Performance test of a G-M cooler in magnetic field

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- Experimental Setup
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2nd stage temperature (Heater power, magnetic field)

Magnetic field limit: abnormal operation of coldhead

Ratio: Cooling power (Field) / Cooling power (without field)

- Summary

Performance test of a G-M cooler in magnetic field. Motivation and background

Motor Area:
Limit: <50-70 mT [1], [2], [3]
30-50 mT – reduce service life [3]
Recommended by SHI: <30 mT [3]

2nd stage regenerator:
Performance degradades at magnetic field above: 1 T [2] or 1.5 T [1]

Displacer:
Parallel <150 mT [1]
Perpendicular < 50 mT [1]

[4] the RDK-415 coldhead is operated at a position where the stray magnetic field is lower than 300 mT.

These limitations strongly affect the cryogen free magnet design

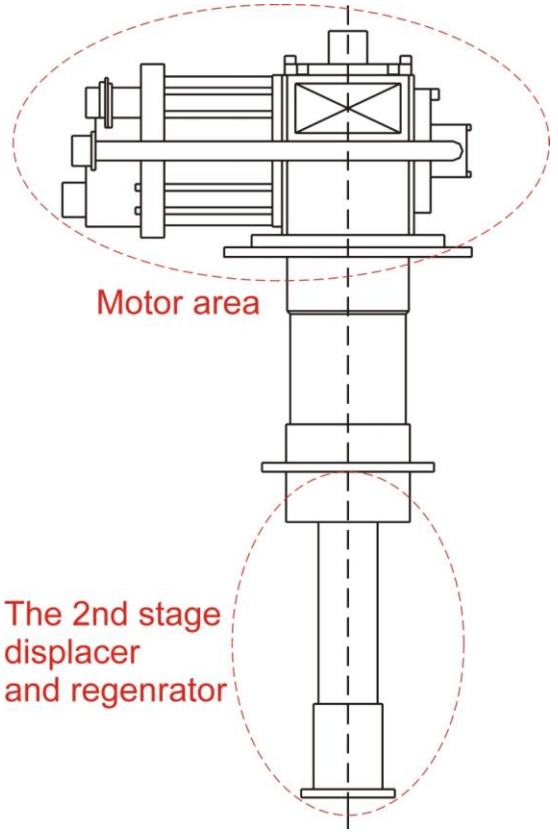

Fig.1 SHI RDK-415 coldhead

The goal of this work: to measure the performance G-M cooler in magnetic field and to determine the magnetic field limit for the second stage region.

[1] M. A. Green, et. al., 2008, The Effect of Magnetic Field on the Position of HTS Leads and the Cooler in the Services Tower of the MICE Focusing Magnet, IEEE Transactions on applied superconductivity, V. 18, NO. 2, 1147-1450
[2]Y.S. Choi et. al., 2009, Cryocooled Cooling System for superconducting magnet, Cryoccolers 15, pp. 665-670
[3] R. Frost, SHI, private communication on magnetic field limit for G-M coldhead
[4] Q. Wang, et. al., 2008, Design of Superconducting Magnet for Background Magnetic Field, IEEE Trans. on appl. Supercond., V. 18, NO. 2, 548-551

