Talk at Urbana Conference: BCS@50

BCS and the

Superconducting Energy Gap

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The Experimental Puzzle:

Kamerlingh Onnes (1911) and many others subsequently showed that, in superconducting metals below T_c,

$$\mathbf{R_{dc} = 0},$$

as proved dramatically by "persistent currents" in rings.

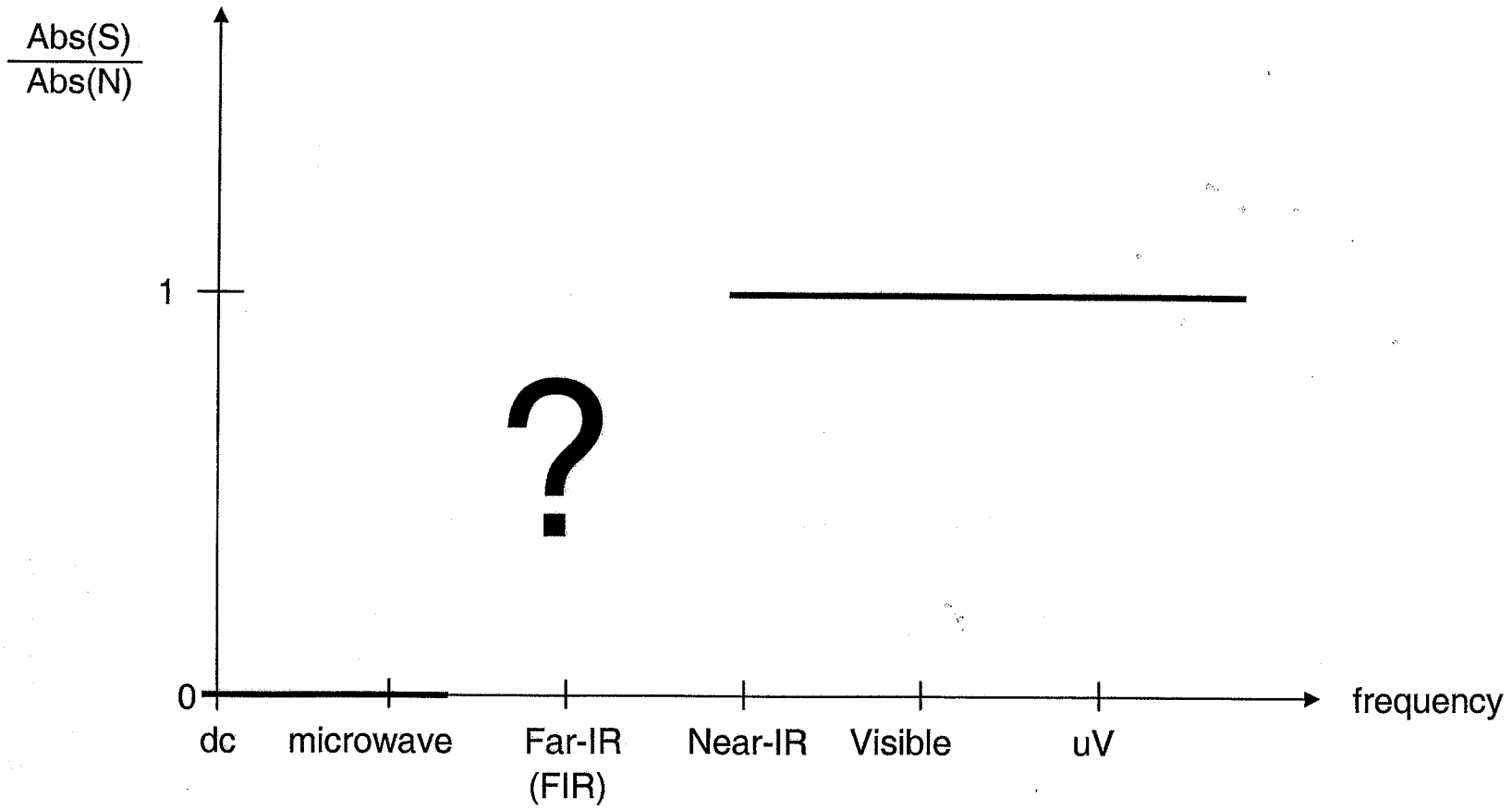
But:

Daunt, Keeley, and Mendelssohn (1937) and Ramanathan (1952) had found ***no change below T_c*** in infrared reflection or absorption coefficient (at ~14 μm).

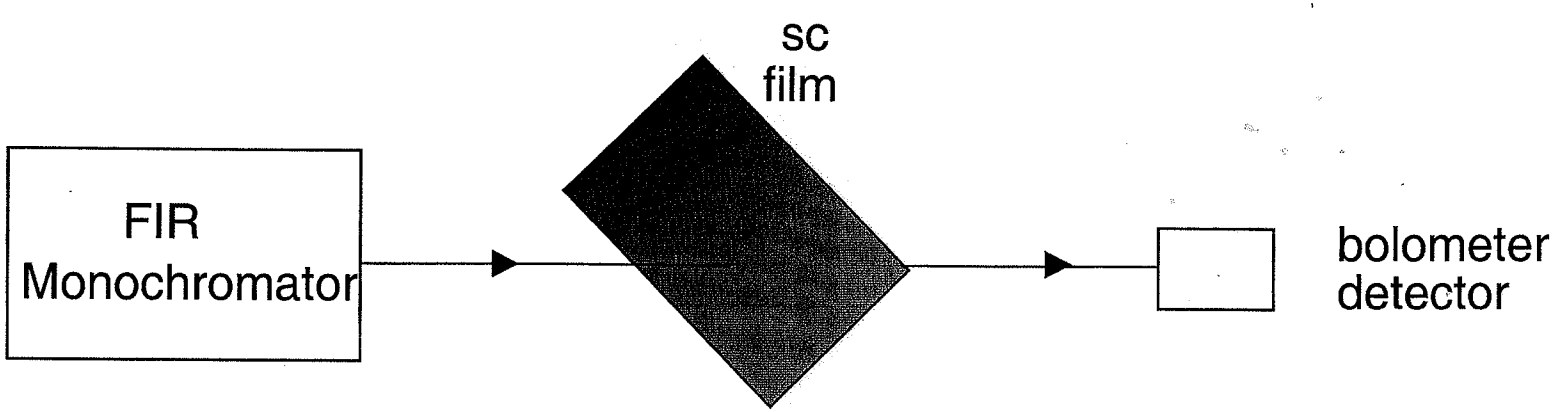
So, the questions:

