SUPERCONDUCTIVITY WS 15-16

Monday 10:00-11:30

SR Exp. physics II

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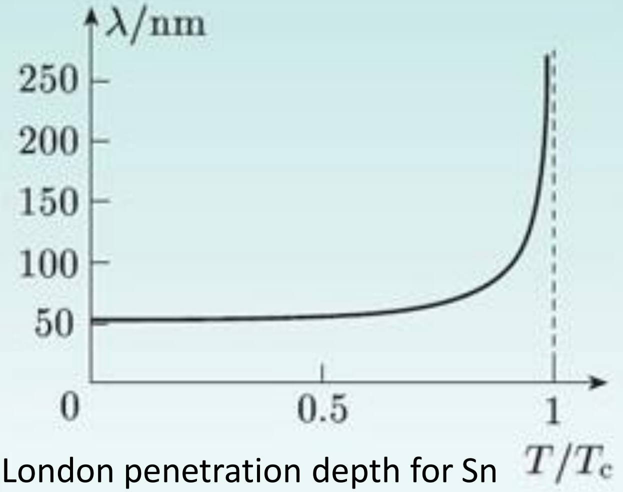
The Electromagnetic Equations of the Supraconductor

By F. and H. London, Clarendon Laboratory, Oxford

(*Communicated by F. A. Lindemann, F.R.S.—Received October* 23, 1934)

Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences ***149*** *(866): 71*

$$\frac{\partial J}{\partial t} = \frac{nq^2}{m} E \qquad \nabla \times J = -\frac{nq^2}{m} B$$



London penetration depth for Sn

London equations

- Phenomenological description of perfect DC conductivity and Meissner effect
- Electromagnetic response for $\hbar\omega < 2\Delta$ (otherwise pair breaking
- Assumes homogeneous state ($n_s \neq n_s(r)$, i.e. not for type II)
- Assumes local response (i.e. response at r caused by field at r)
- Can be derived in analogy to drude + maxwell eqns
- Alternatively from macroscopic wavefunction

Measure inductance SC rod

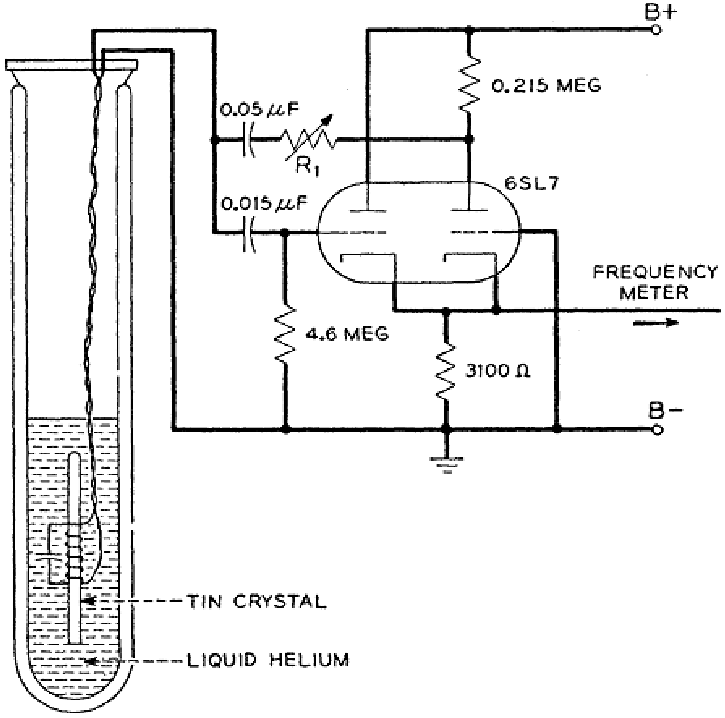


Fig. 3. Oscillator circuit for penetration depth measurement.