Performance test of a G-M cooler in magnetic field. Experimental setup

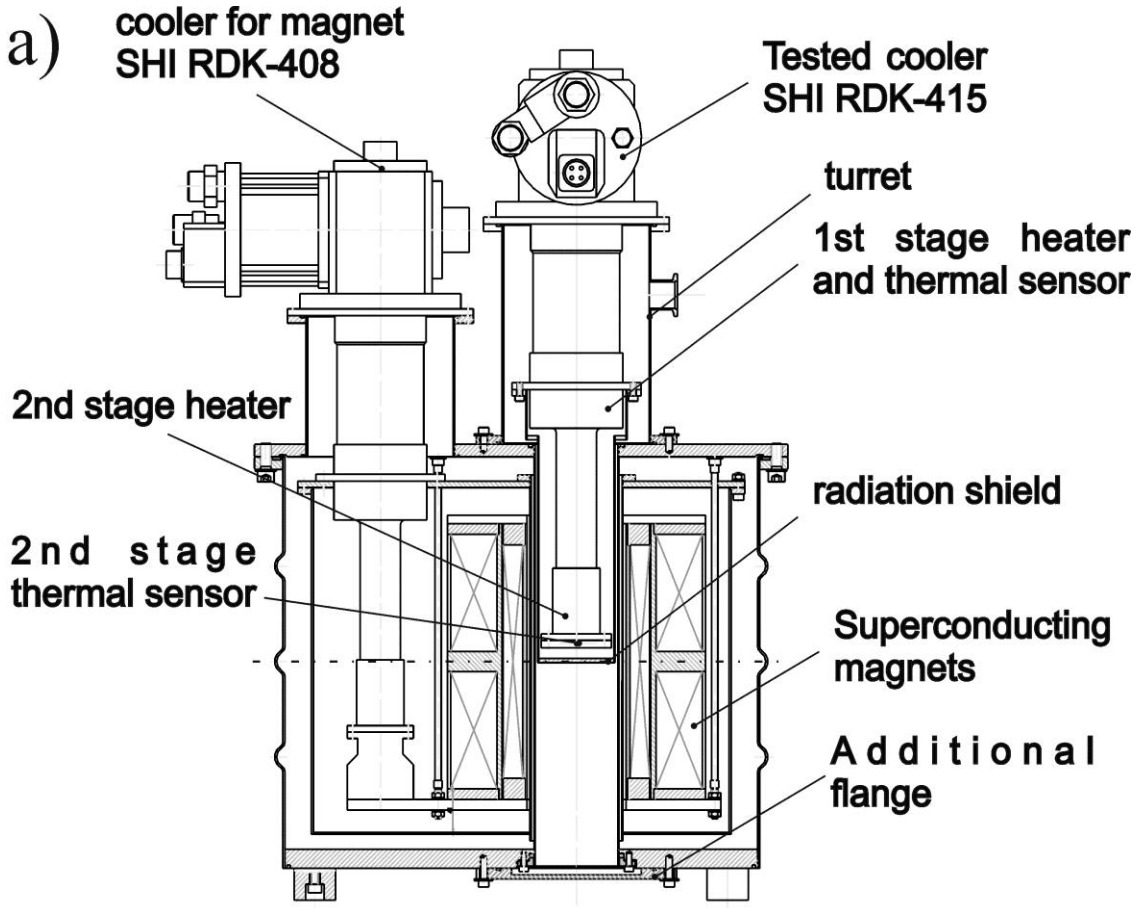

Fig.2 Experimental setup scheme and photo

Performance test of a G-M cooler in magnetic field. Experimental setup

Fig.3 Tested cooler

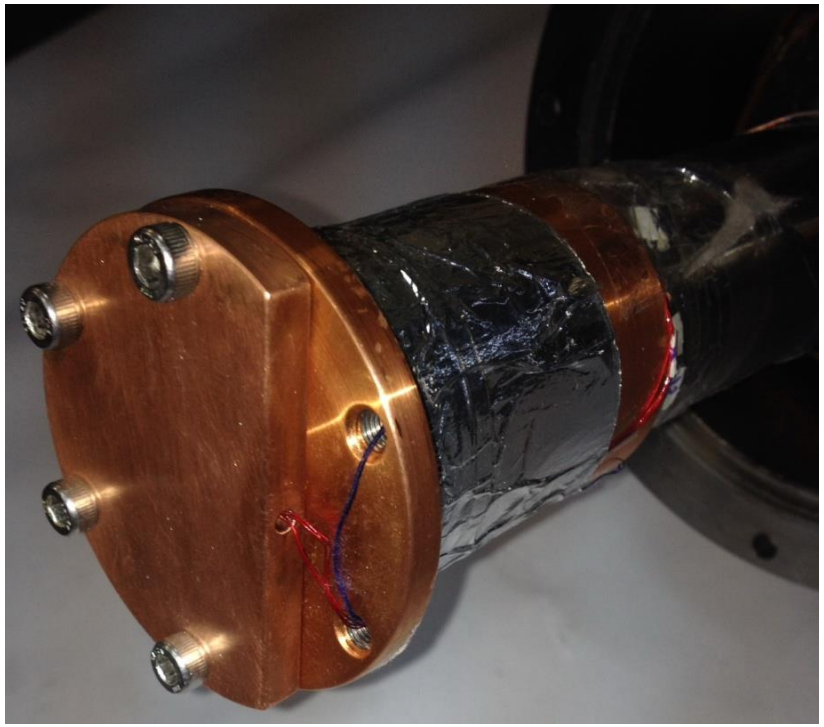

Fig.4 The 2nd stage with thermal sensor and heater

Heaters: Manganin wire. Additional voltage taps for precise measurement

The 1st stage: TVO thermal sensor

No magneto resistance > 5K at 2 T (Y.P. Filippov, 2010 ,How to find magneto-resistance of TVO temperature sensors in the range 0.1–10 K, Cryogenics 50, 243–247)

The 2nd stage: Cernox™ 1050-AA-1.4L

temperature error 10 mK for 3-6 K in 2 T (B.L. Brandt and D.W. Liu, 1999, Low temperature thermometry in high magnetic fields. VII. Cernox™ sensors to 32 T, Review of scientific instruments Vol.70, No. 1, 104-110)