Is there a **maximum frequency** at which superconductivity is effective? If so, is it set by an **"energy gap" in the superconducting state?**

Historical Data



Measure Film Transparency at FIR



Method used by Glover, Tinkham, Ginsberg, Palmer

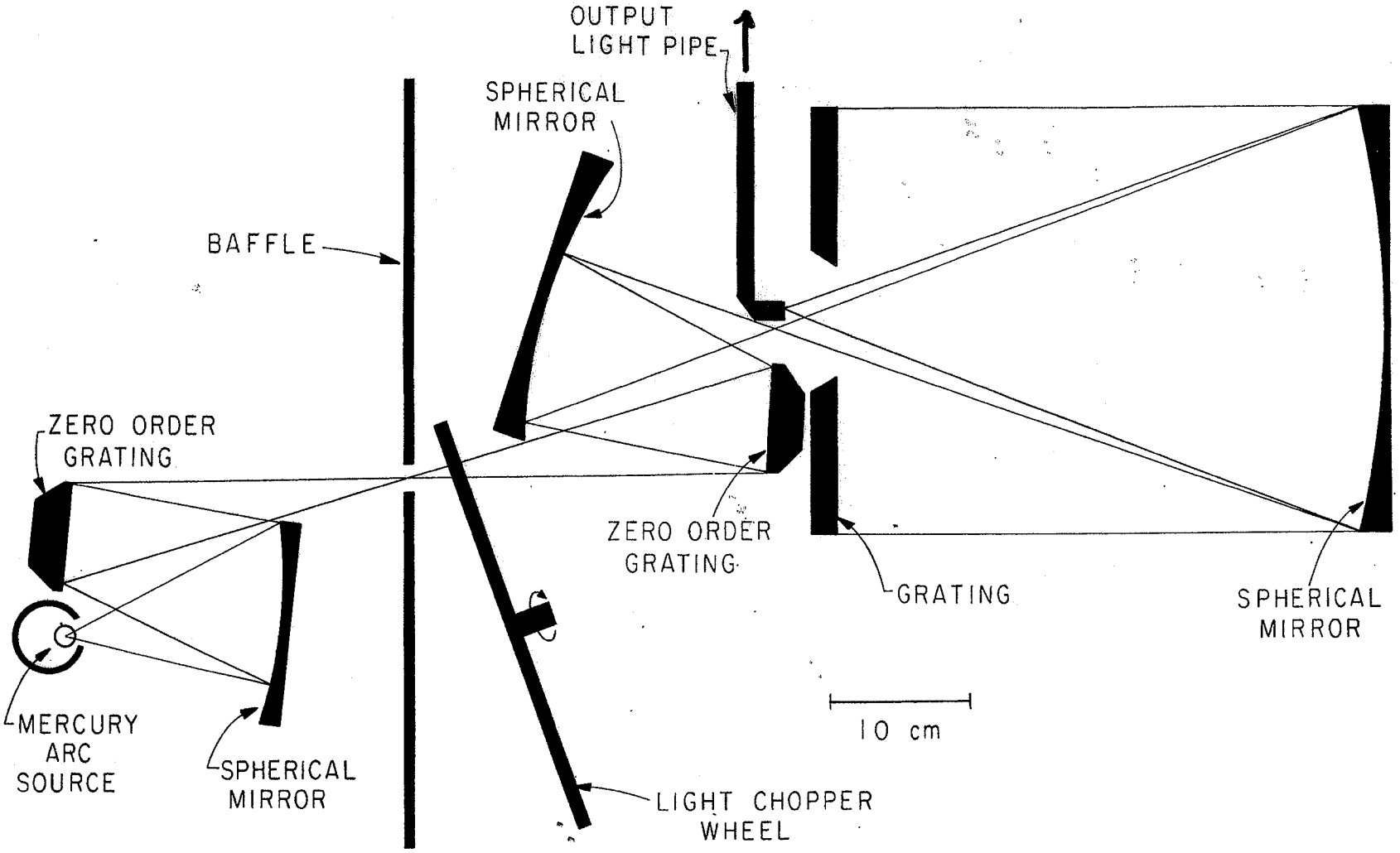


Fig. 3. Infrared Monochromator.

