# RF uncertainties and surface resistance

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# QPR Cheat Sheet

HZB Helmholtz Zentrum Berlin

- Calorimetric measurement
  - Thermal equilibrium: T, $P_{DC}$, $P_{trans}$

$$B_{\text{Sample, pk}} = \sqrt{\frac{c_2 \cdot Q_t \cdot P_t}{\omega}}$$

$$P_{\text{diss}} = \Delta P_{\text{Heater}}$$

$$R_S = 2\mu_0^2 \cdot c_1 \frac{\mathrm{P}_{\text{diss}}}{\left(B_{\text{pk}}\right)^2}$$

- Penetration depth: T, Δf

$$\Delta\lambda = -\frac{G_{\text{Sample}}}{\pi\mu_0 f_0^2}\Delta f$$

# QPR Cheat Sheet

- Surface resistance and RF field

$$B_{\text{Sample, pk}} = \sqrt{\frac{c_2 \cdot Q_t \cdot P_t}{\omega}}$$

$$c_2 = \frac{\left(B_{\text{Sample, pk}}\right)^2}{U}$$

$$P_{\text{diss}} = \Delta P_{\text{Heater}}$$

$$R_S = 2\mu_0^2 \cdot c_1 \frac{\mathrm{P}_{\text{diss}}}{\left(B_{\text{pk}}\right)^2}$$

$$c_1 = \frac{\left(B_{\text{Sample, pk}}\right)^2}{\int_{\text{Sample}} |B|^2 \, \mathrm{d}S}$$

- Penetration depth: T, Δf

$$G_{\text{Sample}} = \frac{2\omega\mu_0^2 U}{\int_S |B|^2 \mathrm{d}S} = 2\omega\mu_0^2 \frac{c_1}{c_2}$$

$$\Delta\lambda = -\frac{G_{\text{Sample}}}{\pi\mu_0 f_0^2} \Delta f$$

$$f\,[\text{GHz}] = 50.4 \cdot G_{\text{Sample}} \frac{c_2}{c_1}$$

# Shape optimization results

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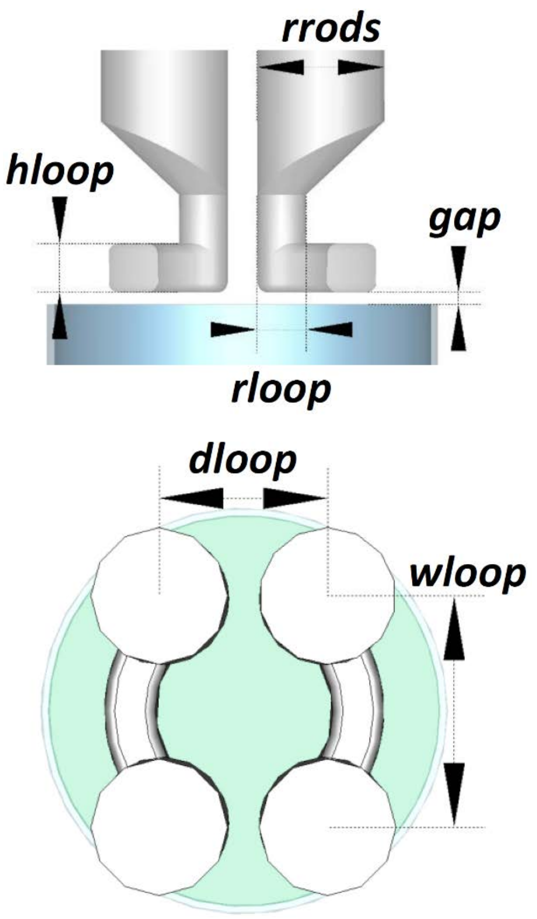
| [mm] | gap | rrods | hloop | rloop | wloop | dloop |
|---|---|---|---|---|---|---|
| Start | 1 | 10.5 | 9.5 | 5 | 40 | 16 |
| Result | 0.54 | 13.4 | 9.45 | 5 | 39 | 16 |
| HZB | 0.5 | 13 | 10 | 5 | 44 | 16 |




