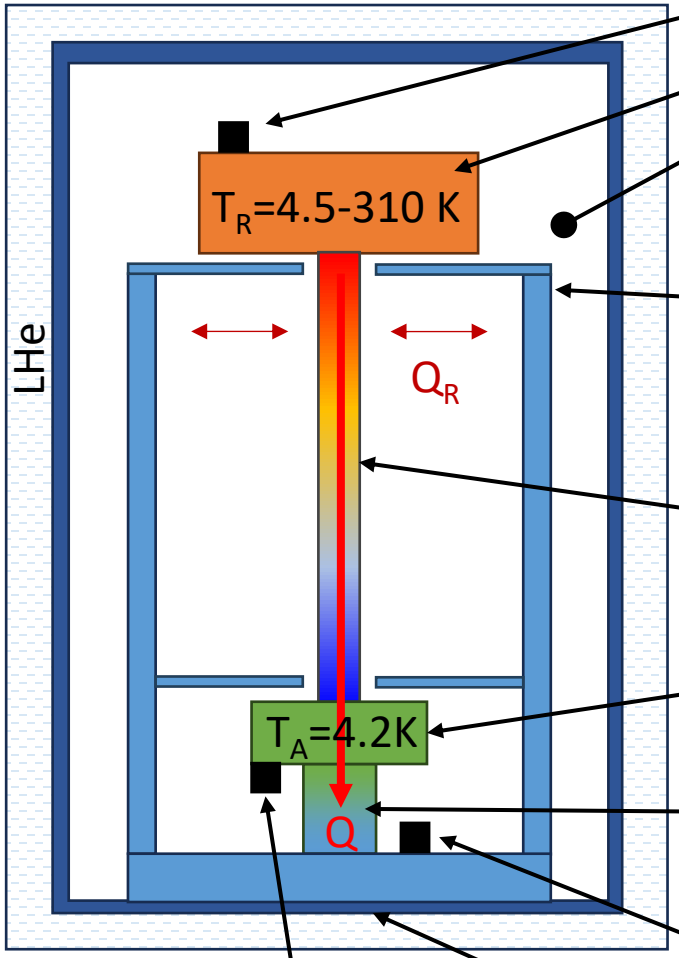
- The thermal conductivity integral $K(T_A, T_R)$ [W/m]; calculated from the sample T_R and T_A, the sample dimensions l and A and the heat flow Q (previous calibration of a heat flow meter at the bottom):

$$K(T_A, T_R) \equiv \int_{T_A}^{T_R} \lambda(T)\,dT = Q\frac{l}{A}$$

  By differentiation of $K(T_A, T_R)$ by T_R we can get the thermal conductivity **λ**(T).

- T_R : 4.5 ÷ 310 K (app. -269°C ÷ +37°C)

- Several upgrades – also possible testing of non-metallic samples



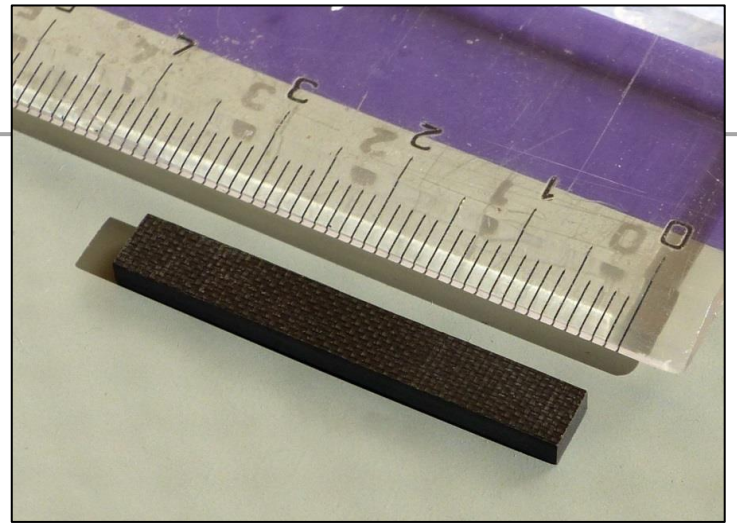
T_R SENSOR
HEATER
VACUUM
IZOTHERMAL CELL
(Cu + absorbing layer);
T_C = 4.2 K; $\varepsilon_C \approx 1$
SAMPLE
ABSORBER
CALIBRATED
THERMAL RESISTOR
T_B SENSOR
T_A SENSOR
CASING TUBE