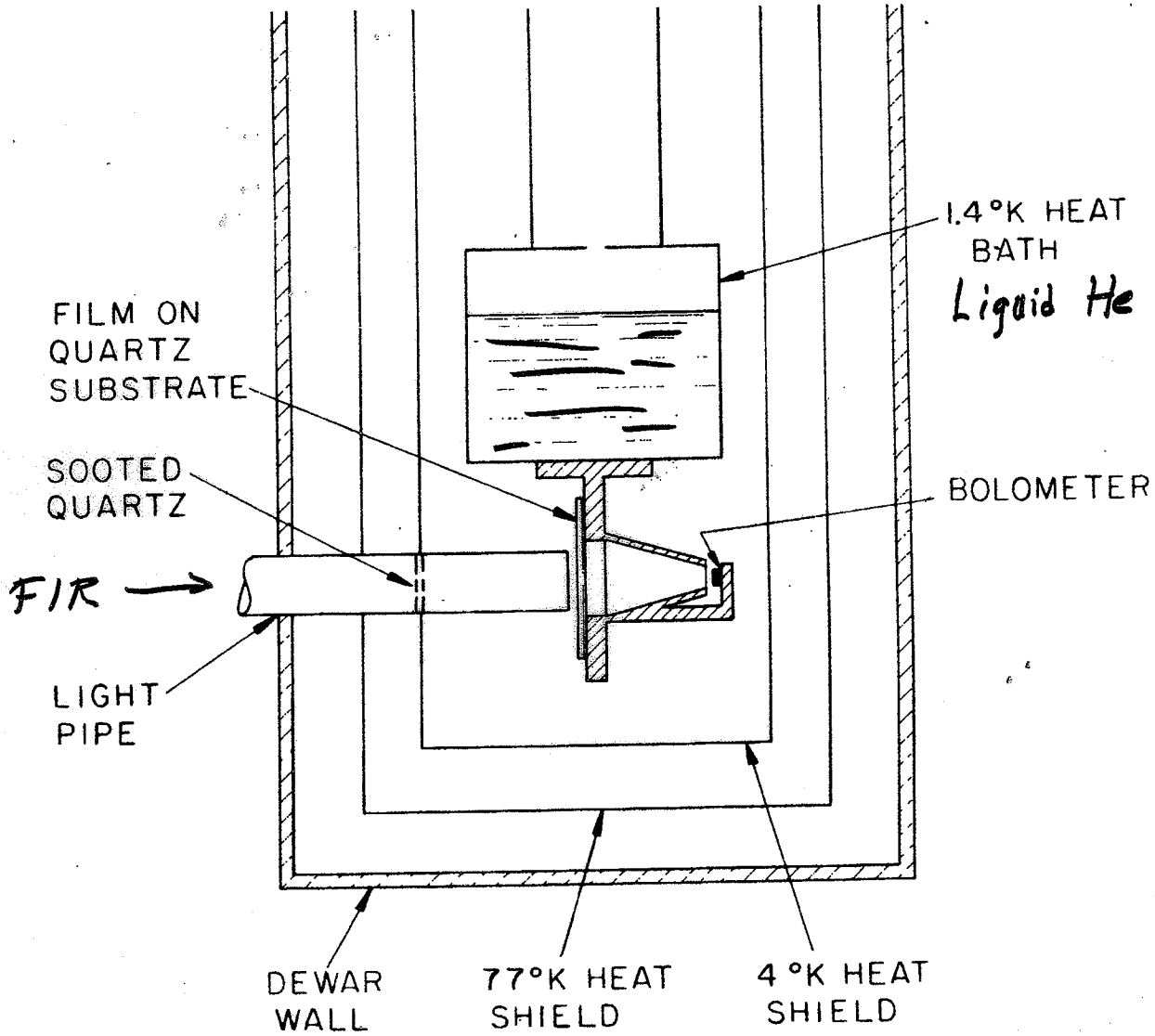


Fig. 2. Schematic Drawing of Dewar.

