Development of a Thermal Conductance Instrument for Nb at Cryogenic Temperatures

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Thermals influence achievable fields

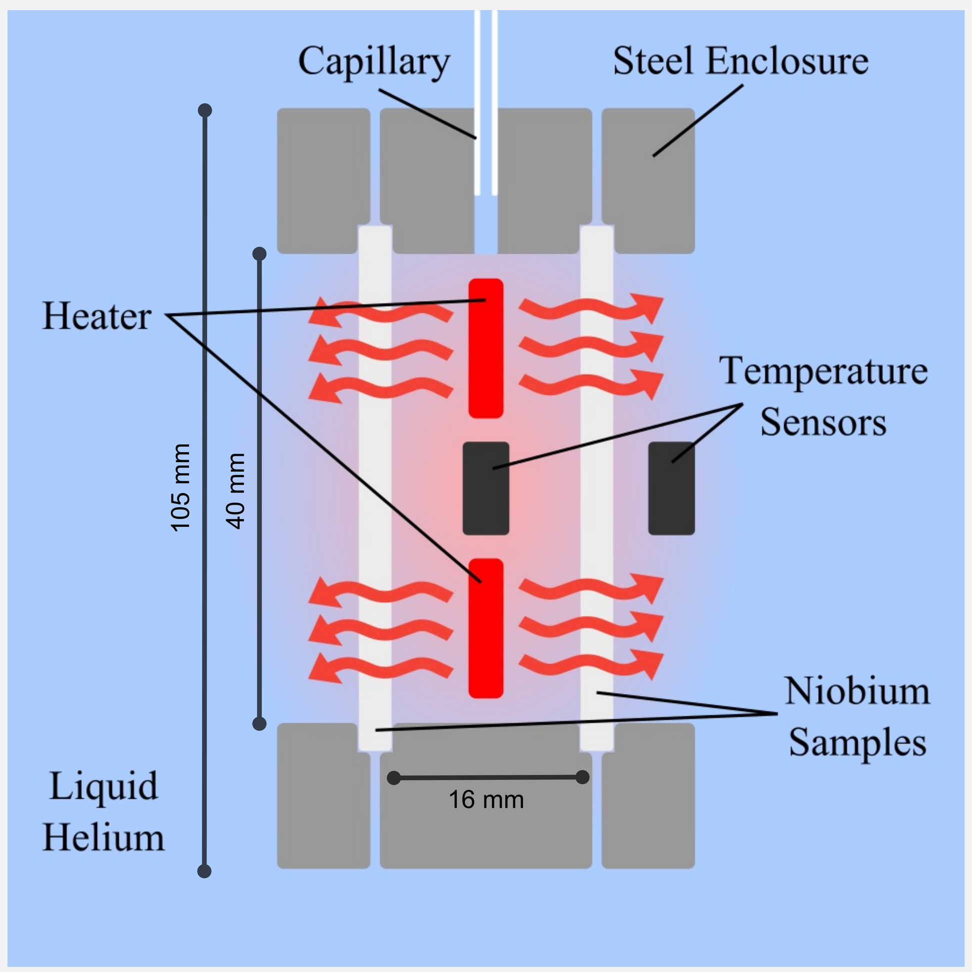
- **we want to achieve higher quality factor for higher fields, cheaper accelerators and lower operation costs**
- interaction between rf field and normal conducting electrons on inner surface of cavity walls generates Joule-heating, increasing temperature and limiting quality factor
- heat needs to be carried out of cavity as freely as possible
- thermal resistance, R, determines cavities response to surface heating

Fourier's Law

$$q = -k\frac{dT}{dx}$$

measure thermal properties with **Niobium Thermal Conductance Instrument (NTCI)**