Performance test of a G-M cooler in magnetic field. Test results

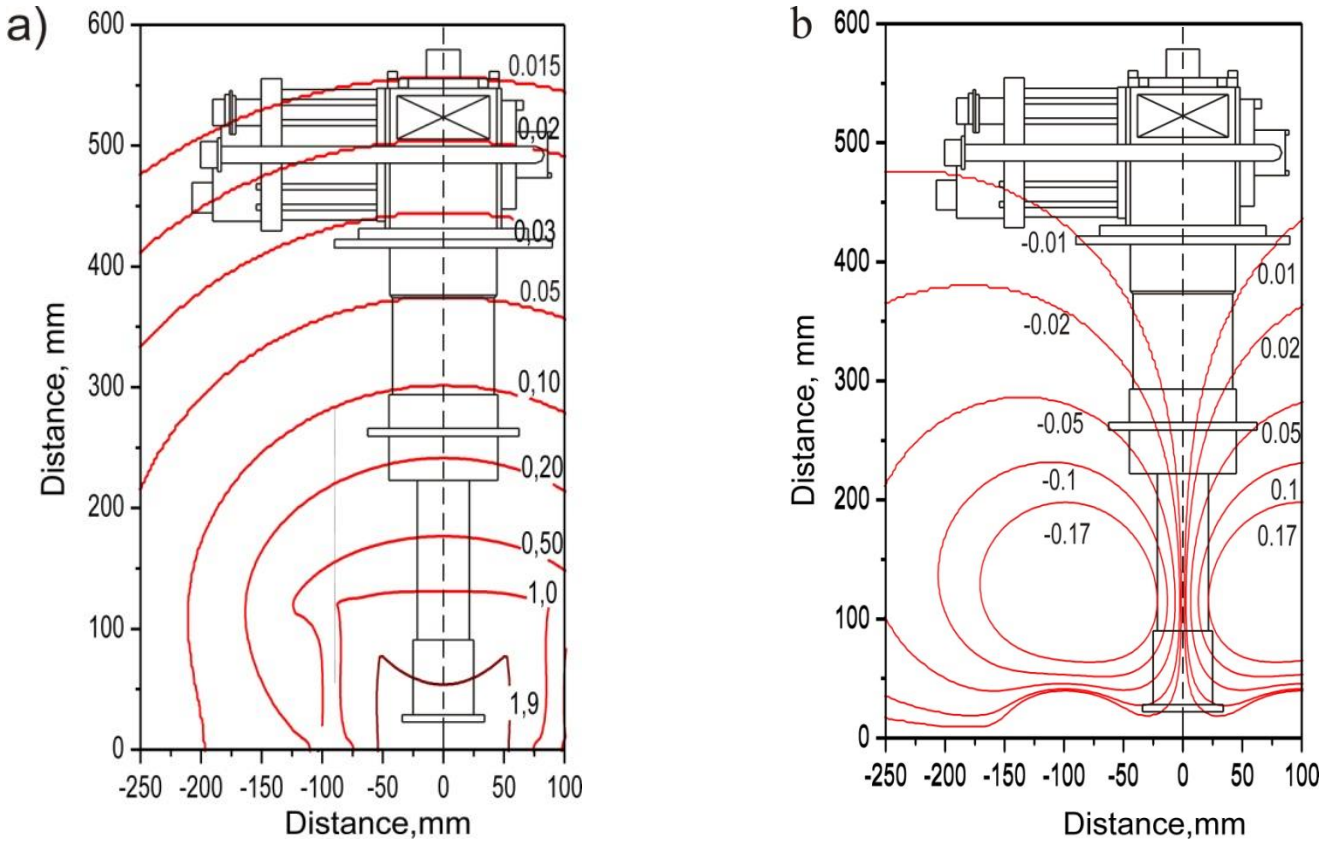

Fig.5 (a) magnetic induction distribution, (b) perpendicular to the coldhead axis magnetic field

abnormal sound at central magnetic field higher than 1.95 T:

Magnetic field: < 35 mT for the motor, 40-150 mT between vacuum flange and the 1st stage flange
150mT-2 T between the 1st and 2nd stage flanges
Perpendicular field on the 2nd stage displacer tube up to 170 mT