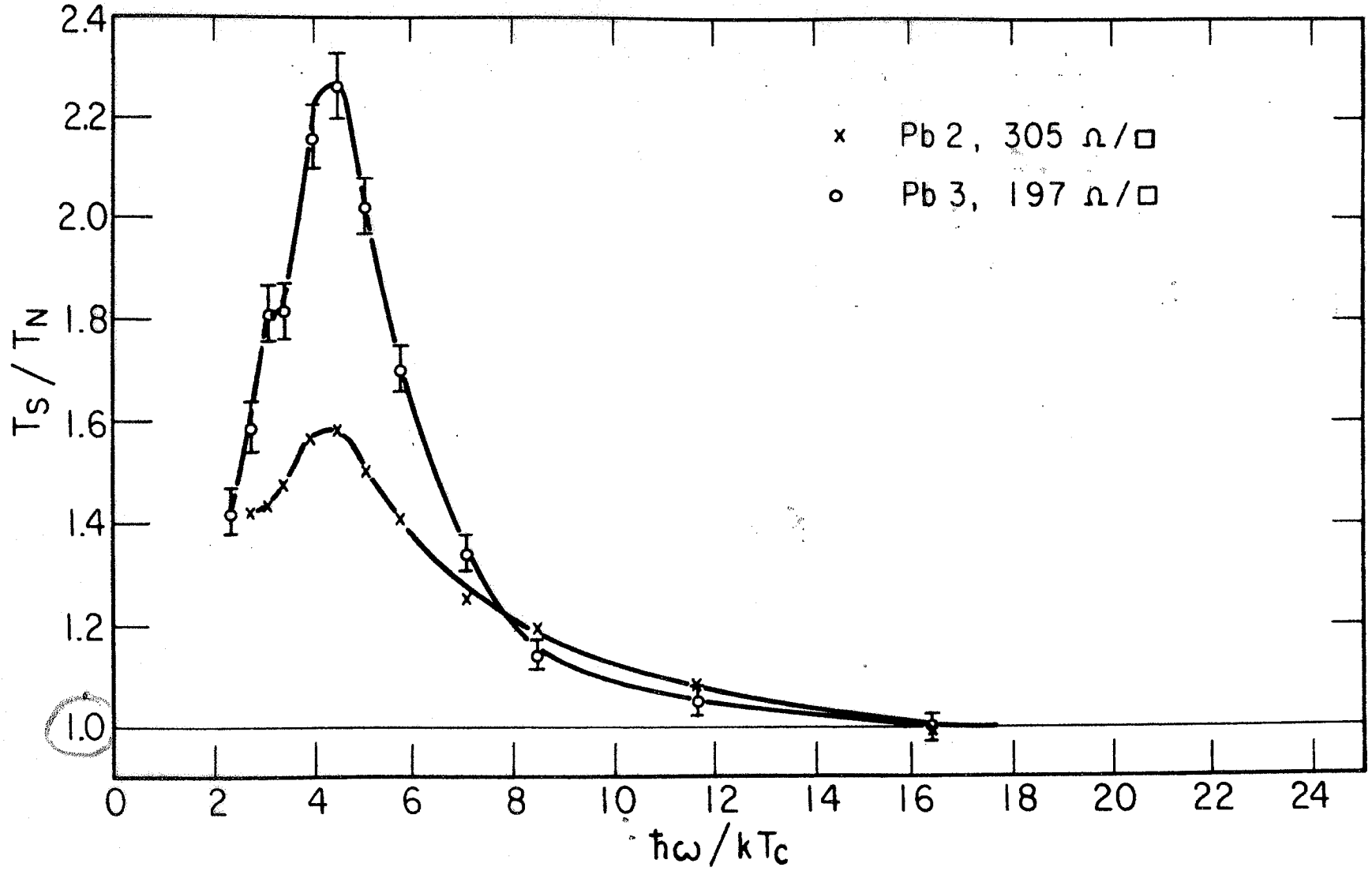


Fig. 2. Transmission Characteristics of Pb2 and Pb3.

