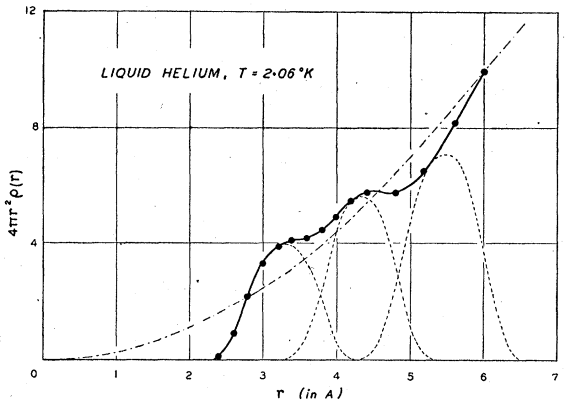

FIG. 1. The distribution function for liquid helium below the λ point.

atoms contained in any shell of radius r and thickness dr; the smooth dotted curve indicates the *mean* atomic density at the same temperature. Using Coulson and Rushbrooke's[3] criterion that $r\rho(r)$ has symmetric similarity about each value of r for which the distribution curve shows a maximum, the latter can then be reduced to its component shells. This is also shown in Fig. 1, from which the following distribution of helium atoms around any one atom may be deduced:

Distance, A	Number of atoms in shell
3.15	4
4.24	6
5.40	8

There may be some uncertainty about the accuracy of the atomic density deduced from our data for the third shell. However, from other considerations there appears to be little doubt that the distribution given is the correct one for liquid helium.

While bulk helium is certainly not possessed of any extensive long-range order, we believe that results of appreciable significance may follow from a consideration of the lattice structure which can be built up to conform to the above distribution. It is readily seen that a simple tetragonal lattice with an axial ratio c/a of $\sqrt{2}$ will approximately satisfy the atomic distribution found for helium, and such a structure with $a=3.15$A could form the unit cell. Early speculations relating to the atomic distribution in liquid helium, based as they were on the idea of order-disorder transitions, suggested that the actual structure might be developed from a face-centered cubic lattice.[4,5] It is instructive in the present case to consider how the tetragonal cell may be derived by a similar procedure. It will be clear that the distribution found can be made up by simply removing in a particular way eight of the twelve nearest neighbors in a face-centered array, all other atom points remaining occupied. Figure 2 shows a structure resulting from this process, and a striking feature of this array will be immediately evident. One set of (100) planes is appreciably more densely populated than any other plane. If the helium had long-range order, this plane would in fact be an exceedingly effective "slip plane."

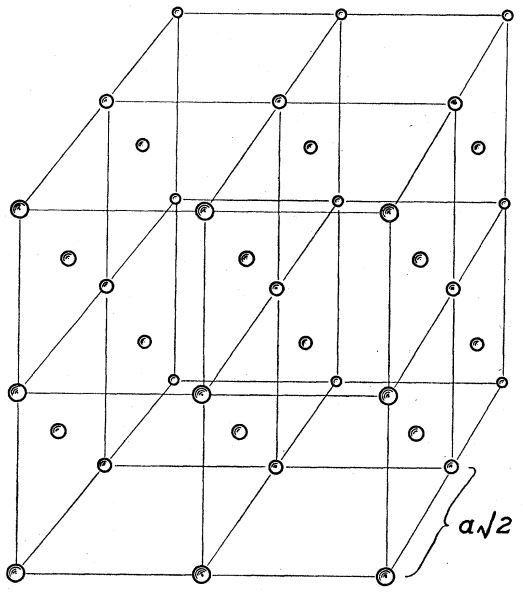

FIG. 2. Lattice configuration for liquid helium, showing preferential (100) planes.