Shawlov and devlin, Phys.Rev. 113, 120 (1959)

LRC circuit,

$$\frac{\text{change in inductance}}{\text{total inductance}} = \frac{\text{change in penetration depth} \times \text{rod circumference}}{\text{total cross section occupied by flux}}.$$

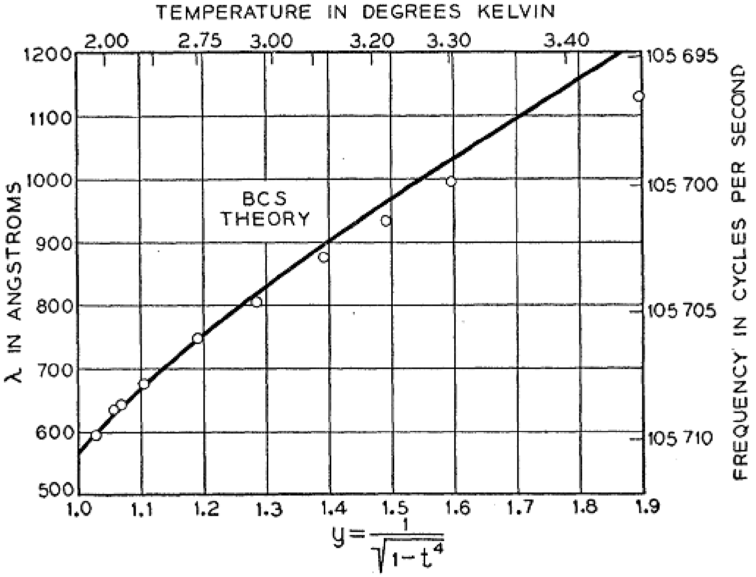


Fig. 6. Temperature dependence of oscillator frequency and penetration depth for tin crystal with transverse *c* axis (sample Sn121) for low temperatures.

Alternative method: resonant cavity

London penetration depth Al

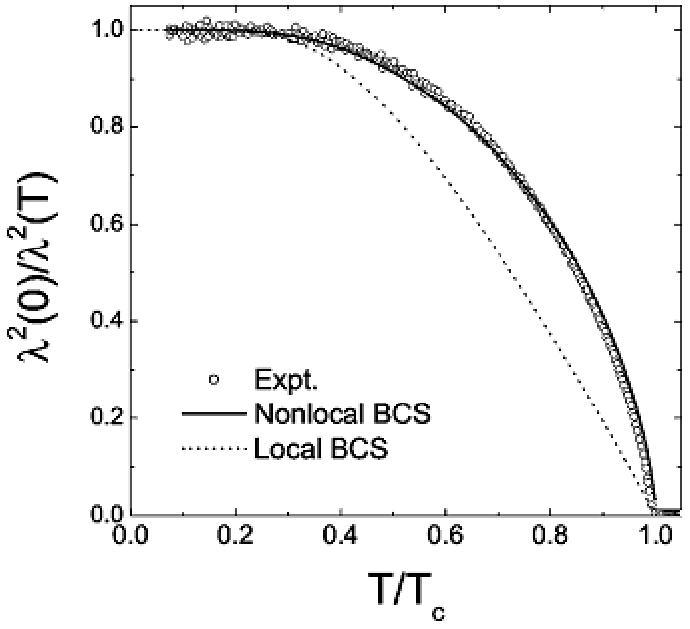


FIG. 1. $[\lambda(0)/\lambda(T)]^2$ against T/T_c up to T_c for the aluminum data and the numerical evaluation of the BCS nonlocal and local expressions of the penetration depth.

λ_{exp} (T=0) ~ 50 nm

[9] T. E. Faber and A. B. Pippard, Proc. Phys. Soc. London, Sect. A **231**, 336 (1955).

[10] M. A. Biondi and M. P. Garfunkel, Phys. Rev. **116**, 862 (1959).

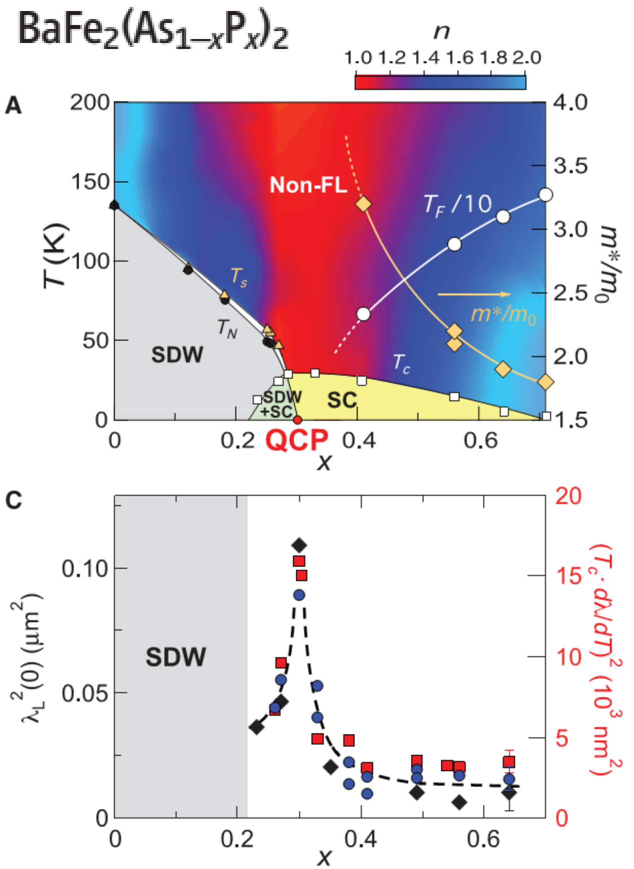
$$\lambda_{calc} = \sqrt{\frac{m}{\mu_0 n e^2}} \approx 13\, nm$$

