COMMISSIONING OF A NEW SAMPLE TEST CAVITY FOR RAPID RF CHARACTERIZATION OF SRF MATERIALS

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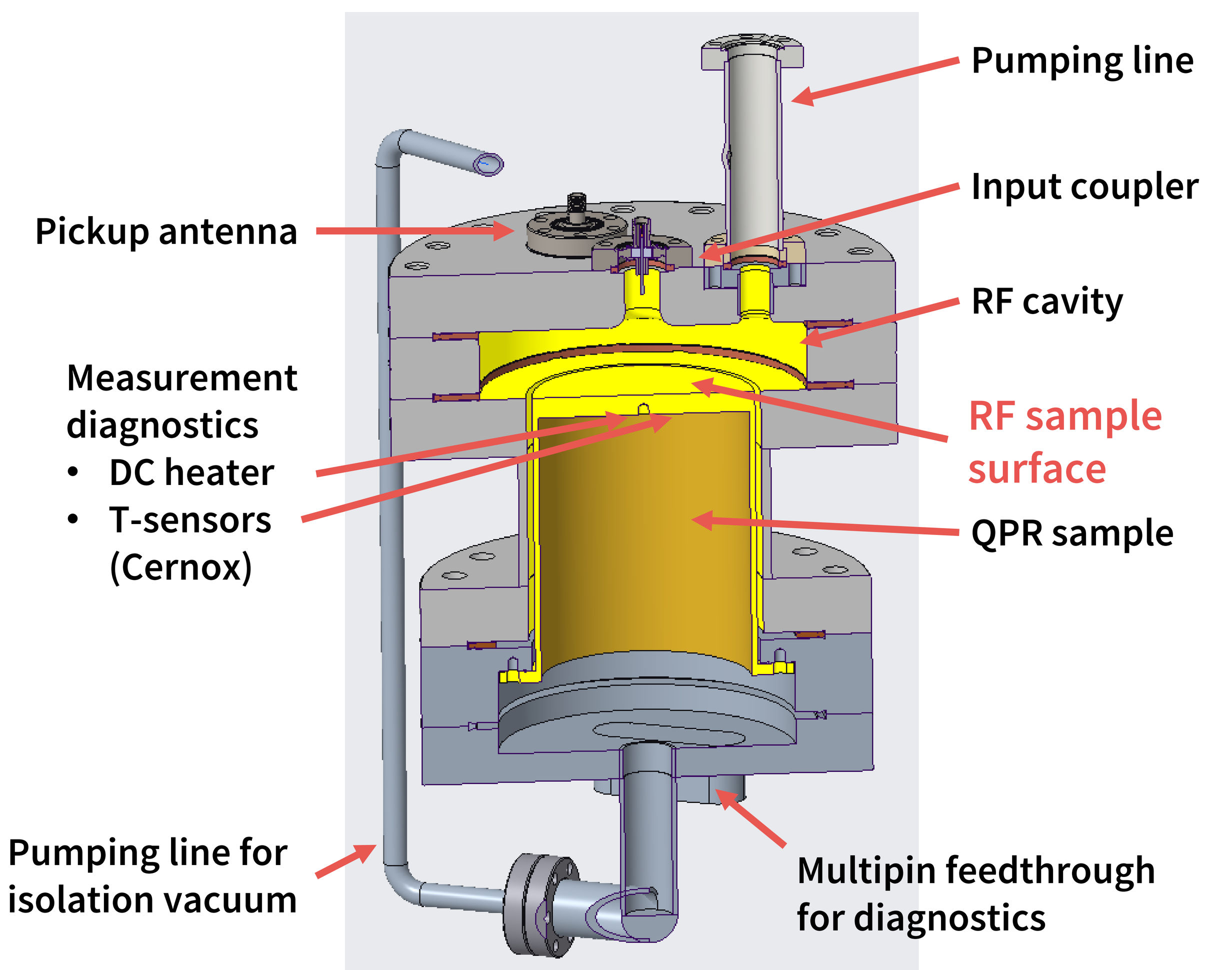
ABSTRACT: RaSTA, the Rapid Superconductor Test Apparatus, is a new sample test cavity that is currently being commissioned at HZB. It uses the established QPR sample geometry but with a much smaller cylindrical cavity operating in the TM_{020} mode at 4.8 GHz. Its compact design allows for smaller cryogenic test stands and reduced turnaround time, enabling iterative measurement campaigns for thin film R&D. Using the same calorimetric measurement technique as known from the QPR allows direct measurements of the residual resistance. We report first prototype results obtained from a niobium sample that demonstrate the capabilities of the system.