Performance test of a G-M cooler in magnetic field. Test results

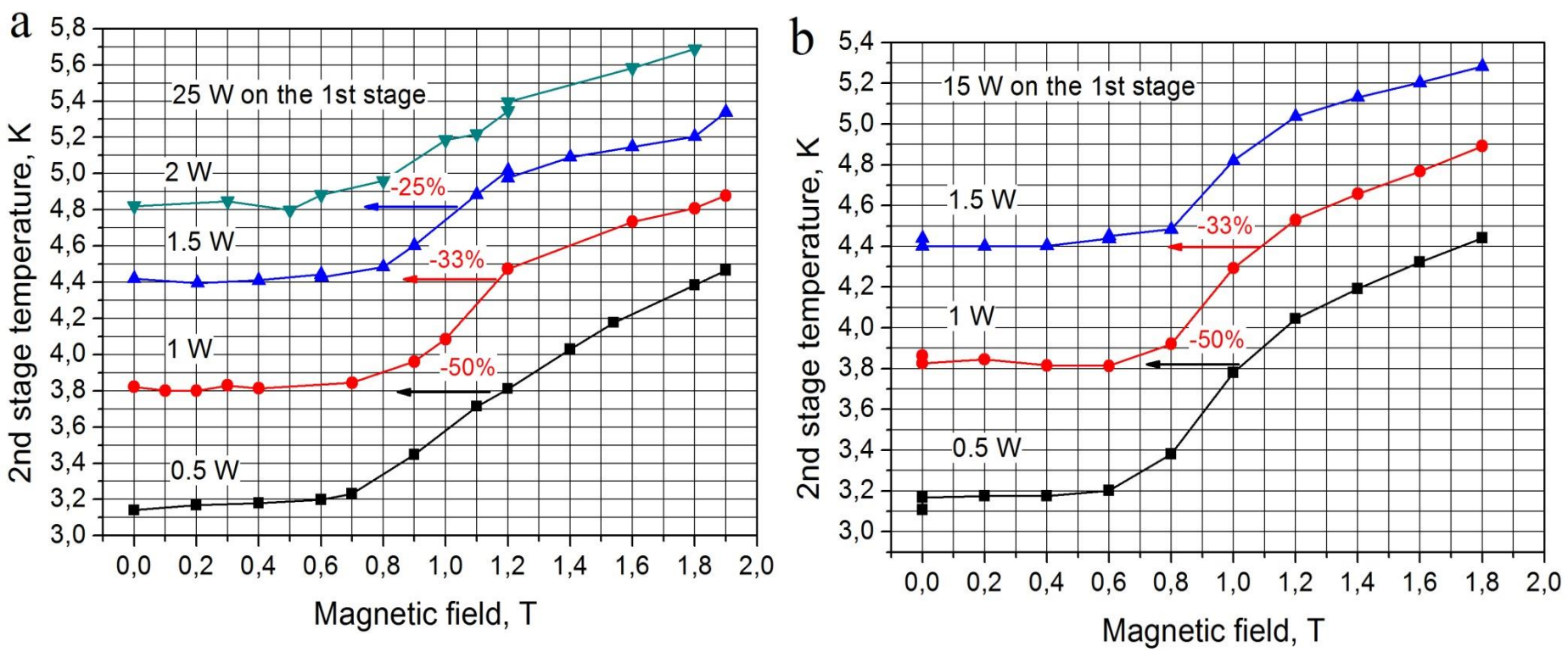

Fig.6 Dependence of the 2nd stage temperature on induction of magnetic field at heater power on the 1st stage of 25 W (a) and 15 W (b).

2nd stage temperature fluctuates with peak to peak value of up to 0.65 K. Temperatures on graphs are averaged values.

