Intrinsic Residual Microwave Loss in d-wave Superconductors

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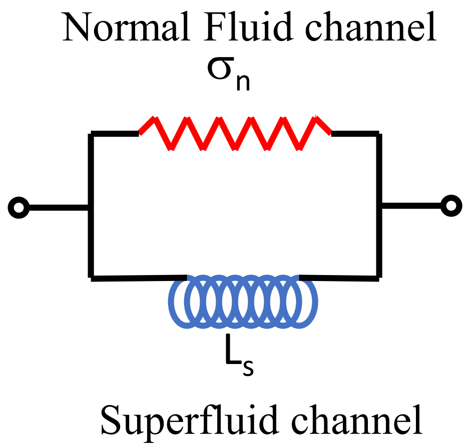
Two-Fluid Surface Impedance



$$Z_s = R_s + iX_s$$

$$\boldsymbol{R_s} = \frac{1}{2}\omega^2\mu_0^2\lambda^3\sigma_n$$ van Duzer p. 129

$$\boldsymbol{X_s} = \mu_0\omega\lambda$$

Universal residual conductivity in a d-wave superconductor:

$$\sigma_{00} = \frac{ne^2\hbar}{m\Delta_0}$$ units of $\frac{1}{\Omega\text{–}m}$

P. J. Hirschfeld, W. O. Putikka, and D. J. Scalapino, "Microwave conductivity of d-wave superconductors," Phys Rev Lett **71 (22), 3705-3708 (1993).**

Estimate $\frac{ne^2}{m}$ using the London penetration depth: $\lambda_L^2 = \frac{m}{\mu_0 ne^2}$ hence $\frac{ne^2}{m} = \frac{1}{\mu_0\lambda_L^2}$

Now calculate the intrinsic residual surface resistance: $\boldsymbol{R_{s,residual}} = \frac{1}{2}\omega^2\mu_0^2\lambda_L^3\sigma_{00}$

$$\boldsymbol{R_{s,residual}} = \frac{1}{2}\frac{\hbar\mu_0\omega^2\lambda_L}{\Delta_0}$$ General result, units of Ω

Example d-wave superconductor: YBCO, optimally-doped

$\Delta_0 = 25\ meV$ – maximum of the d-wave gap in YBCO

$\lambda_L = 150\ nm$ – estimate of London penetration depth. Maybe it is a bit smaller?

$\boldsymbol{R_{s,residual}} = 9.8 \times 10^{-6}\ \Omega$ at 10 GHz

So the 10 GHz residual resistance of YBCO is expected to be about 10 $\mu\Omega$, and should scale as ω^2

Scaled down to 1.5 GHz the intrinsic residual microwave loss in YBCO should be about 225 nΩ
The residual loss in Nb at this frequency is roughly 1 nΩ