thought to explain the nature of mass.

If the Higgs particle does materialize in a photon collider, the frequency of its creation might yield clues to the shadowy world of physics beyond the bounds of current theory. For one, the rate at which light can convert to Higgs particles could reveal what other particles remain to be found, explains Peskin. So long as these unseen particles have mass, they would "couple" with the Higgs, just as they do with the photon. Their presence should affect how readily one turns into the other. As a result, the rate at which photon collisions generate the Higgs could hint at "the sum of all the particles that could exist," explains Peskin. That sum could help theorists distinguish among different proposed extensions of the Standard Model of particles and forces, as each extension predicts a different set of as-yet-unobserved particles.

How bright a prospect? To Brodsky and other theorists, such potential argues for devoting up to half of the NLC's running time to photon-photon collisions, perhaps by operating it as a photon collider and a particle collider in alternating years. Physicist David Burke, leader of NLC planning efforts at SLAC, agrees the facility should be set up to accommodate photon experiments. He says he'd like to see it include two detectors, one for particle collisions and the other for collisions between photons.

But Howard Haber of the University of California, Santa Cruz, warns that such dual use is "a very difficult thing to accomplish, though I don't want to say it's impossible." One hurdle is inventing powerful enough lasers, notes Burke. "Establishing photon-photon collisions requires lasers we don't have now," he says. Conventional lasers can generate enough power, but only for fractions of a second. Producing an observable number of photon-photon collisions would take lasers with more stamina, explains Lawrence Berkeley's Sessler. One candidate is the free-electron laser (FEL), a device studied during the Star Wars era as a possible anti-missile defense. "Right now, the FEL has neither the peak power nor the average power you need," Sessler says, but with further work, it might do the job.

There's also the problem of rounding up funding for the NLC from the U.S. government and others. And even in the physics community, some factions support alternatives, such as upgrading the country's most powerful current accelerator, the Tevatron at the Fermi National Accelerator Laboratory in Illinois. But physicists eager to probe ever more remote corners of the subatomic world have gotten used to hanging their hopes on dreams, schemes, and speculations. And perhaps it's not so hard to imagine such schemes materializing into real projects once you've seen matter appear out of light.

–**Faye Flam**

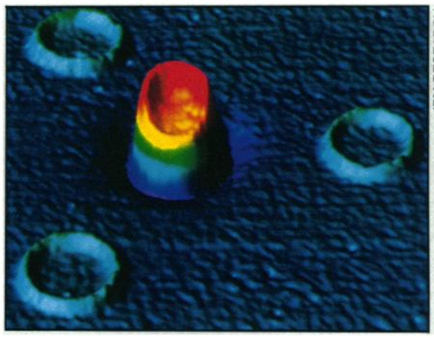
MEETING BRIEFS

Superconductivity Researchers Tease Out Facts From Artifacts

High-temperature superconductivity researchers are a skeptical bunch. But they can be drawn in by a good mystery. And at the Seventh Conference on Superconductivity and Applications earlier this month in Buffalo, New York, about 100 researchers were treated to both hard evidence and tantalizing clues. Among the progress reports on applications of high-temperature superconductors, researchers viewed new evidence pointing to the mechanism behind such superconductivity and a review of strange glimmers of superconductivity near and above room temperature.

Riding the d-Wave

Ever since 1986, when researchers showed that certain materials conduct electricity without losing any energy at temperatures starting at 30 kelvin (-243° Celsius), two camps of theorists have been battling to explain high-temperature superconductivity, or HTS. Both hold that HTS involves electrons traveling in pairs, but they differ on the crucial question of how these pairs form. In Buffalo, one of the two camps, which argues that pair-bonding is the result of magnetic attraction brought about by the electrons' spins, got a big boost from an elegant new experimental result.



IBM RESEARCH

Is that d-wave? A computer image shows a magnetic field emanating from a circular superconducting crystal, designed to prove a mechanism called "d-wave symmetry" is behind high-temperature superconductivity.