One is tempted to consider, therefore, whether the helium II film (or the "superfluid" component of the liquid) does actually have such an ordered structure as shown in Fig. 2, and whether such order exists over a sufficient extent to permit of easy slip on the preferential (100) plane. The fact that the helium II film is effectively at a temperature of 0°K and has zero entropy[6] lends support to the necessity of its having *some* kind of order, and such physical order is in many ways a more satisfactory concept than an ordering in "momentum space." So long as no appreciable momentum interchange occurs between the preferential (100) planes, the formation of a helium II film on any surface in contact with the liquid, and its nonviscous flow on that surface, would naturally follow. On this view, viscosity would suddenly appear in any extended "superfluid" portion of the liquid, as soon as bulk helium II adjacent to that portion had reached a sufficient temperature that its ("normal") atoms possessed enough energy to destroy the "superfluid" structure. It is of interest to note that a simple calculation of the binding energy[7] between opposite pairs of atoms on the preferential (100) planes of the proposed lattice structure yields a value of about 2×10^{-16} erg. If this is equated to $kT/2$, a value of nearly 3°K is obtained for T. The onset of viscosity in the superfluid regions when the bulk liquid reached this temperature would, of course, be associated with the λ-point transition.

According to this picture, *both helium I and bulk helium II* would simply have the liquid-type distribution actually found; we should not expect present x-ray methods to show any structural change at the λ point.

Finally, we may remark that a calculation of the total energy at 0°K of such a structure as shown in Fig. 2, using the Slater-Kirkwood[7] potential function and London's curve for zero-point energy,[8] gives a binding energy of 15 calories per mole and a molar volume of 27 cc. These figures agree remarkably well with the experimental values deduced for helium II, and give further confidence in the correctness of the proposed structure. Full details of this work will be published elsewhere.

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Čerenkov Effect at Microwave Frequencies*

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ČERENKOV radiation at microwave frequencies has been experimentally detected. Approximately 10^{-7} watt of Čerenkov radiation at a wavelength of 1.25 cm was obtained.

In the arrangement used (see Fig. 1), the radiation is excited by a flat electron beam which passes as closely as possible over

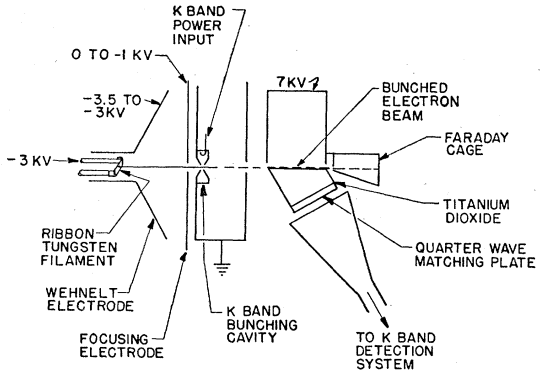

FIG. 1. Schematic diagram of experimental arrangement.

the surface[1] of a dielectric material after having been bunched at a K-band frequency. The radiation leaves the dielectric through a quarter-wave matching plate and is then picked up by a microwave horn and detected with a 1N26 crystal. The electron beam is 4 mm wide and approximately 0.3 mm high and passes over a 1.9-cm length of dielectric which is polycrystalline TiO_2.[2] The measured dielectric constant of this material at $\lambda=1.25$ cm is 105. The beam voltage is 10 kv, the current 0.2 ma, and the bunching frequency 24 000 Mc/sec. The beam is bunched by passage through a klystron-like cavity. The K-band klystron which energizes this cavity is switched on and off at a 6-kc rate to facilitate the subsequent amplification of the signal. In addition, the electron beam is "chopped" at 20 cps, thereby providing a means of discriminating between the leakage power coming from the bunching cavity and radiation due to the electron beam. Radiation is detected by a crystal, the signal amplified and displayed on an oscilloscope.[3]

Because of the bunching of the beam, the radiation contains only the bunching frequency and its harmonics. At the present writing, only the fundamental has been examined.

To verify that the signal was indeed due to Čerenkov radiation, the distance between the electron beam and the dielectric was varied. The signal intensity decreased very rapidly as the distance between dielectric and electron beam was increased. This is to be expected for Čerenkov radiation.[4]

It was estimated that under the conditions of the present experiment a power in the order of 10^{-6} w can be expected.