Experimentally much larger than predicted
Origin: non-local behavior because
london length << coherence length ~ 1000 nm

Temperature dependence:
phenomenologically from 2 fluid model

$$\frac{\lambda(T)}{\lambda(0)} \sim \left(1 - \left(\frac{T}{T_c}\right)^4\right)^{-1/2}$$

Bonaldi et al. Phys.Rev.B 67, 012506 (2003)



Composition evolution of the square of the London penetration depth $\lambda_L^2(0)$ in the zero-temperature limit determined by three different methods: aluminum coating method (black diamonds), microwave cavity perturbation technique (blue circles), and the low-temperature slope of the change of the penetration depth with temperature (red squares, right-hand scale)

Hashimoto et al. Science 336, 1554 (2012)

Basov et al. PRL 74, 598 (1995)

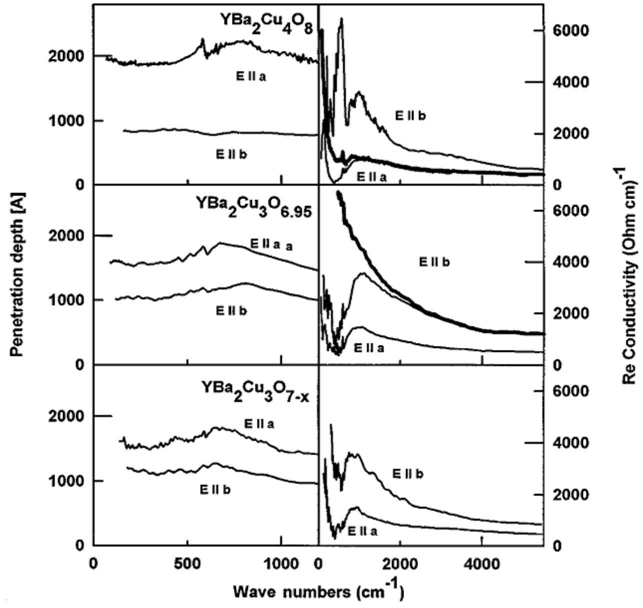
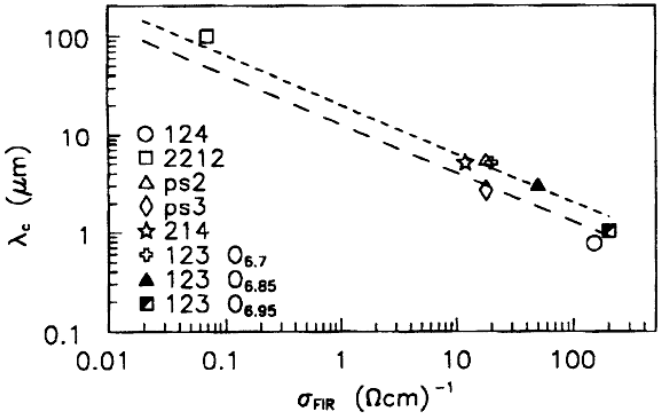


FIG. 2. Left panels: Frequency dependent London penetration depth $c/\lambda_L = [4\pi\omega\sigma_2(\omega)]^{1/2}$ for 124 sample (upper panel), 123 sample 1 (middle panel), and 123 sample 2 (lower panel). Right panels: the real part of the complex conductivity. All curves shown are at 10 K except for sample 1 where the b-axis conductivity is also shown at 95 K by the thick line and 124 sample where the a-axis conductivity is also shown at 85 K by a thick line.



Basov et al. PRB 50, 3511 (1994)