At the Buffalo meeting, researchers led by Chang Tsuei and John Kirtley at IBM's Thomas J. Watson Research Center in Yorktown Heights, New York, reported detecting a quantum mechanical phenomenon known as d-wave symmetry in a superconductor made of yttrium-barium-copper-oxide, or YBCO. D-wave symmetry is associated primarily with spin-paired electrons. The alternative theory, which holds that pairing is a product of interactions between the electrons' charge and their surroundings, suggests such electrons will show a different signal, called s-wave symmetry. The new result "seems to be the most irrefutable experiment I've seen that shows it's d-wave," says Ted Geballe, a physicist at Stanford University in Palo Alto, California.

Although s-wave still has adherents, recently the bulk of experiments has been coming up d-wave. Indeed, the IBM researchers followed up on work by Dale Van Harlingen and his colleagues at the University of Illinois that favored d-wave (*Science*, 12 August, p. 860). Despite that experiment's success, critics such as Argonne National Laboratory's Richard Klemm noted that the experiment compared superconducting behavior from edges and corners of a YBCO crystal to produce a signal of d-wave activity, but edges and corners have different magnetic properties, and that may have biased the outcome.

Enter Tsuei and colleagues. The IBM group circumvented the edge and corner problem by crafting superconductors of a circular shape and designing their experiment to show a unique magnetic signal if d-wave symmetry was present. The group arranged three separate wedge-shaped YBCO crystals into a shape like a pie, each wedge like a pie slice. They then used photolithographic techniques to etch away much of the pie, turning it into a ring shape. Each crystal still made up a segment of the ring. Because of the YBCO material's properties, quirks of quantum mechanics within the superconducting crystals spontaneously produce electron "pair waves." Once generated, the waves try to move around the ring. To do that, they must jump between crystals, each of which has a different orientation of its atomic grid.

For pair waves, making this jump may require changing "sign": shifting phase from a peak to a trough as they cross from one crystal to the next. If they make an odd number of sign changes during a single revolution, the result will be a quantum mechanical condition, the result of which is a superconducting current; the current then gives off a unique magnetic signature.

Pair waves with d-wave symmetry can change their sign in the absence of an external magnetic field and thus trigger this scenario. Pair waves with s-wave behavior, in contrast, can only change their sign in the presence of a magnetic field, and so without the field they can't circle the ring and produce a superconducting current. The IBM researchers left out this external field and oriented their crystals to insure that pair waves always made an odd number of sign changes. And as published in the 25 July issue of *Physical Review Letters*, when Tsuei's group performed the experiment, they found the magnetic signature of a supercurrent, supporting the notion of d-wave symmetry.

But critics noted that, as in Van Harlingen's experiment, the signal may have been an artifact of magnetic impurities in the sample. So the group reoriented the three crystals in such a way that pair waves would have to make an even number of sign changes to circle the ring. That would eliminate supercurrent produced by any pair waves with d-wave symmetry. Any remaining magnetic signal from the experiment would have come from magnetic impurities. But in Buffalo Tsuei reported that the team found no signal in the new experiment, further evidence that the signal in their original experiment was in fact a d-wave superconductor.

Those on the research team weren't the only ones who found the new results persuasive. Princeton's Philip Anderson, a theorist who has raised questions about theories involving d-wave symmetry, calls the experiment "very good." University of Illinois physicist David Pines, who has supported d-wave superconductivity theories, says "this very recent development is quite convincing for those hanging on hoping [the signal] was caused by magnetic impurities."

But the battle of the HTS theories has been running for 8 years, and it isn't likely that any one experiment, no matter how elegant, will put an end to it once and for all. Measurements on other YBCO crystals and other HTS materials such as neodymium-cerium-copper-oxide (NCCO) suggest s-wave behavior, says Robert Dynes of the University of California at San Diego. One possible explanation for this apparent contradiction, says Dynes, is that HTS materials may show both s-wave and d-wave behaviors and range from those showing predominantly d-wave, such as YBCO, to others showing largely s-wave, like NCCO. HTS researchers are now hurrying to perform complementary s-wave/d-wave tests on other HTS materials to learn if this is the case. If so, theorists on both sides of the high-temperature superconductivity battle lines will need to forge a compromise.