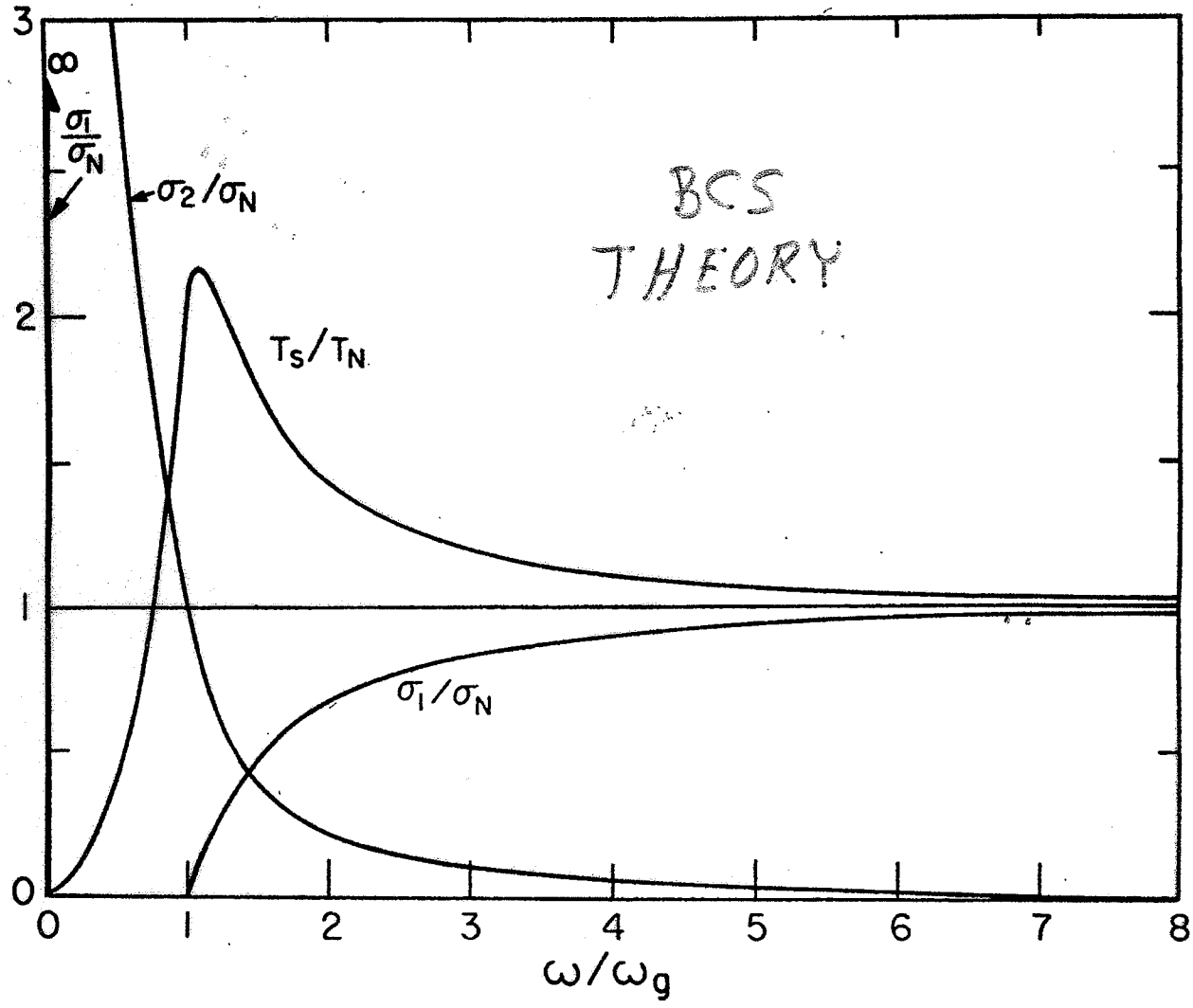
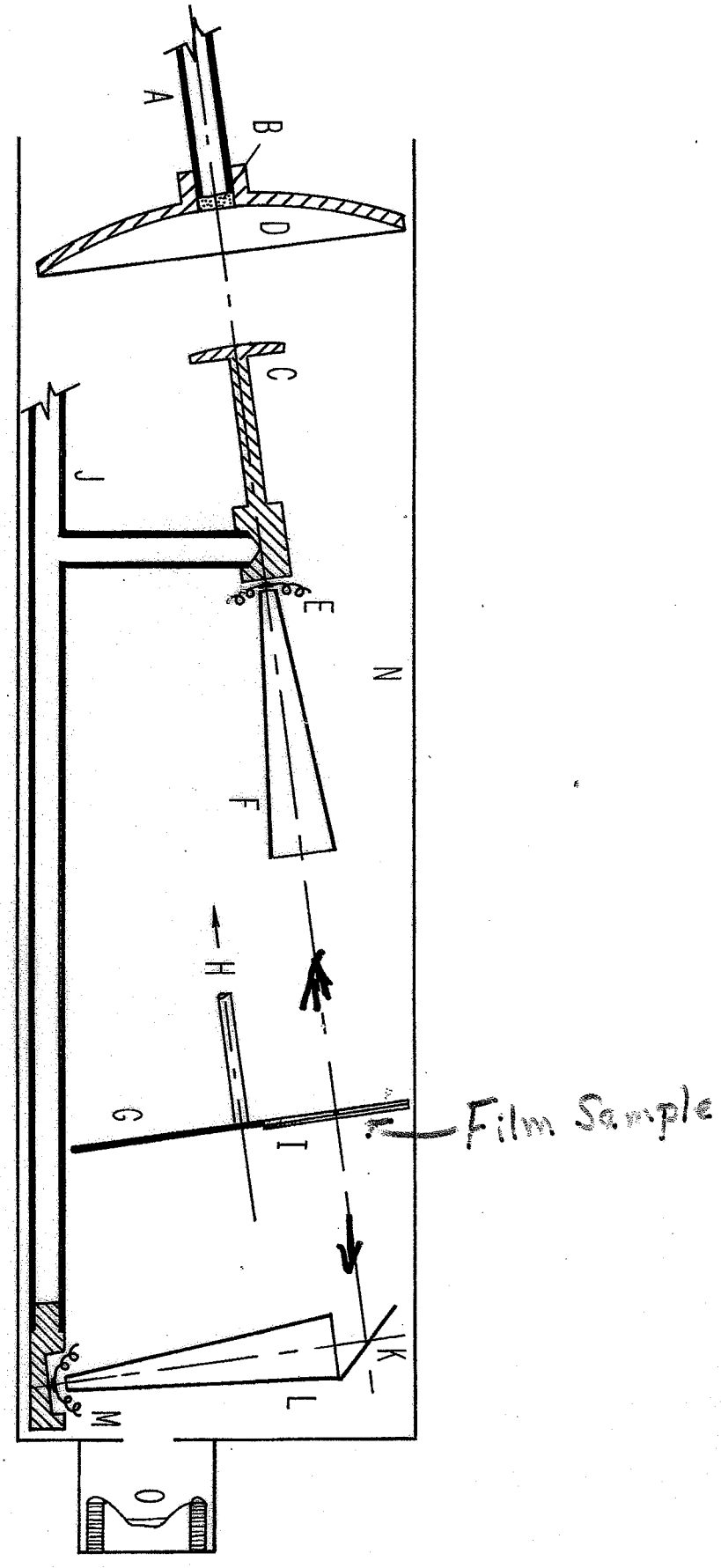
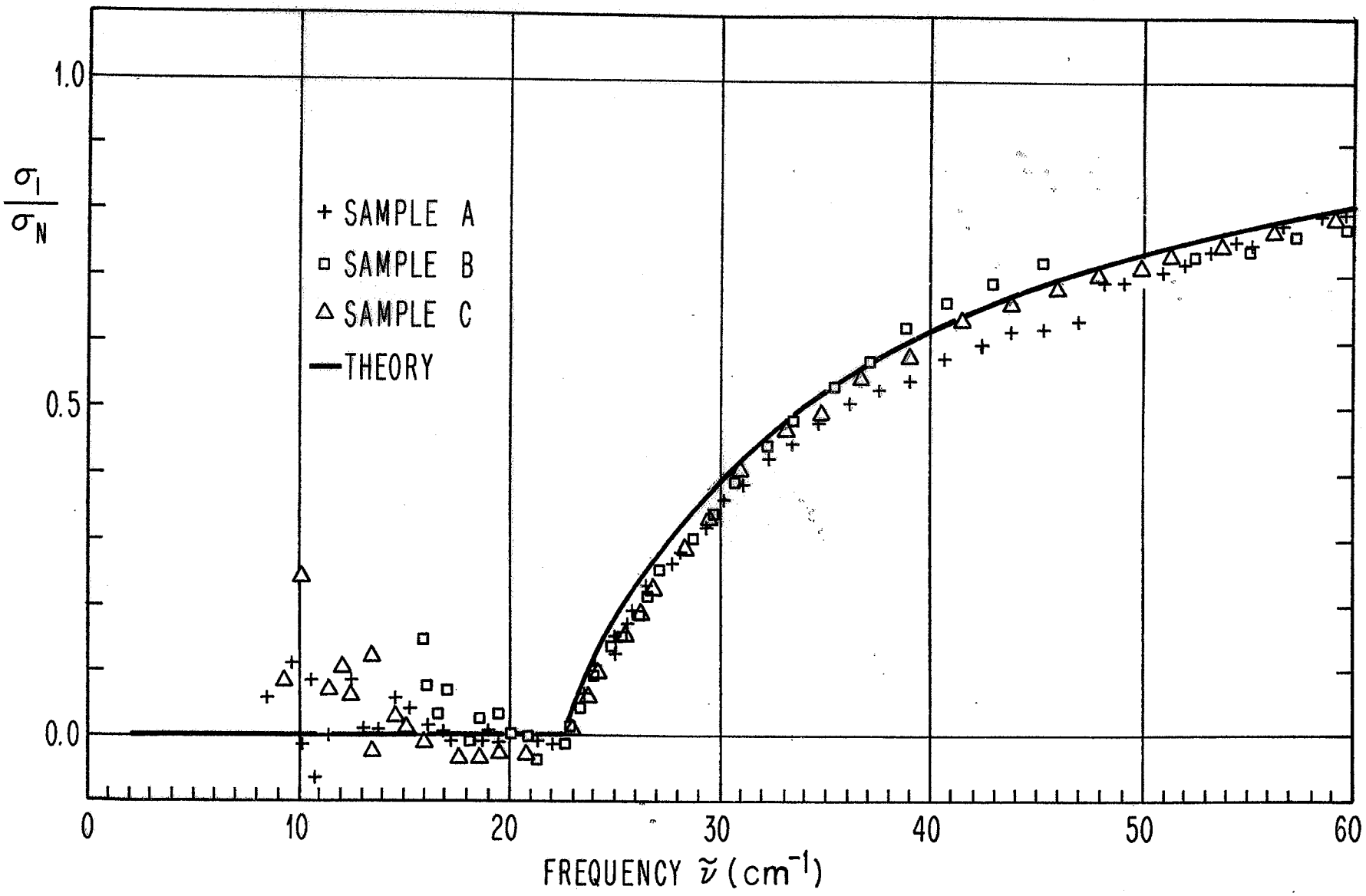
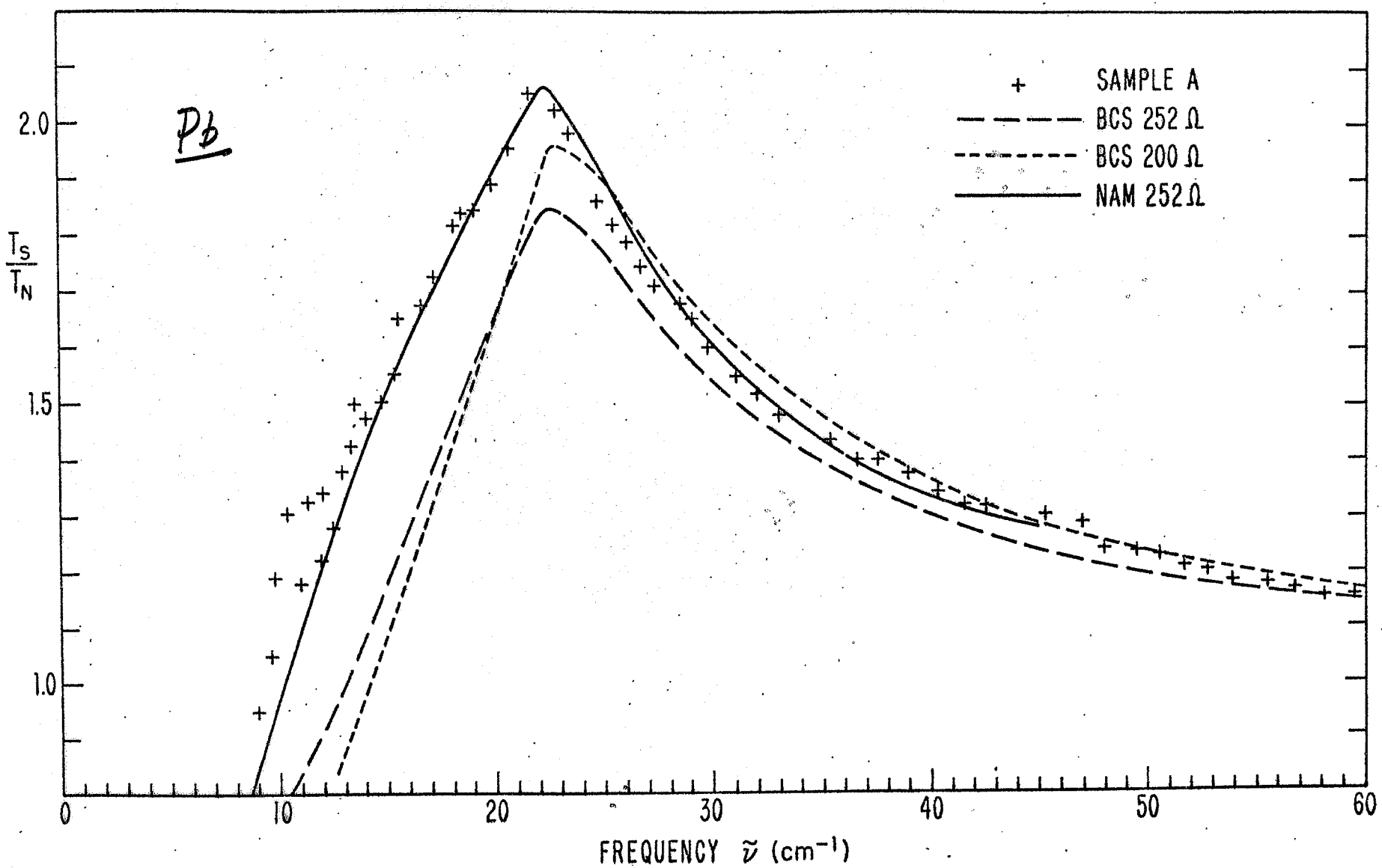