P. Putek et al., “Shape optimization of quadrupole resonator for the RF characterization of superconductors”, Compumag 2019

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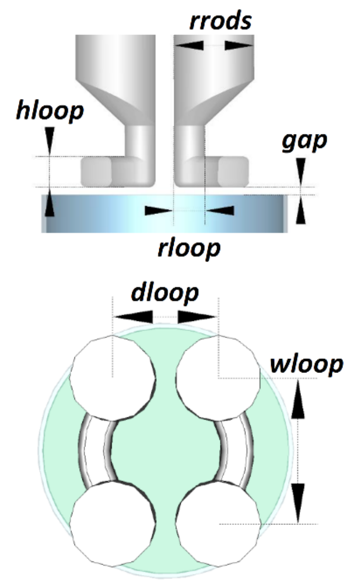


| | $f_1 = \frac{\int_S \lvert H \rvert^2}{2U} = \frac{1}{2\mu_0^2}\frac{c_2}{c_1} = \frac{\pi f}{G_S}$ | $f_2 = \frac{\langle H^2 \rangle}{H_{\text{pk}}^2} = \frac{1}{c_1 A_S}$ | $f_3 = \frac{H_{\text{pk,S}}}{H_{\text{pk,rods}}}$ | $f_4 = \frac{H_{\text{pk,S}}}{E_{\text{pk,rods}}}$ |
|---|---|---|---|---|
| Start | 2.93e7 [$A^2/J$] | 0.157 | 0.844 | 5.312 [mT/(MV/m)] |
| Result | 4.38e7 | 0.132 | 0.933 | 8.071 |
| $HZB_{\text{initial}}$ | 5.15e7 | 0.18 | 0.81 | 4.76 |
| $HZB_{\text{result}}$ | 11.2e7 | 0.16 | 0.89 | 7.69 |

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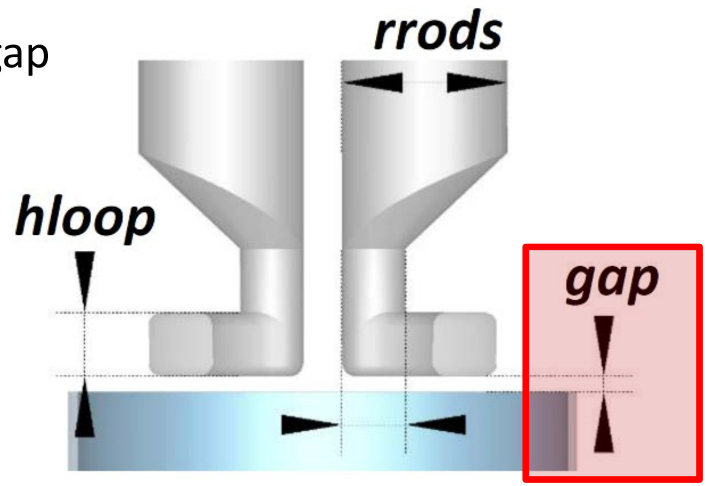
# RF gap calibration

- Quadrupole mode frequencies strongly depend on gap




$$\frac{\mathrm{d}f}{\mathrm{d}gap} \approx -\frac{1\ \mathrm{MHz}}{100\ \mu\mathrm{m}}$$

- Operational experience so far: max. $\Delta f = 4.2\ \mathrm{MHz}$ !

$$G_{\mathrm{Sample}} = \frac{2\omega\mu_0^2 U}{\int_S |B|^2 \mathrm{d}S} = 2\omega\mu_0^2 \frac{c_1}{c_2}$$

$$f\ [\mathrm{GHz}] = 50.4 \cdot G_{\mathrm{Sample}} \frac{c_2}{c_1}$$

# Links, publications, …

- SRF`13
  http://accelconf.web.cern.ch/AccelConf/SRF2013/papers/tup074.pdf
- SRF`15
  http://accelconf.web.cern.ch/AccelConf/SRF2015/papers/tupb067.pdf
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