Unexplained Sightings

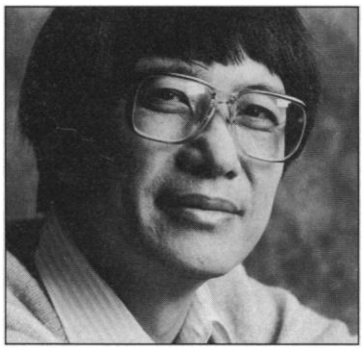
They have many of the hallmarks of flying saucer sightings, and even sport a similar name: "unidentified superconducting objects" or USOs. But these aren't spaceships, they're mysterious glimmers of superconductivity at temperatures near or even above room temperature. Named by superconductivity expert Paul Chu from the University of Houston, these brief glimpses generally don't fulfill all the criteria for true superconductivity and remain virtually impossible to reproduce. Nevertheless, at the Buffalo meeting, Chu urged his colleagues not to discard them like reports of little green men. "All the USOs are tantalizing enough for us not to ignore," says Chu.

RANDOM USO SIGHTINGS

Material	Temperature (degrees kelvin)
Yttrium-barium-copper-oxide	240–340
Mercury-based copper-oxides	250–270
Bismuth-based copper-oxides	250–270
Calcium-strontium-copper-oxide	90–180

Unsolved mysteries. Unproven examples of high-temperature superconductivity have been sighted repeatedly.

Chu and others are ever cautious but suspect there is hard reality behind the glimmers. "I think there's certainly something there," says Lowell Wenger, a superconductivity researcher at Wayne State University in Detroit, Michigan, whose team has recorded more than a dozen USOs. "There's too many different groups of different nationalities of good experimental integrity that have seen these things." In the last 2 years, for example, researchers including a group led by Tomoji and Shichio Kawai at Osaka University in Japan and Jean-Louis Tholence at the Centre National de la Recherche Scientifique in Grenoble, France, have reported measuring superconducting anomalies at temperatures ranging from 180 to 250 degrees kelvin (see table)—far above the present accepted ceiling for superconductors of 133 K at normal pressure.


UNIVERSITY OF HOUSTON

Skeptical inquirer. Physicist Paul Chu is intrigued by USOs.

Confirming such hot sightings has proven to be a difficult task, however. To qualify as a *bona fide* superconductor, a material must start by passing two critical tests. First, superconductors need to transfer electrical current without energy losses due to electrical resistance. Many of the USO compounds do show sharp drops in resistance, suggestive of superconductivity. But most of these compounds then falter when it comes to the second test: counteracting a surrounding magnetic field.

In conventional conductors, the positive and negative poles in the material's own magnetic field will align with the poles of an external field. In superconductors, however, the internal field points in the opposite direction, counteracting the external field's effect. In most USO sightings, this magnetic cancellation is never seen. Tholence's group, for instance, showed a drop in resistance at 250° kelvin in their mercury-based materials, but was not able to see any magnetic counteraction; Chu had a similar experience.

Both researchers suspect the magnetic signals may be there but just aren't being detected. If superconductivity is indeed occurring in these samples, it is likely occurring only in a tiny portion of the material, says Chu. The strength of magnetic signals is related to the mass of the material that produces them; it's possible that the USO magnetic signals are vanishingly small. Devices that measure electrical resistance can pick out a signal moving through a tiny filament of superconducting material in the sample. But traditional magnetic measurement devices, such as magnetometers, are not so precise. It's possible that the magnetic signal from a USO, which counteracts the external field, gets swamped by the signal from the rest of the material, which is in line with the external field, Chu says.

To find out whether that conjecture is correct, Chu and others are attempting to improve the resolution of their magnetic measurements and screen out some of the background from the rest of the material. They are planning to use a scanning tunneling microscope (STM) to search for magnetic signatures from USOs on an atomic scale. Because STMs can look at signals from clusters of atoms, they should help the researchers screen out background noise and focus on the magnetic signal from a tiny grain of superconducting material in the sample. Until that happens, though, researchers are following their instincts that the USOs are the genuine article. "I believe [the USOs] are real," says Frank Owens, a superconductivity researcher at the U.S. Army Research and Development Center in Picatinny, New Jersey. "But it's just basically a feeling. And until other labs can isolate the material and reproduce the results, they'll remain a mystery."

–Robert F. Service