

Solid Staters Study Fluctuations in Superconductors

How do superconductors act in the narrow transition region, as they become normal conductors? During the past year many theorists and experimenters have been answering this question by investigating the fluctuation and critical properties of superconductors.

The macroscopic theory of superconductors, formulated in 1950 by Vitaly Ginzburg and Lev Landau, was an outgrowth of the more general Landau theory of second-order phase transitions. In the general theory an order parameter characterizes the ordered phase; in the normal state the equilibrium value of this parameter is zero. Many similarities exist between different systems. For example, the order parameter in ferromagnetism can be represented by the magnetization and in the liquid-gas transition by the density; in superfluid helium and superconductors the order parameter is related to the amount of superfluid.

Above the critical temperature T_c of the condensed phase, calculations of fluctuations of the order parameter lead to the Curie-Weiss theory of paramagnetism and van der Waal's theory of gases. For some time experimenters and theorists have been investigating for magnetism and the liquid-gas transition the critical region (very close to T_c), where fluctuations of the order parameter become comparable to the order parameter itself and the Landau theory breaks down.

However, for superconductors hardly anyone hoped to observe any effect of fluctuations of the order parameter above T_c because they believed the temperature interval over which the effect should be observable was about 10^{-8} K or even less.

Then last year at the University of Maryland, Rolfe Glover III, following a suggestion of Richard Ferrell and Hartwig Schmidt,¹ observed that the conductivity above T_c contained an additional contribution from the pair conductivity $\sigma_{\text{pair}} = K/(T - T_c)$. Later Myron Strongin, Otto F. Kammerer, Jack Crow, Richard Thompson and Howard Fine² at Brookhaven and R. O. Smith, Bernard Serin and Elihu

Abrahams³ at Rutgers found similar results.

The explanation for these observations was contained in a paper by Lev Aslamazov and A. I. Larkin⁴ of the Institute of Theoretical Physics, Moscow, written independently of Glover's work. Their paper showed that in disordered two-dimensional systems, which are reasonably well approximated by superconducting films, the effects of fluctuations of the order parameter are considerably enhanced and should be observable. Their theory in fact predicted both the temperature dependence and the coefficient observed experimentally.

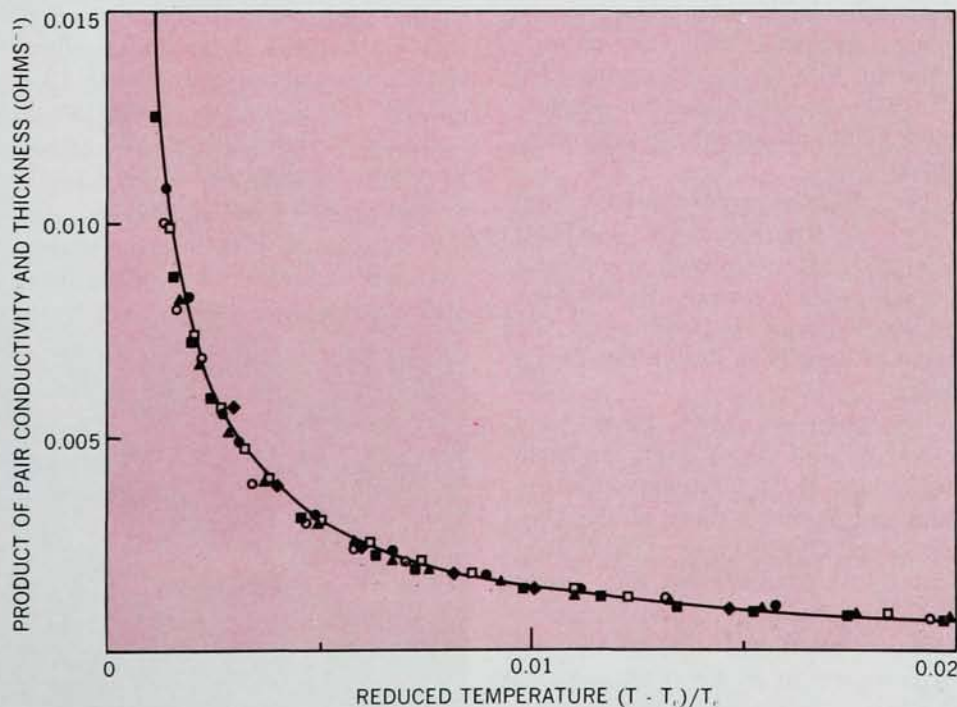
More recent experimental tests have confirmed the qualitative features of the theory. In certain materials, however, marked discrepancies between experiment and theory have been reported.

Lost dimension. Superconductivity is a particularly interesting case to study: The order parameter varies rather slowly in space, and in each di-

mension where the extent of the film is less than the distance over which the order parameter can change, the film can be considered to have lost this dimension. So one, two and three-dimensional systems can be studied using films and very fine wires or whiskers.

Below the critical temperature, fluctuations limit the supercurrent that can be carried by a thin superconductor. William Little⁵ at Stanford considered the nature of the transition and found an effective depression of T_c , even before the interest in fluctuations above T_c began. Ronald Parks and R. P. Groff at Rochester, and T. K. Hunt and James Mercereau⁶ of Ford Scientific Laboratory measured a suppression of the critical current below T_c that was larger than predicted.

Using Ginzburg-Landau theory Jim Langer and Vinay Ambegaokar⁷ at Cornell calculated the fluctuation-limited critical current of a thin superconductor and found the effect to be much smaller than had been observed.



PRODUCT OF PAIR CONDUCTIVITY AND THICKNESS as a function of reduced temperature for a series of lead-alloy films above the transition temperature. In each case a temperature-independent normal-state conductance has been subtracted from the measured conductance per area. The solid curve is that predicted by the Aslamazov-Larkin theory. Disordered samples are shown by open points and amorphous samples by closed points. Measurements are by D. Naugle and R. Glover III.