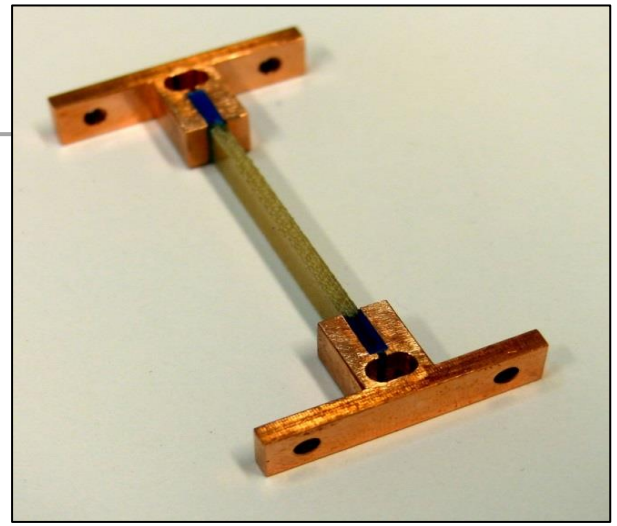
Samples

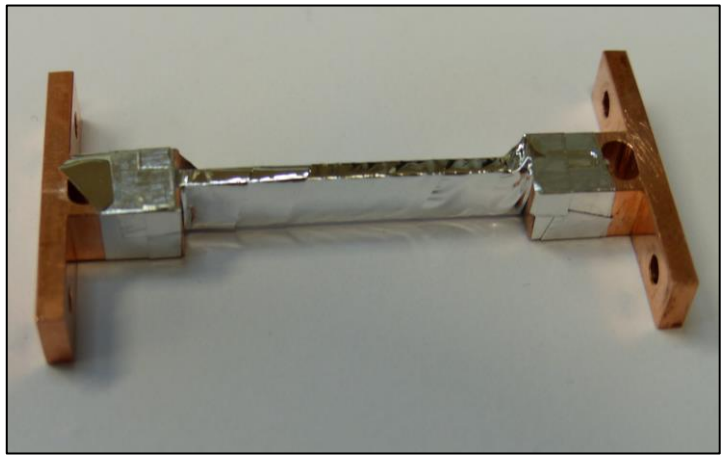
- Composite samples – typical dimensions approx.:
  L: 30 ÷ 60 mm
  W: 5 mm
  H: 2 mm

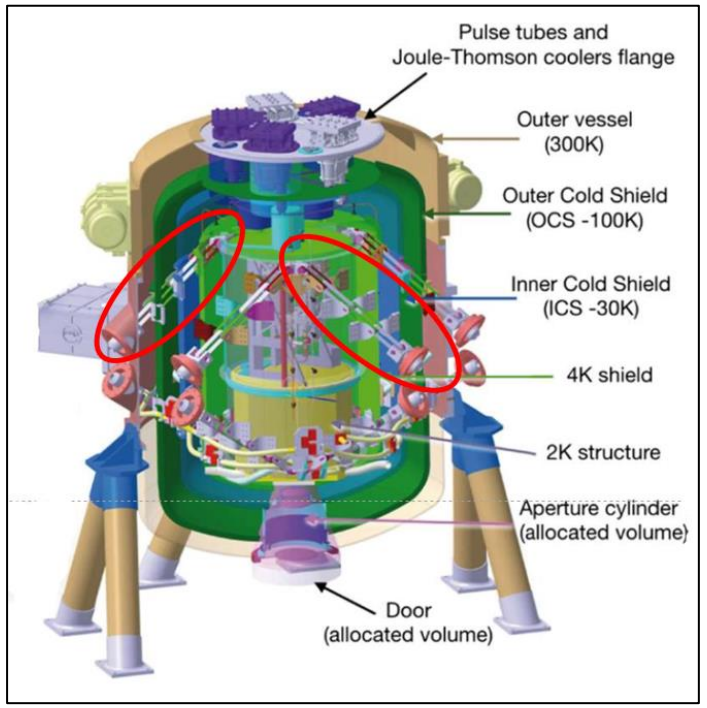
- The sample bonded with thermally conductive epoxy (Stycast 2850 FT) to copper flanges.