Performance test of a G-M cooler in magnetic field. Test results

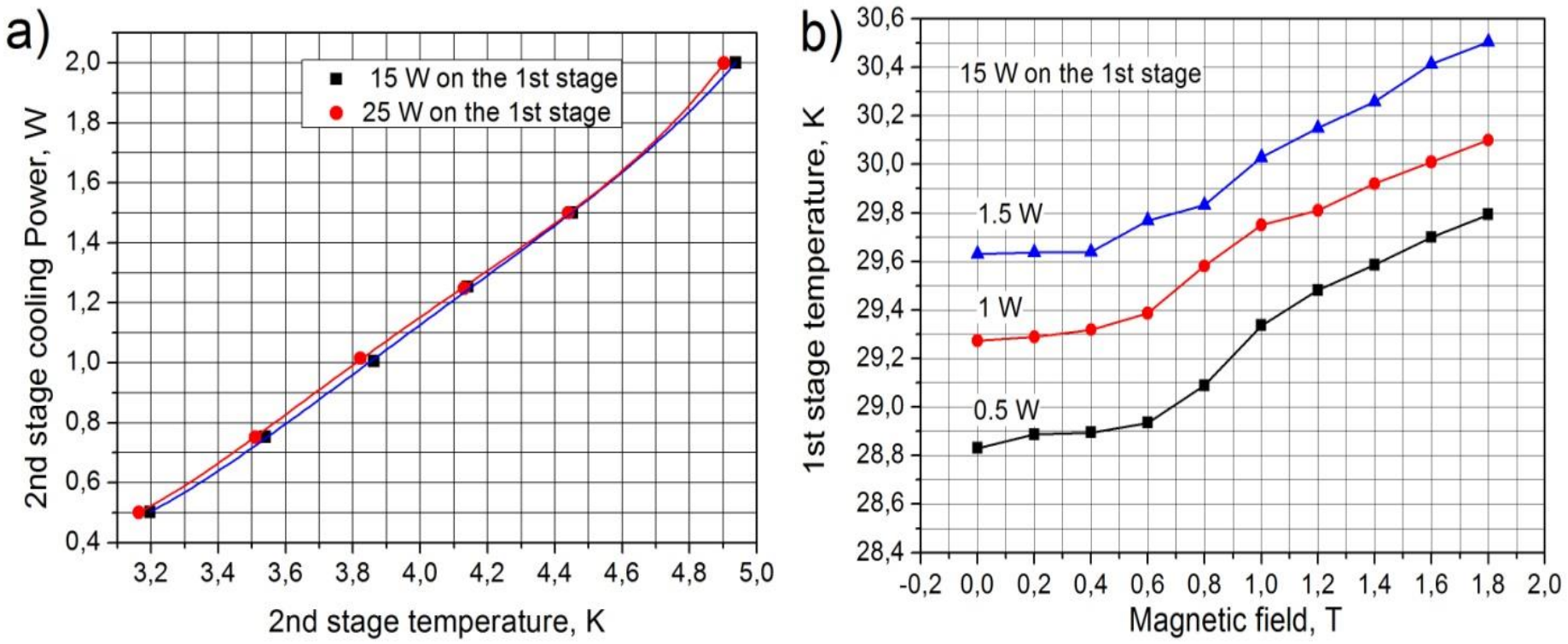

Fig.7 (a) The 2nd stage heater power as a function of the 2nd stage temperature at zero magnetic field;
(b) Dependence of the 1st stage temperature on magnetic induction at heater power on the 1st stage of 15 W.