W. W. Webb and R. J. Warburton,⁸ also at Cornell, were thus moved to try new experiments. Choosing to observe the transition in highly perfect tin whisker crystals, they found that the effect was at least as small as had been predicted by the detailed theory, but that the tiny effect of intrinsic fluctuations did seem to occur.

References

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Interstellar Medium Has Biological Preservative

Interstellar formaldehyde (H_2CO) has been discovered by a group working with the 140-foot radio telescope at Green Bank, W. Va. They observed the molecule in absorption against many galactic and extragalactic sources. The discovery suggests that all the known ingredients for development of life are present in interstellar space.

Five different molecules have been found in the interstellar medium: H_2O and NH_3 were both recently reported (*PHYSICS TODAY*, March, page 63 and February, page 67); OH, CH and CN have been known for several years.

The observers, Lewis Snyder and David Buhl of Green Bank, Benjamin Zuckerman of the University of Maryland and Patrick Palmer of the University of Chicago, say (*Phys. Rev. Letters*, 31 March) that they found H_2CO in clouds at various distances between earth and the background radio sources in 15 out of 26 positions checked. They conclude that large regions of the galaxy may be filled with clouds containing formaldehyde at densities comparable with that of OH. Its "widespread distribution indicates that processes of interstellar chemical

evolution may be much more complex than previously assumed," the observers say.

It is generally believed that primitive life forms could develop in an atmosphere of methane, ammonia, hydrogen and water. Despite the inability of radio telescopes to observe methane transitions, the presence in interstellar space of water, ammonia and now formaldehyde suggests that methane and a number of other molecules are up there, too.

Giant Scintillation Counter Is Good for High Energies

An overgrown NaI(Tl) crystal makes an excellent detector of all kinds of high-energy particles (including neutrals), according to Robert Hofstadter of Stanford, who spoke at the New York meeting of the American Physical Society. He, E. Barrie Hughes, William L. Lakin and Ingo Sick tested their total-absorption detectors in a secondary beam of electrons and pions at SLAC and also at the Stanford 1-GeV linac.

Although total absorption gamma detectors, in which a large block of scintillator produces a light pulse proportional to the gamma energy, are popular for nuclear-physics experiments, the Stanford work is the first to explore such detectors in the GeV range (*Nature* **221**, 228, 1969). Hofstadter and his collaborators used NaI(Tl) because it has an excellent scintillation yield, a high density (3.7 g/cm^3) and a correspondingly small radiation length (about 2.5 cm). However, for detection of GeV particles the crystals must be huge.

The Stanford detector consists of six separate crystals, whose sizes ranged from 29 to 33 cm in diameter and 9.5–18 cm in thickness. Each crystal is sealed in a thin aluminum case and viewed radially by four photomultipliers. The six crystals are mounted coaxially to simulate one large crystal 69 cm thick along the beam axis.

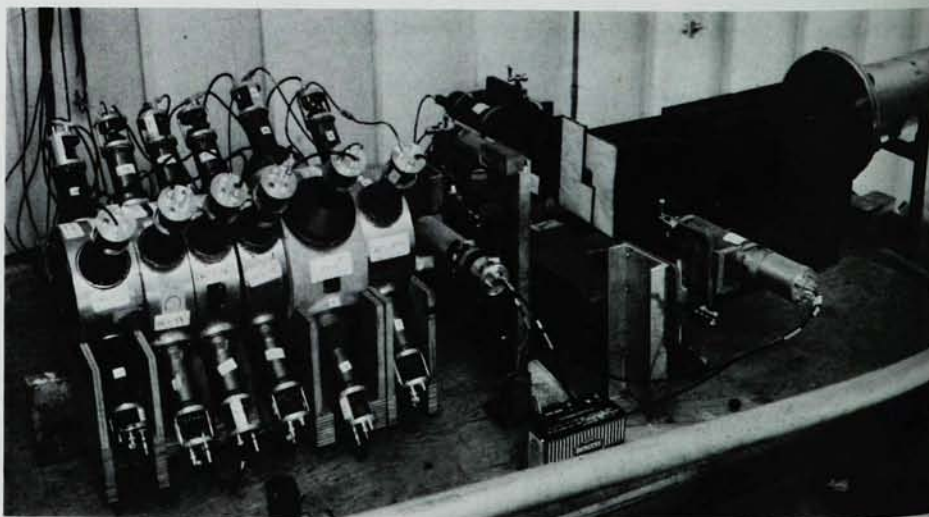
Energy resolution for an incident electron or gamma ray is 1–2% for the energy range 4–14 GeV. Unlike some other devices this resolution improves as energy increases. Hofstadter says that the theoretical resolution of the detector is 0.02%, but a more realistic figure is 0.1%.

The NaI(Tl) crystals can also be used to detect strongly interacting particles, but they must have larger diameters and greater lengths. The Stanford experimenters constructed a total-absorption nuclear-cascade counter by stacking crystals in a 1.5-meter row. Using a tin simulator they studied containment of particle energy as a function of detector radius and length. Results, allowing for equipment limitations, suggest that a TANC counter made with crystals of sufficient size (about 80-cm diameter) should give very useful resolution.

Hofstadter says that there is "virtually no limit to the highest energy detectable by the detector."

Electron Cloud to Produce Highly Stripped Heavy Ions

Positive ions trapped in electron clouds are exciting interest among high-energy and low-energy physicists alike. While those interested in making high-energy protons (and perhaps heavy



TOTAL-ABSORPTION DETECTOR at Stanford has six NaI(Tl) crystals. Energy resolution for electrons or gammas is 1–2% for the energy range 4–14 GeV.