- In case of higher T_R (> 100 K / -173 °C): sample shielded by thin double aluminized mylar foil (very low λ).









Project CRYSA – CRYostat Straps for Athena: Choice of optimal composite for cryostat fixation inside the space probe.

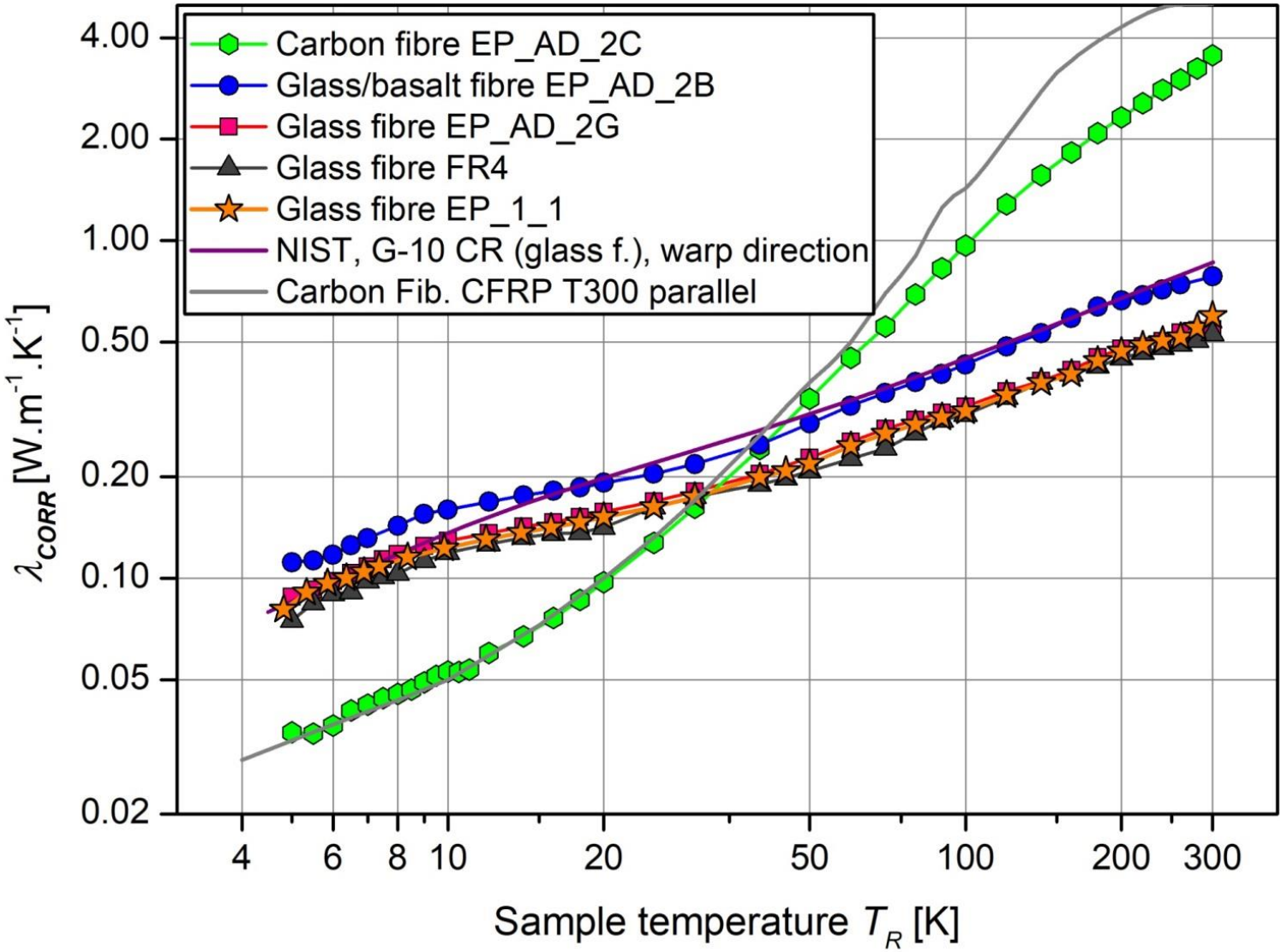
Examples of measured λ - composite materials (reinforced by glass or carbon)

