Physical Sciences

Superconductivity without BCS

It was about 45 years from the discovery of superconductivity, the ability of some metals to pass electric currents without resistance when chilled to temperatures near absolute zero, to the formulation of a satisfactory theory of why it happens. The theory is called BCS for its originators, John Bardeen, Leon Cooper and Robert Schrieffer.

Recently what seems to be a new kind of superconductivity has been found, which is called heavy-fermion superconductivity (SN: 4/7/84, p. 212) and seems qualitatively different from the earlier known variety. Evidence is mounting that a new theory, not BCS, will be necessary to explain it.

The latest such datum deals with the absorption of ultrasound by heavy-fermion superconductors. Brage Golding of AT&T Bell Laboratories in Murray Hill, N.J., and six others from Bell Labs, Los Alamos (N.M.) National Laboratories and the Swiss Federal Institute of Technology in Zurich report the latest evidence in the Nov. 25 PHYSICAL REVIEW LETTERS.

They studied the absorption of sound frequencies between 0.9 and 2.4 gigahertz by the uranium-beryllium compound UBe_{13} when it is in the heavy-fermion superconducting state. Just below the critical temperature at which superconductivity sets in, they find the ultrasound absorption rising to a peak and then declining as the temperature drops further. In BCS superconductors this peak does not appear; the ultrasound absorption declines steadily from the critical temperature toward absolute zero. The experimenters suggest that the peak in UBe_{13} appears because the ultrasound triggers some kind of collective behavior by the electrons that form currents and supercurrents in the metal. BCS theory attributes the lack of resistance to a pairing of these conduction electrons: Paired, they can sail through the metal without resistance. However, the paired electrons in BCS theory are in a quantum state (L=0) that does not allow them the freedom for the suggested collective action. This finding seems to indicate that for heavy-fermion superconductivity such pairing has to take place in a higher state (L=1 or higher) that gives them the freedom, as some theorists have already suggested.

Mapping the microwave background

About 20 years ago the discovery of the cosmic background of microwave radiation, which comes to us from all directions and appears to represent blackbody radiation at 2.7 kelvins, brought the Big Bang theory of cosmology out of the shadows and made it *the* standard cosmology. In recent years continuing evidence that the background is strictly isotropic, the same in all directions, has necessitated serious revisions of the Big Bang, the so-called inflationary Big Bang theories.

The latest addition to the evidence, published by Philip Lubin, Thyrso Villela, Gerald Epstein (now at the Office of Technology Assessment in Washington, D.C.) and George Smoot of the Lawrence Berkeley (Calif.) Laboratory in the Nov. 1 ASTROPHYSICAL JOURNAL LETTERS, involved measurements at a wavelength of 3.3 millimeters taken during four balloon flights – three from Palestine, Texas, and one from Cachoeira Paulista, Brazil. They covered 85 percent of the sky and enabled the observers to make a map of the sky that indicates overall isotropy and supports current inflationary Big Bang theories. The well-known dipole anistropy, which is interpreted as being due to a motion of our local group of galaxies and is not a cosmological problem, does appear. According to it, this group is moving at about 550 kilometers per second toward a point at right ascension 10.7 hours and declination −22°. This point is about 44° away from the center of the Virgo cluster, our nearest cluster. *Quadrupole* anisotropies, which have been reported by other observers and which *would be* a cosmological problem, do not appear in these data.

Technology

Rating reverberation

A speaker's thundering voice, echoing through a great hall, can sound dramatic, but too much reverberation often makes it practically impossible for listeners to understand what the speaker is saying. Until recently, evaluating such problems in places like theaters, lecture rooms, churches, train stations and airplanes involved time-consuming experiments and subjective judgments. Now a Danish company has developed an electronic technique for measuring speech intelligibility objectively and quickly.

In the RASTI (rapid speech transmission index) method, a portable transmitter located where a speaker would stand sends out a special test signal that sounds a little like a chugging train. A small receiver placed at the listener's position captures and analyzes the sound, and within 10 seconds calculates and displays a speech intelligibility rating.

The method was tested in a Copenhagen church with a very long reverberation time. The measurements corresponded very well with reports from the church congregation, says Klaus Højbjerg of Brüel & Kjaer in Naerum, Denmark. He described the RASTI method at a recent Acoustical Society of America meeting in Nashville, Tenn. Using the new method, Højbjerg was able to take 400 measurements and get a complete picture in just one day. An earlier study, applying a subjective method, had taken two weeks.

Switching on wave power

A little of the energy in the waves that crash against Norway's rocky cliffs is now being converted into electricity. What may be the world's first wave-powered station was switched on earlier this month at Tostestallen in Norway. It can generate up to 850 kilowatts of power for a small, local electricity grid.

The station includes two different wave-powered generators. One is a steel canister enclosing a set of specially designed turbine blades and open at the top and bottom. As the water level in the tank rises and falls, air is forced upward and downward to turn the blades. In the second generator, water is forced up a long, tapered channel to an elevated reservoir. Overflowing water falls down over turbine blades, causing them to rotate.

A steamy end to seals

Bentonite clay swells when it comes in contact with water. This property makes it very useful in science and industry as a sealing agent. This also makes bentonite attractive as an impermeable barrier surrounding high-level nuclear waste packages or to fill in tunnels, shafts and rooms in deep, underground geologic repositories. Recent experiments, however, show that bentonite, under the conditions likely to be found in a repository, loses its ability to slow the trickle of groundwater toward waste packages.

In mined repositories like those in basalt, the waste package would sit below the water table in fractured rock. Temperatures could rise to 300°C. Any water present would be turned into steam. Reporting in the Nov. 7 NATURE, Rex A. Couture of the Argonne (Ill.) National Laboratory says that contact with steam at 150° to 250°C rapidly and irreversibly reduces bentonite's ability to swell and fill fractures. Reduction of the swelling capacity may also occur at temperatures below 150°C, especially after long periods of time, says Couture. Bentonite used to fill tunnels in nuclear waste repositories could reach high enough temperatures to be adversely affected by water vapor.

"The effects observed here need to be addressed for safe design of nuclear waste repositories," says Couture, "and additional work on the mechanism of alteration may be required."

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