GOALS and REQUIREMENTS

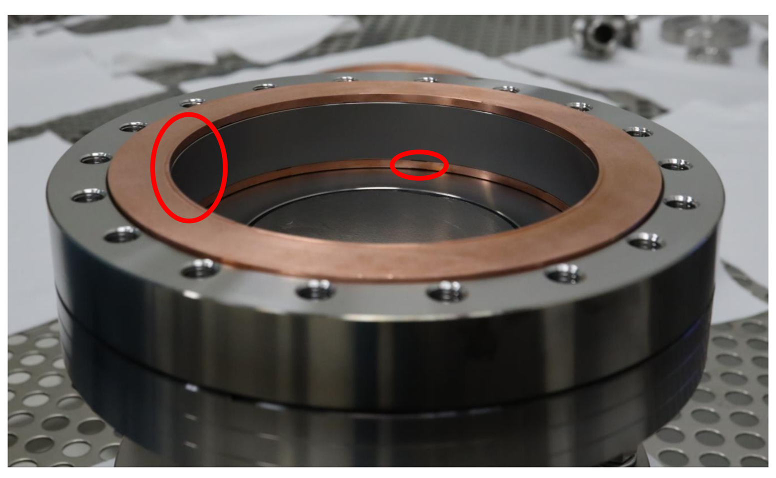
Thin-film R&D requires RF measurements of many samples, R_S is most important figure of merit
- Iterative optimization of coatings and procedures
- Most measurements just for „yes/no“ answers and monitoring of relative changes

Design criteria of RaSTA:
- Full compatibility to QPR samples
  Sample Ø = 75 mm, h = 85.5 mm
- Calorimetric measurement of R_S
- R_{BCS} low enough to measure R_{res}
- Higher throughput, > 1 sample per week
- Compact cavity, fit into 200 mm cryostat
- No radiation protection needed (V_{RF} max. few kV)

→ Fixed higher frequency and lower RF field are ok
→ Pre-testing of samples with RaSTA, use QPR for detailed studies



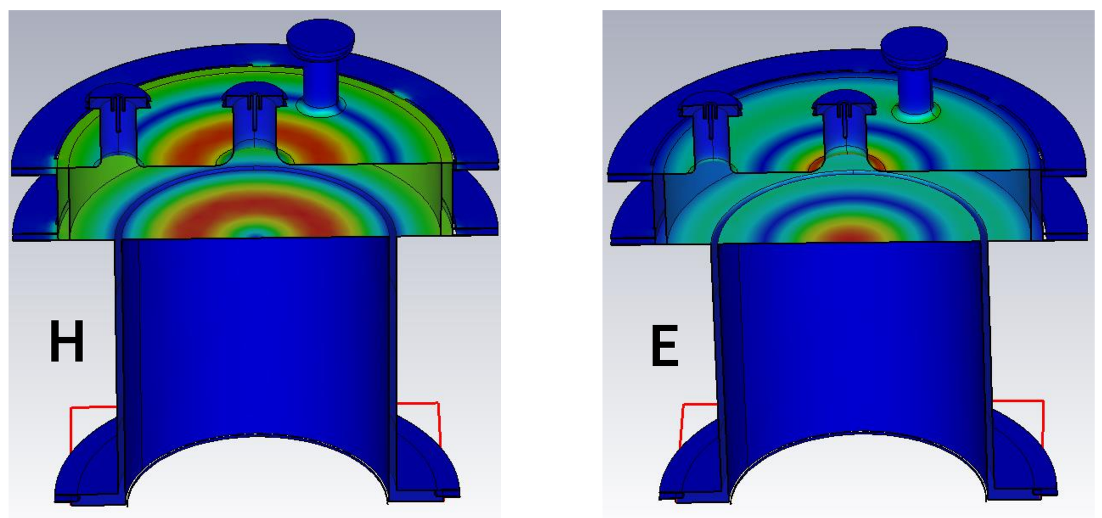
CAD cross section of the assembled cavity
- First prototype based on CF125 (quick production)
- Yellow: Niobium coating or bulk niobium
- 2 antennas
  - Center: Input coupler with critical coupling
  - Pickup coupler at second maximum of E-field
- Bottom part identical to QPR
  (sample, adapter flange, feedthrough, diagnostics)