- Curves with symbols: measured samples by our method
- Plain curves: references for similar materials

Reference G-10: National Institute of Standards and Technology - Material Measurement Laboratory: Properties of solid materials from cryogenic- to room-temperatures.

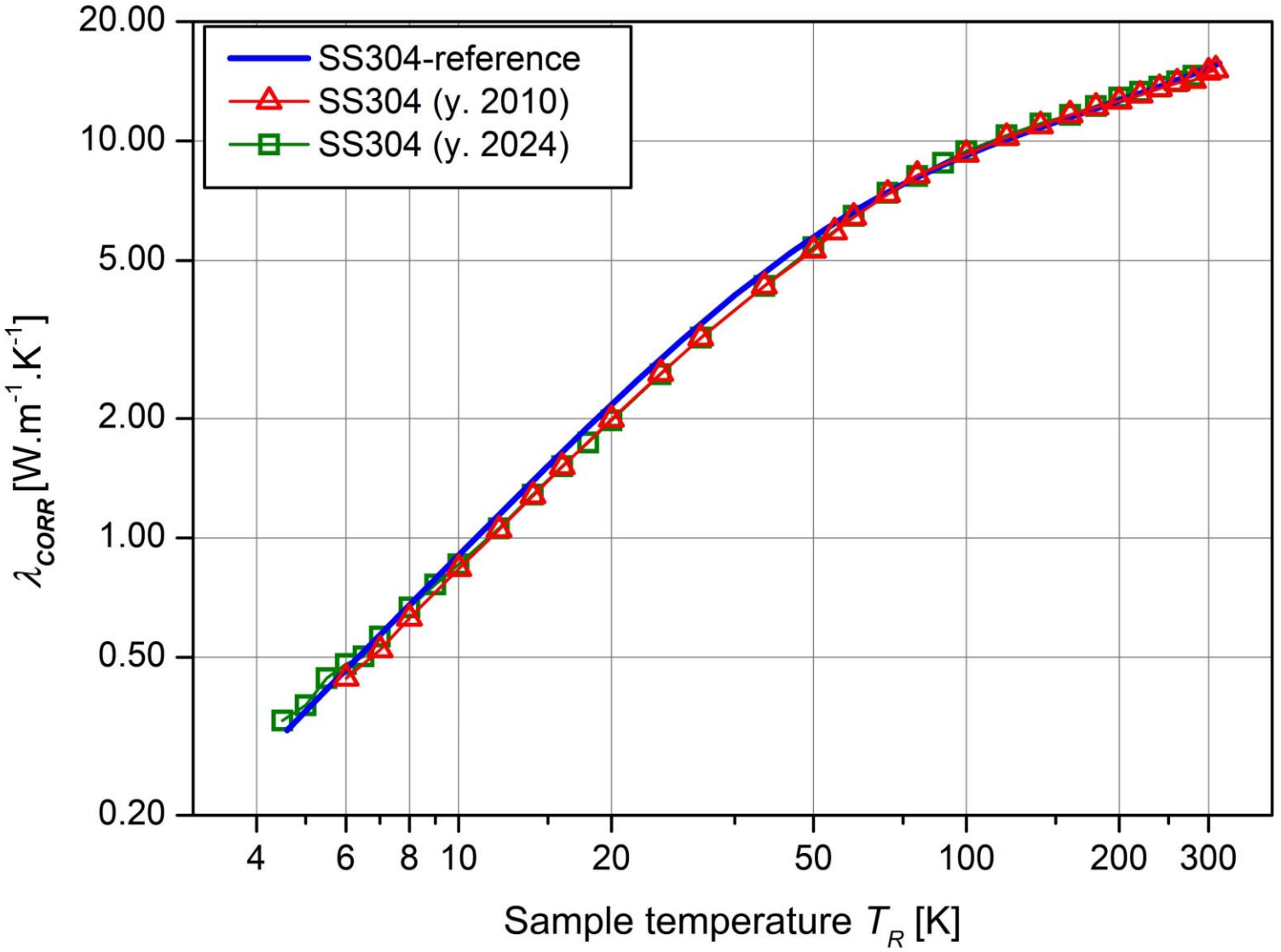
Reference CFRP: CRYOCOMP software / Thermal design of the CFRP support struts for the spatial framework of the Herschel Space Observatory. P.C. McDonald, E. Jaramillo,B. Baudouy.