The 1st stage temperature increased on 0.7-1.0 K in 1.8 T

Performance test of a G-M cooler in magnetic field. Test results

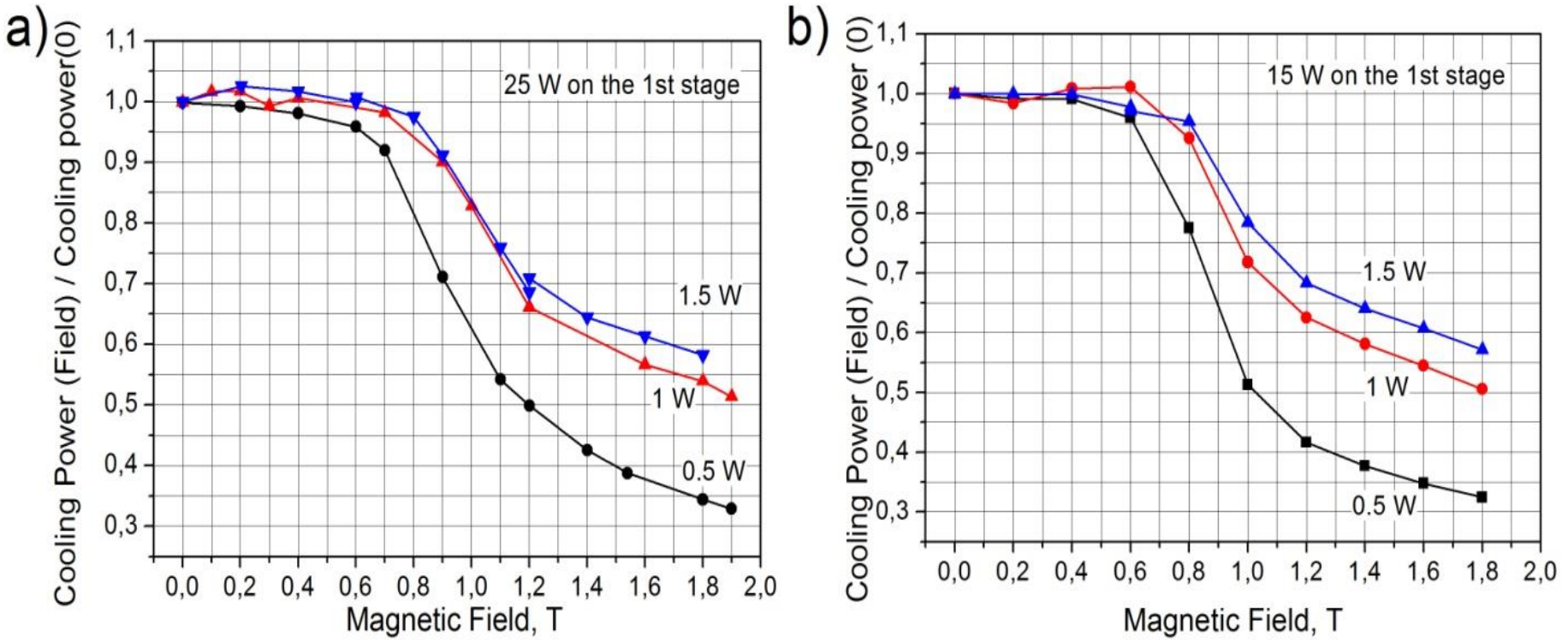

Fig.8 The ratio of the 2nd stage cooling power in magnetic field to cooling power in zero field at the same temperature for the 1st stage heater power of 25 W (a) and 15 W (b).