- RF contacts at the inner edge of the gaskets provide a cylindrical cavity
- CF-125 sealing for leak tight cavity in superfluid LHe
- Small openings to evacuate dead volume near knife edge

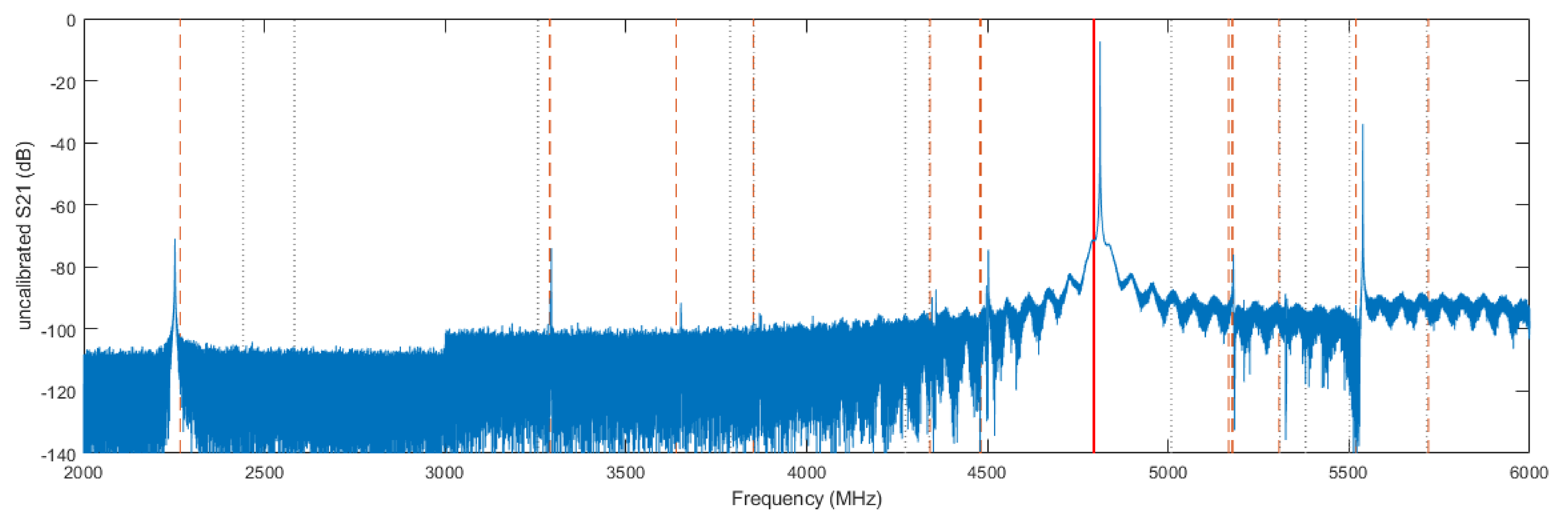
RF DESIGN

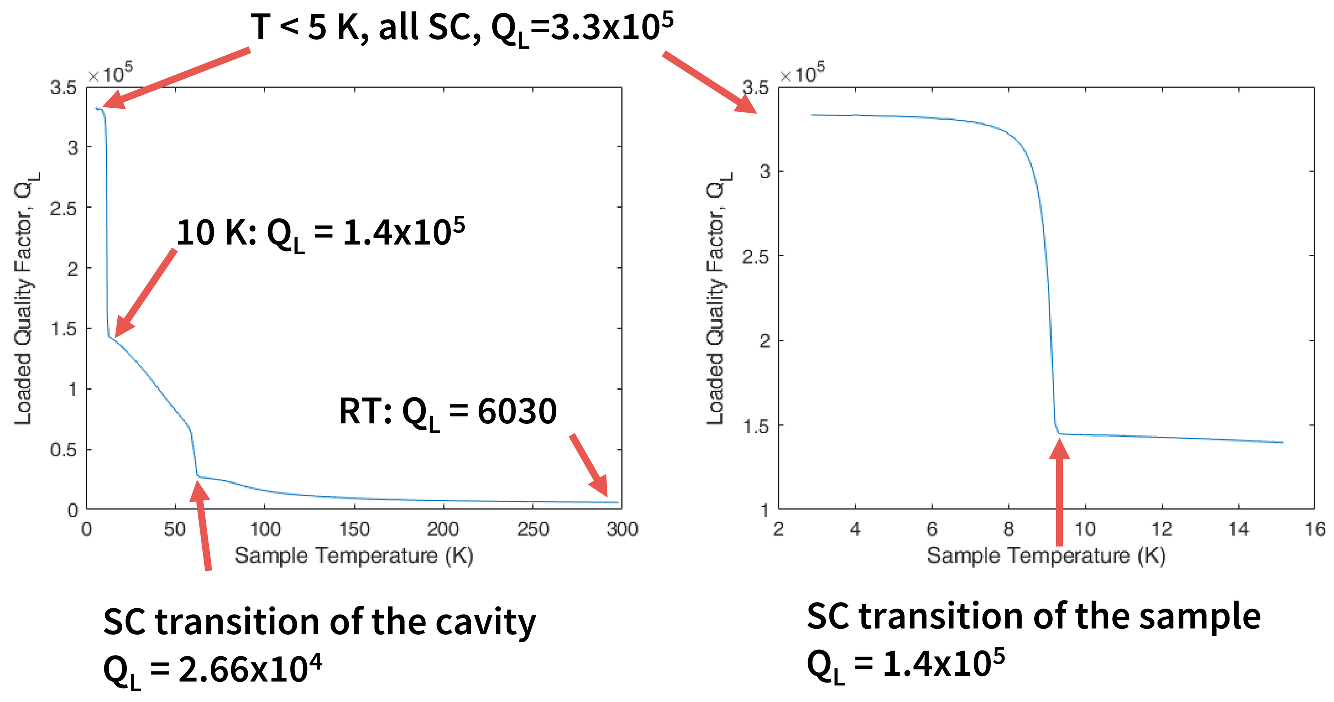
- TM_{020} mode at 4.8 GHz
- Zero-crossing of B-field allows to insert QPR sample
- Special gaskets needed for cylindrical cavity to suppress field enhancement at knife edges



MEASUREMENT RESULTS

VNA mode spectrum at 4 K
- Solid line:
  - Operational mode TM_{020}
  - Separation to next modes by more than 200 MHz
- Dashed and dotted lines: Simulated modes (CST)