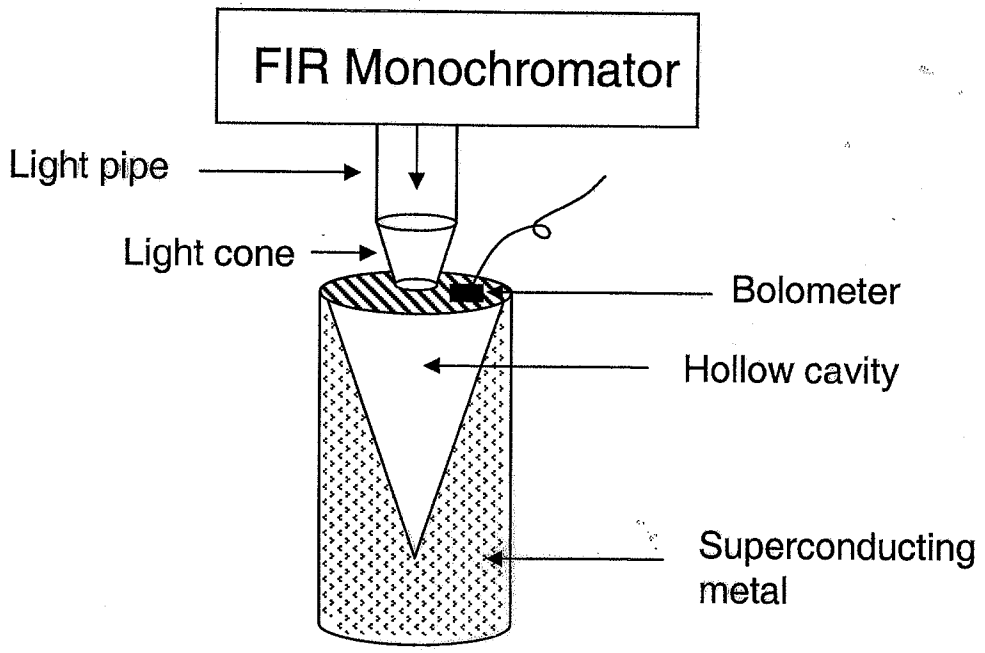
Fig. 10 Frequency dependence of σ_1/σ_N, σ_2/σ_N and T_S/T_N according to the calculation of Mattis and Bardeen. The transmission curve is for a film of resistance $377/(n + 1)$ ohms per square, where n is the refractive index of the substrate.