We wish to thank Professor Townes for his help and encouragement during the course of the experiment.

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‡ Present address: Warande 182A, Schiedam, Holland.
[1] Mandelstam (unpublished) quoted, e.g., in reference 4.
[2] Supplied by Bell Telephone Laboratories, Murray Hill, New Jersey.
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Capillarity in Helium II*

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IN the course of developing apparatus for experiments on the surface tension of He^3-He^4 mixtures, we have observed a rather interesting phenomenon connected with superfluid He^4. The method employed is the standard "capillary rise" technique using, however, parallel plates rather than the more usual capillary tube.

Figure 1 indicates one of the arrangements. Two optically flat glass plates GG are separated by two strips of aluminum foil SS thus forming a clear region about 20 mm long, 6 mm wide, and with a gap of 36 microns. These plates were suspended by two stainless steel wires, each 1 mm in diameter, from the top of the cryostat, and provision was made to raise or lower the plates from outside the cryostat. A cathetometer was employed to observe liquid levels and the light source was a low-power fluorescent lamp with heat-absorbing glass filters.

The procedure consisted in lowering the assembly until the bath level was at position a in Fig. 1 (i.e., both plates immersed) and measuring the height of the meniscus and the bath level as a function of time. Figure 2 shows two such typical runs, at 1.25°K and 2.15°K, respectively. As the bath level falls (due to evaporation) so does the meniscus, the difference in level at any time being the capillary rise. The vertical broken line in Fig. 2 indicates the point at which the bath level just falls below the gap between the two plates, i.e., to the right of this line only one plate is immersed (position b in Fig. 1). Nevertheless, the distance between meniscus and bath remains the same. This continues, as the bath level falls, until the immersed plate presents a certain minimum periphery to the bath, at which point the meniscus suddenly collapses and all liquid drains out of the space between the plates. The minimum periphery where this occurs was temperature dependent, being approximately 41 mm at 2.15°K and 21 mm at 1.25°K.

The above effect also occurred in reverse. Thus, as the plates were lowered into the bath no meniscus formed between them until this least periphery on the single plate was reached; thence the meniscus slowly rose between the plates (time of the order of 1 minute) until it reached its equilibrium height equal to the capillary rise appropriate to the temperature in question.

Clearly the mobile helium film (thickness $\sim 10^{-6}$ cm) is the agent which feeds the liquid via the surface of the lower plate into the volume between the plates. Actually, this process must involve a fairly complex balance since the meniscus loses liquid both by evaporation and also from the mobile film which forms there. Naturally, we checked to see whether this process occurs in He I; it does not.

In addition, if, with the meniscus between the plates, the latter are suddenly raised so that contact with the bath is broken, the meniscus then falls (in He II) and liquid drips from the sharp tip of the lower plate. But in He I the meniscus "stays put" for a considerable time and only slowly drops by evaporation (this is true also of water). This, of course, is a variation on one of the well-known beaker experiments of Daunt and Mendelssohn.

The above results appear to have some interesting practical implications. Thus it appears that, when the mobile film is constrained to flow through a narrow channel (as wide as 75 microns in some of our runs), bulk liquid is formed in this channel. A number of experiments[1-3] involving He II or superfluid He^3-He^4 solutions have made use of narrow channels in the form of capillary leaks and, up to now, it has always been supposed that only the film passes through such channels whereas, most probably, they held bulk liquid. The interpretation of such experiments is, therefore, open to some doubt. In view of the fact that the bulk

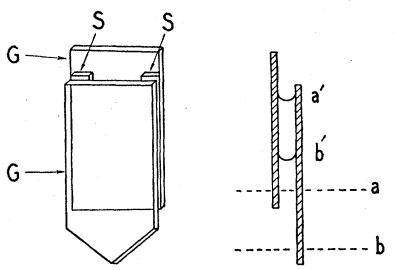

FIG. 1. Isometric view of the glass plates plus a vertical cross section through the center line.