theirs, and our minimum cross section near 1100 Å is about half theirs and occurs at a longer wavelength.

This discrepancy gives rise to the usual delicate question. We feel that we can have some confidence in our results since our calculations for the $2s$ state were done twice, with completely different computer programs, and agreed exactly. Nevertheless, it is not our purpose here to insist that our result must be the right one but merely to point out that a disagreement over the exact numerical results exists so that, if and when precise experimental data become available, the calculations should be done over, preferably by a third party.

Finally, we remark that if there is an error in Gontier and Trahin's result for the two-photon case, then it seems likely that the error would become larger as one goes to higher orders in perturbation theory.

[1]Y. Gontier and M. Trahin, Phys. Rev. 172, 83 (1968). The analytical portion of this paper has also been published in Compt. Rend. 264, 499 (1967).

[2]W. Zernik, Phys. Rev. 135, A51 (1964).

[3]W. Zernik and R. W. Klopfenstein, J. Math. Phys. 6, 262 (1965). This might be an appropriate place to point out that in Eq. (3) of this paper an interference term for the transitions $l \to l-1 \to l$ and $l \to l+1 \to l$ has been omitted. This affects the numerical results for initial states with $l > 0$.

PHYSICAL REVIEW VOLUME 176, NUMBER 1 5 DECEMBER 1968

Superfluid Fraction of Liquid Helium Contained in Porous Vycor Glass*

J. C. Fraser and I. Rudnick

Physics Department, University of California, Los Angeles, California

(Received 29 July 1968)

Using fourth sound, there have been recent determinations of the superfluid fraction in helium contained in pores small enough that size effects modify the superfluid state. The results reported for porous Vycor glass,[1] which is presumed to have a random cylindrical capillary system, are sufficiently different, in several respects, from those reported for packed granular powders[2] that the question arises whether there is an inherent difference in the effect of the two kinds of porous geometries. The purpose of this note is to report the results of some measurements on Vycor (Corning porous glass 7930) which do not show these differences.

The superfluid fraction was obtained in a manner entirely similar to that of Refs. 1 and 2 from the measurement of the second and fourth harmonic resonant frequencies of a fourth-sound plane-wave resonator. A more complete description of technique and measurement is given by Guyon and Rudnick.[3] In the present instance the resonator was packed with disks of Vycor glass 2.51 mm thick, 13.13 mm in diameter, separated by layers of lens paper 0.05 mm thick. The total length of the resonator was 12.70 mm. The Q's of the resonant modes varied from about 400 at the lowest temperature to less than 100 at the higher temperatures. Because of the uncertainty in the magnitude of the scattering correction, the measurements are normalized to give the bulk value of $\rho_S/\rho = 0.98$ at 1.2°K. The ratios between the normalized velocity u_4 and the unnormalized velocities at 1.2°K were 2.15 and 2.23 for the second and fourth harmonics, respectively. The results are shown in Fig. 1 compared with the bulk values for He II. Also shown for comparison purposes are results obtained with a packed carbon black, Carbolac I, (curve F of Ref. 2) whose grains are approximately 80–100 Å in diameter. The crosses are the results for Vycor reported by Brewer *et al.*[1] It is clear the present results fall into the pattern found for the packed powders and differ markedly from those reported previously for Vycor.

A noticeable difference between the Vycor data here reported and the packed powder data is the reduced values of ρ_S/ρ for the former at the high-temperature end. This may well be a result of imperfectly filling the volume of the resonator with Vycor – a similar effect has been observed with a resonator packed with powder when one end was left unfilled to a length of a few tenths of one percent of its total length. The Vycor of Ref. 1 came from a batch, a sample of which had an average pore diameter of 62.4 Å, and there is evidence that its superfluid onset temperature is close to 2.05°K. We have no independent pore diameter determination for our sample[4] and estimate the temperature onset of superflow to be be-

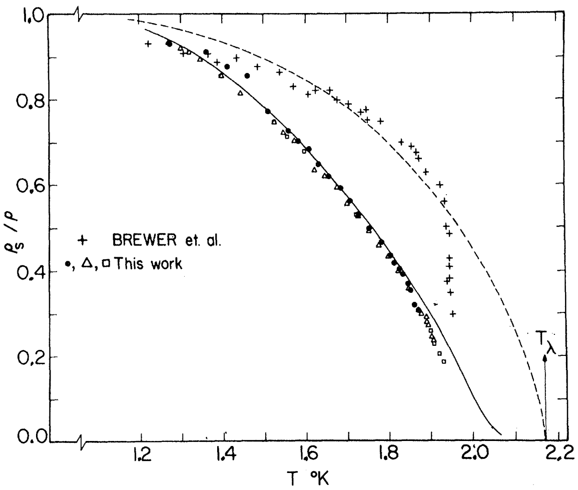

FIG. 1. The temperature dependence of the superfluid fraction. Dashed curve: bulk helium. Solid curve: measured values in a packed powder whose grains are 80–100 Å in diameter (curve F of Ref. 2). Points + : measured values in Vycor, Ref. 1. Points ●, △, □: measured values in Vycor, this work (●: second harmonic. △, □: fourth harmonic).

tween 2.05 and 2.10°K on the basis of a comparison of values of ρ_s/ρ with those of measured packed powders, and the known onset temperatures for those powders.

Since reporting the initial measurements,[2] considerably more data have been accumulated on ρ_s/ρ for other packed powders which fit the same temperature-dependence pattern. It is worth noting that Vycor does not seem to be as well suited as packed powders for measurements of this type. One finds many more unexplained acoustic responses below and above the superfluid onset temperature. These may be associated with (1) transmission paths between the source and receiver, part of which are in the glass matrix, and (2) the generation of first and second sound in those avoidable clearance spaces between the solid Vycor and the body of the resonator where the normal fluid becomes unlocked.

---

*Research sponsored by U. S. Office of Naval Research, Acoustics Branch, Nonr 233 (48).

[1]D. F. Brewer, G. W. Leppelmeier, C. C. Lim, D. O. Edwards, and J. Landau, Phys. Rev. Letters 19, 491 (1967).

[2]I. Rudnick, E. Guyon, K. A. Shapiro, and R. A. Scott, Phys. Rev. Letters 19, 488 (1967).

[3]E. Guyon and I. Rudnick, to be published.

[4]T. H. Elmer of the Technical Staff Division, Corning Glass Works, Corning, New York, supplied the information that "The pores in Code 7930 glass are generally about 45 Å in diameter as measured by the Brunauer-Emmett-Teller method using nitrogen at its boiling point. In thicker porous glass samples, the average pore diameter could be somewhat larger than 45 Å."