A
B
D
C
J
E
N
F
H
G
I
Film Sample
K
L
M
O


1.0
0.5
0.0
$\frac{\sigma_1}{\sigma_N}$
+ SAMPLE A
□ SAMPLE B
△ SAMPLE C
—THEORY
0
10
20
30
40
50
60
FREQUENCY $\tilde{\nu}$ (cm^{-1})


Pb
SAMPLE A
BCS 252 Ω
BCS 200 Ω
NAM 252 Ω
$\frac{T_S}{T_N}$
2.0
1.5
1.0
0
10
20
30
40
50
60
FREQUENCY $\tilde{\nu}$ (cm^{-1})

Measure FIR Absorption in Bulk Superconductor



Method used by Richards and Tinkham

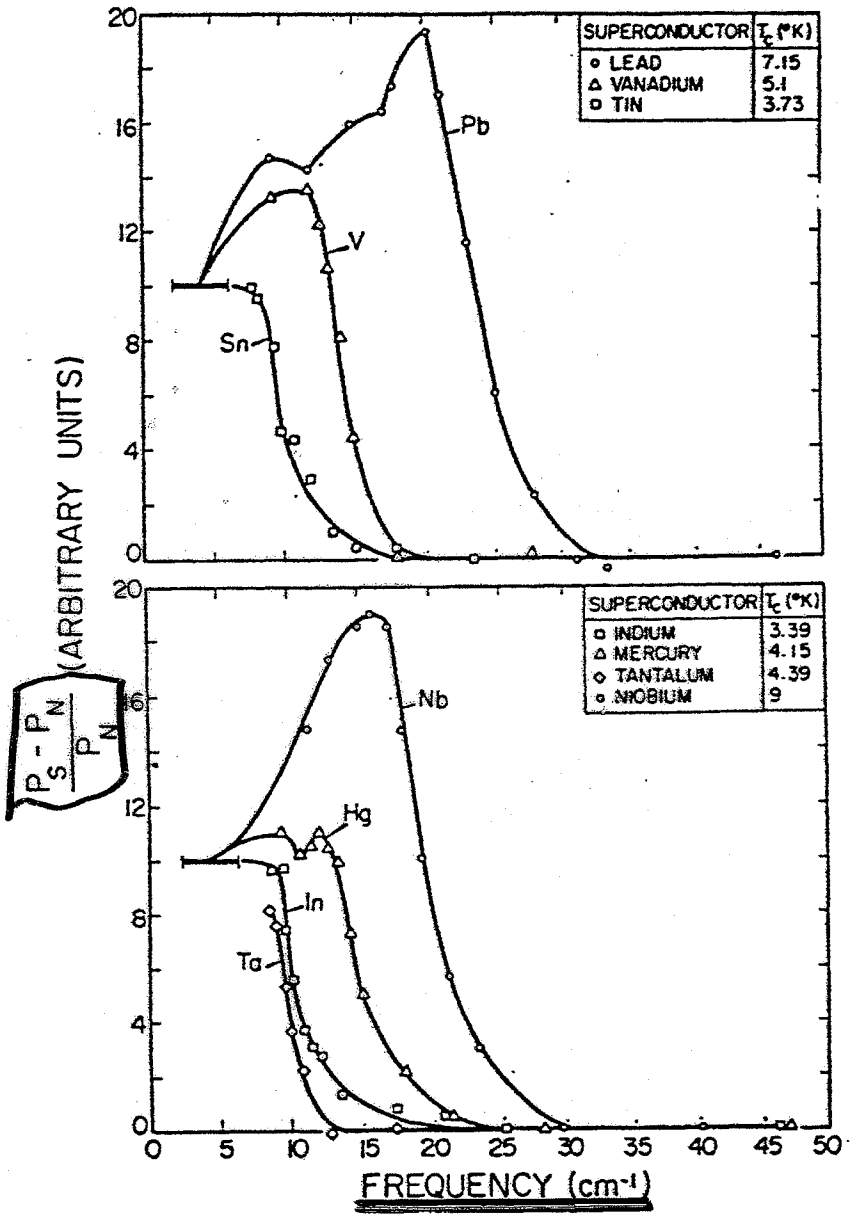


FIG. 4. Low-temperature absorption curves for seven pure superconductors plotted as a function of frequency in wave numbers. These curves have been normalized for display purposes so that the ordinate of the lowest frequency point is the same for each. This point is obtained by using the coarsest dispersion grating in zero order. The estimated spread of frequencies is indicated by the horizontal bar. All other points have band widths of the order of 10%.