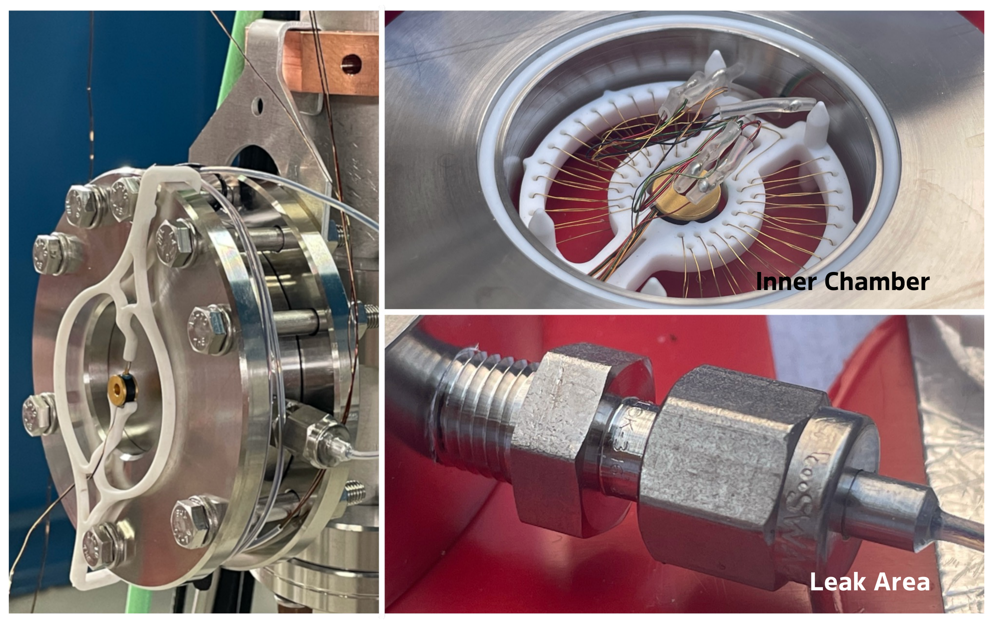
- **we need to find out how standard and advanced cavity treatments affect thermal behavior**
- measure the combined effect of thermal resistance of bulk niobium and helium-niobium-interface [1]



Schematic view of NTCI

Heat is lost intrinsically

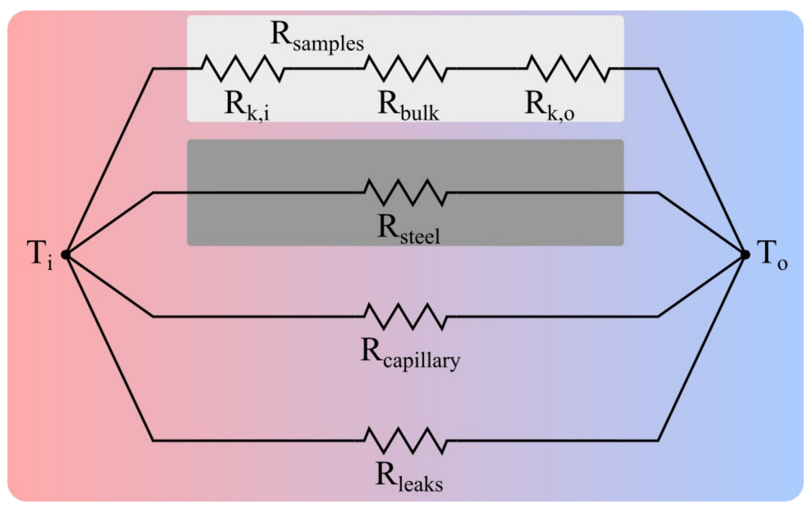
- **filling line capillary: < 5%**
- **stainless steel enclosure: <0.5%**
- **copper wires of inner electronics: <0.1%**



Images of NTCI

Additional losses through leaks compensated with empirical fit

- **thermal resistance increases with heating power**
- resistance increase can be explained by **microscopic leaks**
- at high heat flux (Gorter Mellink regime) mutual friction between normal und superfluid component decreases leak activity [2]
- **view heat flow paths as parallel resistances** to obtain thermal resistance of samples



Resistance picture of heat flow paths

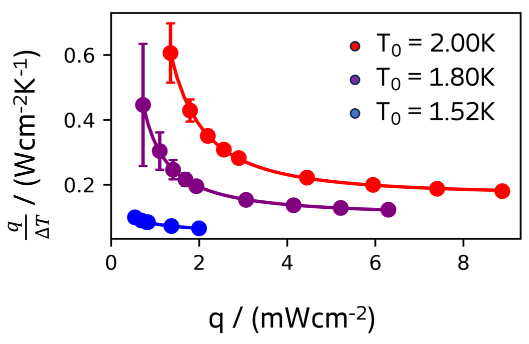
- neglect filling line capillary and stainless-steel enclosure
- switch to **conductance picture**

$$q/\Delta T = K_{samples} + aq^{-n}$$

conductance of sample — empirical fit for conductance of leaks

Fitting results

- convergence at large heat fluxes
- obtained n is smaller than 3, which is expected for liquid helium in cylindrical capillaries[3] → **slit-shaped leaks not directly comparable to cylindrical capillaries**
- slight changes in screwed connection in-between cool downs influence a and n → **leaks expected to lie in screwed connection**