Tested samples provided and published in collaboration with:
Krzak et al. Cryogenics, Volume 145, 2025 (Article: 103995).



Examples of measured λ - stainless steel

- Rod of stainless steel 304.
- Dimensions: 2 mm x 43 mm.
- Soldered to the copper flanges.
- Tested in the modified apparatus.
- High repeatability of λ.



Ref: Properties of selected materials at cryogenic temperatures. National Institute of Standards and Technology.

Conclusions

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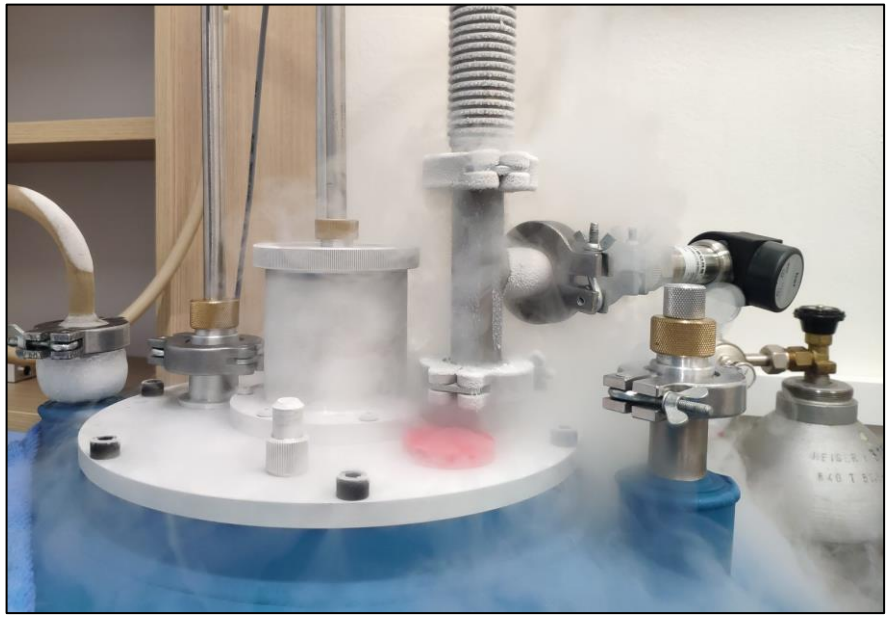
- Cryogenic apparatus for measurements of thermal conductivity (λ).
- Suitable for testing low-λ samples (e.g. fibre-reinforced composites) as well as metallic materials (high λ).
- Wide temperature range (hot end):

  4.5 ÷ 310 K (approx. -269°C ÷ +37°C).
- Testing of λ - application:

  Cryostats design or new materials for the space industry.



Thank you for your attention!

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