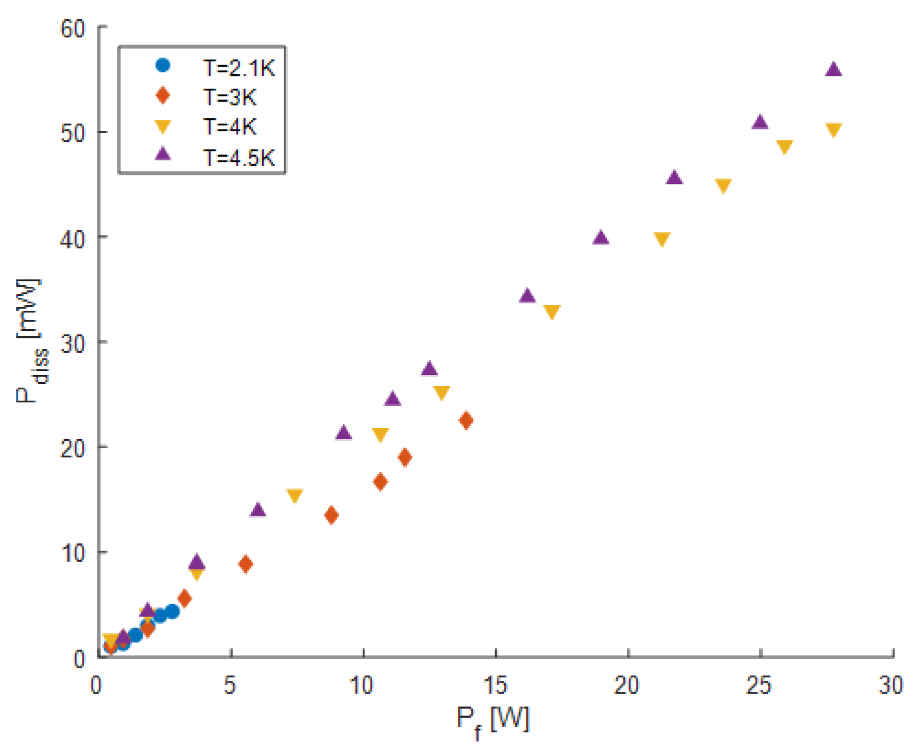




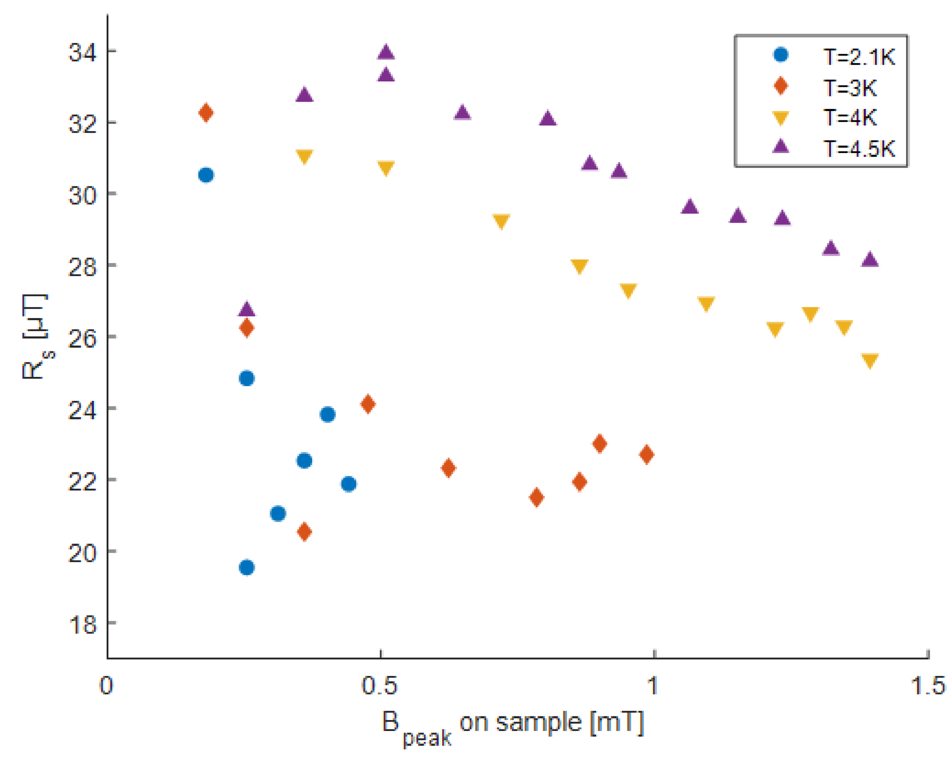
Q_L during initial cooldown (left) and thermal cycling of the sample only (right).
- In the under-coupled case $Q_L \approx Q_0$ allows to estimate the average RRR of the niobium parts

$$\mathrm{RRR} = \left(\frac{Q_{10\,\mathrm{K}}}{Q_{\mathrm{RT}}}\right)^2 = \left(\frac{26630}{6030}\right)^2 = 19.5$$

- For T < 9.2 K the cavity Q_0 is dominated by the copper gaskets
- Q_0 lower than expected (1.4x10^6) led to under-coupled input antenna ($\beta \approx 0.05$)



RF dissipation measured on the sample vs. forward power travelling to the cavity.



Surface resistance vs. RF field on sample for different sample temperatures. High uncertainties due to under-coupled input antenna. Offset approx. 22 μΩ.

CONCLUSION

- Rapid Superconductor Test Apparatus (RaSTA) as new sample test cavity for QPR samples at 4.8 GHz with reduced turnaround times
- First prototype results verify mode spectrum and calorimetric measurement of R_S, approx. 22 μΩ offset independent of temperature

OUTLOOK

- Adjust input coupling for $\beta \approx 1$
- Study parasitic losses with Nb coated flange

REFERENCES

[1] S. Keckert and O. Kugeler, „Vorrichtung zur Ermittlung von Oberflächenwiderständen,“ German Patent DE 10 2021 123 261, Sep. 08, 2021.

[2] S. Keckert, R. Kleindienst, O. Kugeler, D. Tikhonov, and J. Knobloch, “Characterizing materials for superconducting radiofrequency applications – a comprehensive overview of the quadrupole resonator design and measurement capabilities,” *Rev. Sci. Instrum.*, vol. 91, no. 6, p. 064 710, 2021

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