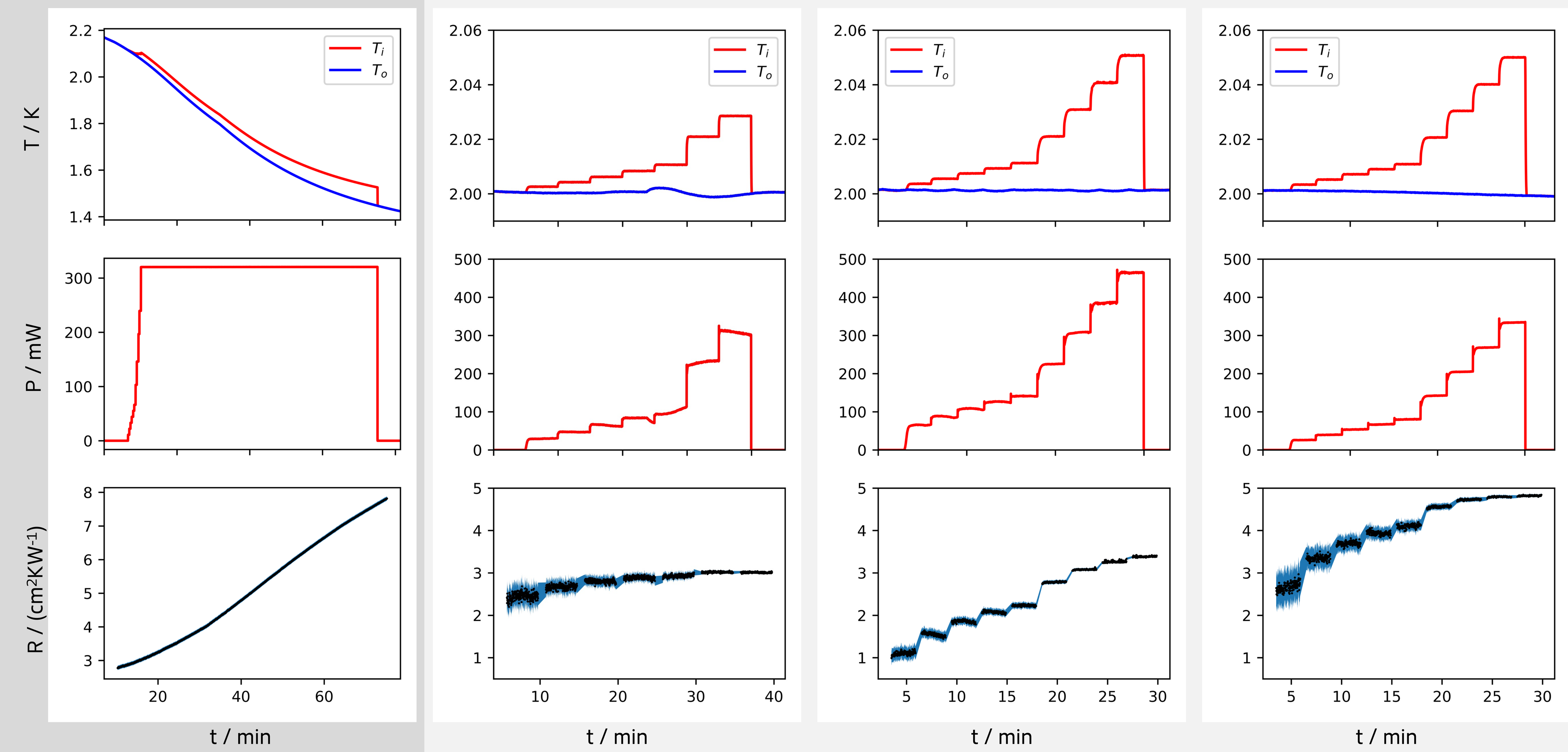


Conductance fit post BCP 2 + baking 2

Cool Down #	2.00 K		1.80 K	
	a	n	a	n
4	0.74	1.77	0.23	1.31
5	2.14	1.72	1.21	1.69
6	0.14	1.25	0.09	1.26