Cooling power reduction: 22%-49% at 1.0 T an 43%-68% at 1.8 T for the heat load of 0.5-1.5W.

Performance test of a G-M cooler in magnetic field.

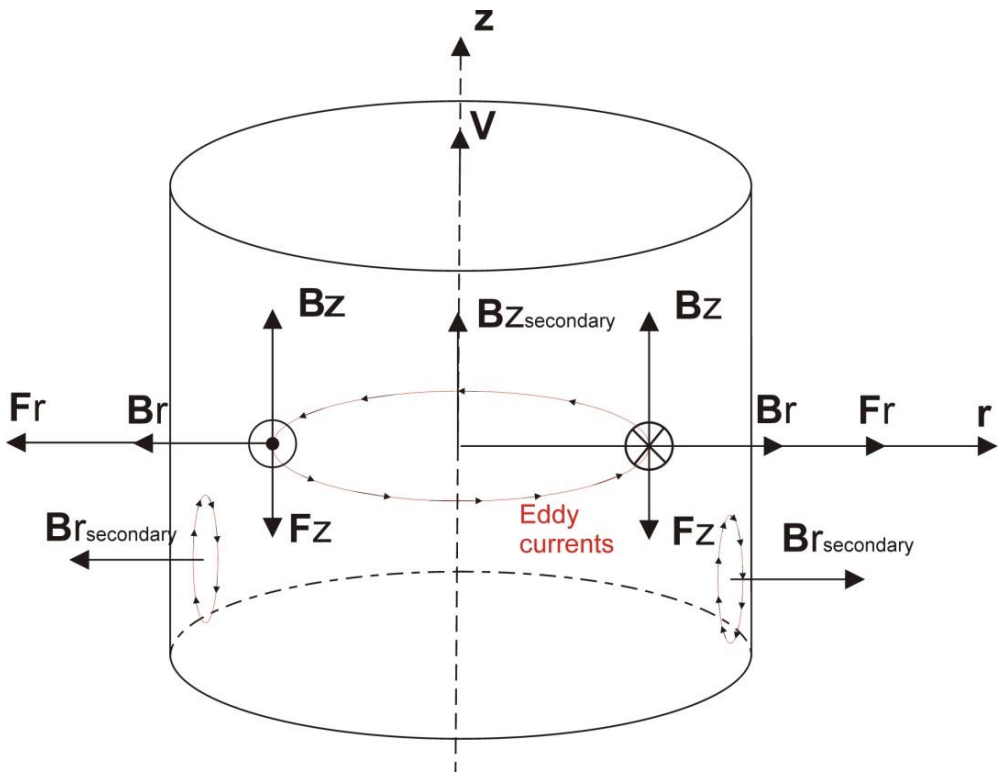

Fig.9 Simple electrical model of displacer

1. Displacer moves up

2. Decrease of magnetic fluxes through top, bottom and side surfaces.

3. Eddy currents according to the Lenz's law to maintain the flux

4. Interaction of eddy currents with magnetic field **F**=[**I**,**B**]*L

Total radial force =0 due to ax symmetry

Total axial force: non zero, opposite to the displacer motion ~ Br

Summary.

Cooling power of coldhead decreases for 22%-49% at 1.0 T and 43%-68% at 1.8 T for 0.5-1.5W heat load

Practically no reduction of cooling power for magnetic field up to 0.6 T (0.05 radial component)

Long term operation at 0.6 T require additional tests.

Abnormal operation at 1.95 T axial and 0.17 T radial magnetic field

Please note! The long term operation of the coldhead in magnetic field may have a detrimental effect on service life.

Thank you for the attention.