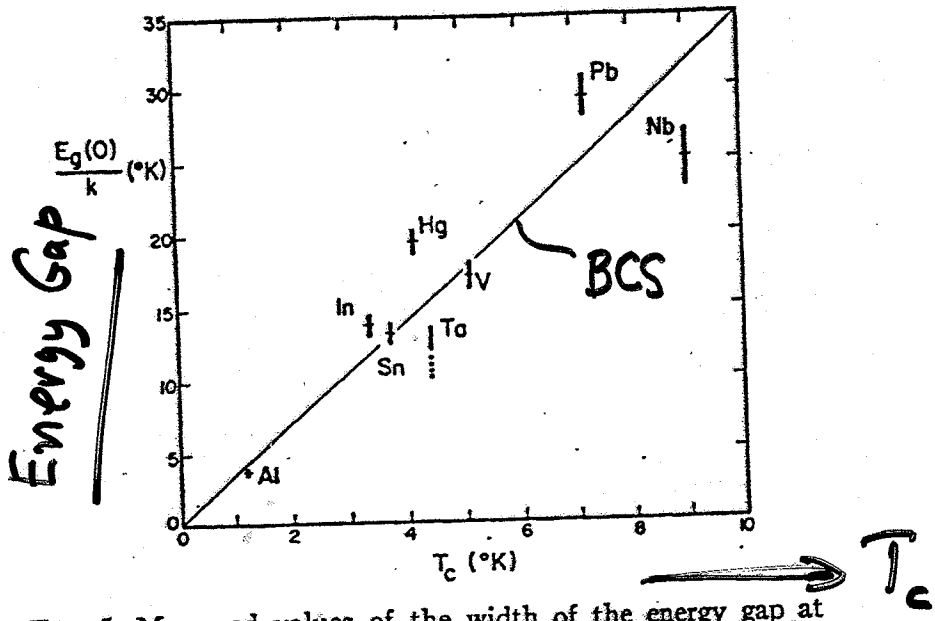


FIG. 5. Measured values of the width of the energy gap at absolute zero in temperature units plotted as a function of the critical temperature. The straight line is the prediction, $E_g(0)=3.5\ kT_c$, of the Bardeen-Cooper-Schrieffer theory. The width of the energy gap of aluminum measured by Biondi and Garfunkel using the microwave surface resistance method is given here, and in the following two figures, for comparison with our data.

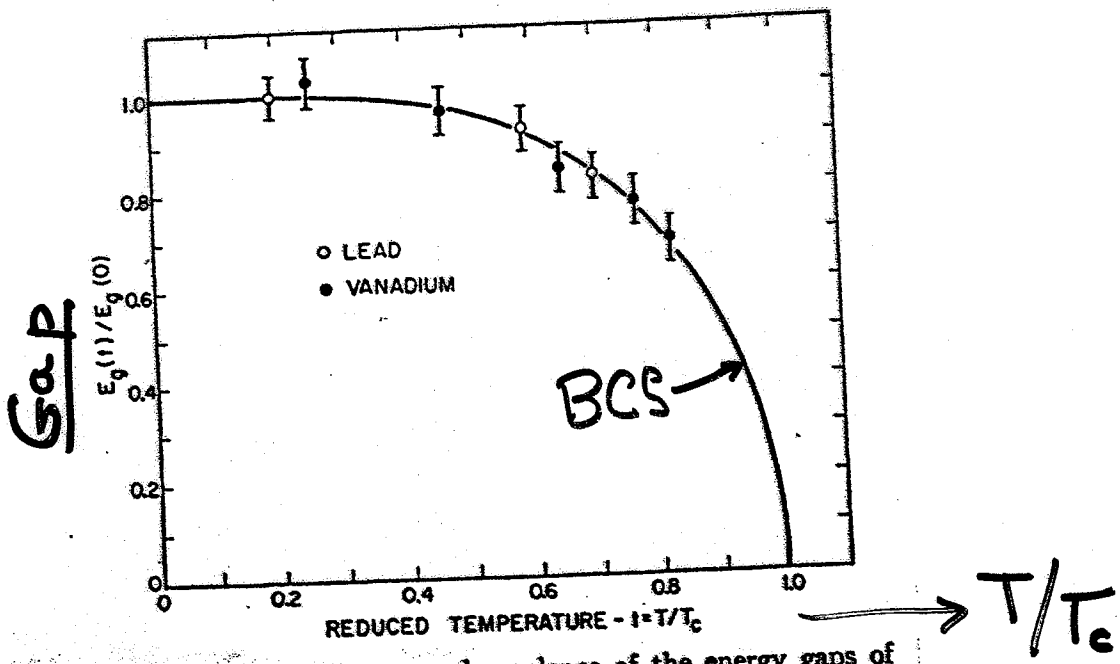


FIG. 10. The temperature dependence of the energy gaps of lead and vanadium. The solid curve is the prediction of the Bardeen-Cooper-Schrieffer theory. In both cases, $E_g(0)$ was chosen for a best fit to the theoretical curve.

CONCLUSIONS

Far-Infared Experiments

quantitatively confirm BCS predictions

of Energy Gap $\Delta(T)$

and Electrodynamics $\sigma_1(\omega)$ and $\sigma_2(\omega)$.

$\therefore$ BCS must be correct!