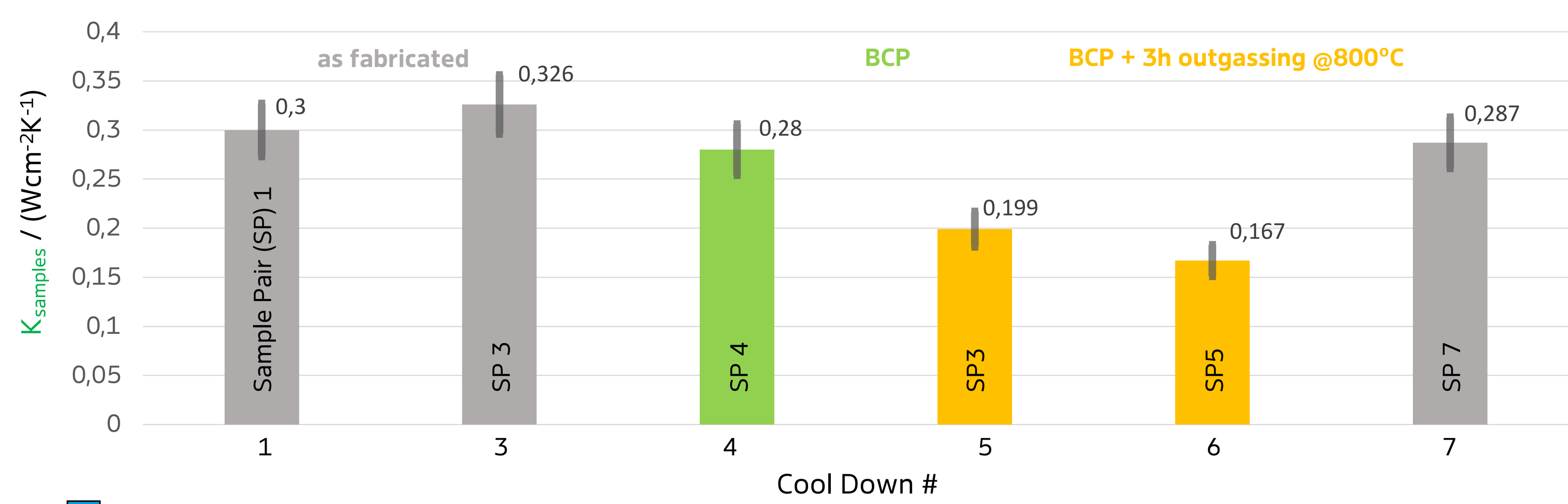
Leak fit parameter values for cool down 4, 5 and 6

A qualitative thermal resistance overview is gained by varying cryostat temperature and more precise values by varying heating power



As fabricated (Cool Down (CD) 3) Variable cryostat temperature | **As fabricated (CD 3) Variable heating power** | **Post 100 um BCP 2 (CD 5) Variable heating power** | **Post BCP 1 + baking 1 (CD 6) Variable heating power**

NTCI sensitive towards conductance changes post basic treatments



- **conductance reduction post BCP** could be due to hydrogen diffusing into surface of sample
- **further reduction in conductance post baking** not understood yet and needs further investigation

Reduce leaks & explore treatments

- continue applying gradual changes to screwed connection in-between cool downs to reduce leaks
- try out different mounting orientations in cryostat (e.g., such that screwed connection points upwards)
- tighten steel enclosure with different torques
- **investigate…**
  - conductance reduction post outgassing
  - fine chemical etching and annealing
  - nitrogen doping and infusion
  - SIS-multilayers

Samples & basic treatments

As fabricated, coarse (100um) buffered chemical polishing (BCP) and 3h outgassing @800°C

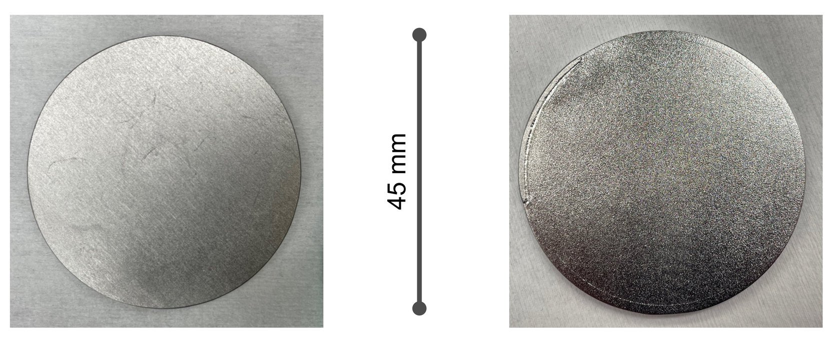


Image of sample post fabrication | **Image of sample post BCP**

[1] J. Amrit, M.X. François, Journal of Low Temperature Physics, 119, 27–40 (2000)
[2] S. W. Van Sciver, "Helium Cryogenics", Plenum Press, 143–144 (1986)
[3] F. Koechlin, B. Bonin, IOP Publishing Ltd, 9(6), 453 (1996)