## The layered geometry of the new superconductors

The geometry of the new 90°K superconductor Y-$Ba_2$-$Cu_3$-O is related to an important class of minerals known as the *perovskites*. These minerals contain three oxygen atoms for every two metal atoms. The yttrium-barium-copper-oxide has six metal atoms in its unit cell. Therefore, if it were an ordinary perovskite, there would be nine oxygens. But, in fact, most samples have between 6.5 and 7 oxygens. That is, one quarter of the oxygens are missing in the case of the new high-temperature superconducting ceramic oxides.

These missing oxygens transform what would otherwise be an ordinary three-dimensional crystalline lattice into a unique, two-dimensional layered structure. The unit cell can be thought of as three cubes, piled on top of one another. Each cube has a metal atom at its center: barium in the bottom cube, yttrium in the middle one, and barium in the top one. At the corners of each cube are copper atoms. In an ideal perovskite, each copper would be surrounded by six oxygens in an octahedral arrangement. And the $CuO_6$ octahedra would be linked at each oxygen. Each barium and yttrium would then be surrounded by 12 oxygens.

But x-ray and neutron diffraction studies have shown that the new superconductor unit cell does not conform to this simple picture because some of the oxygen positions are vacant. For example, all of the oxygens in the plane of the yttrium atom are missing. Thus, the yttrium is surrounded by eight—instead of 12—oxygens. And the copper atoms on either side of the yttrium are surrounded by only five oxygens, making a square pyramid. The yttrium can be thought of as being sandwiched between two slightly puckered two-dimensional sheets of copper and oxygen atoms. This is actually layers of square pyramids. This feature has never been seen before.

Oxygens are also missing from the top and bottom copper layers of the unit cell. The vacancies occur in some of the equatorial positions of the $CuO_6$ octahedra, leading to the formation of square planar arrangements ($CuO_4$) that are perpendicular to the other copper-oxygen sheets. The bariums are surrounded by 10, not 12, oxygens.

Actually, the crystal structure is much more complicated than this simple description, much like the case as seen in the recently developed quasi-crystals. For example, some of the vacant or oxygen-deficient sites are occasionally occupied by oxygen, but in an arbitrary man-

1 is literally a computer built inside an air conditioner, with each circuit-board frame containing freon pipes. The heat-sinking of ECL circuits adds to the already low density permitted for fabricated integrated circuits. This bulk further limits systems' speed, since electronic impulses traveling at the speed of light will move only 1.5 centimeters in 100 picoseconds.

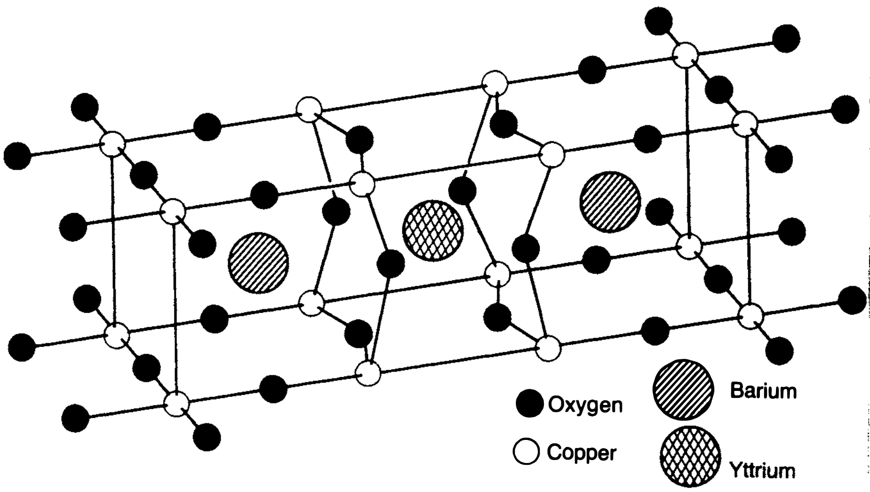
### Most probable development strategy

The first thing that will most probably be done with the new high-temperature Josephson junctions is to construct a new generation of supercomputers. **Table 3** gives a rough cut at what this would look like. The hardware performance of this Josephson junction-type supercomputer would be about 40 times greater than that of the existing top-of-the-line CRAY-XMP. More significantly, the much longer bit widths, 512 as opposed to 64 for the CRAY, and address widths, also 512, means that the existing barriers to fast program composition and parallel processing would be removed. This would increase the computers' applied computing power capabilities by a further several orders of magnitude.

This new supercomputer would then provide the essential tool for design and production of a new generation of chips, supercomputer chips—both general purpose and specialty items. According to leading computer design experts, development of such a new supercomputer is currently the main bottleneck to incorporating a large number of circuit miniaturization techniques currently available. Computers must be utilized in the design of these super-complex integrated circuits. But the existing supercomputers fall short of the required computing power needed. The imminent high-temperature Josephson junction supercomputer would fit the bill by more than an order of magnitude for what is required in chip design. Overall, experts expect that a millionfold increase in single chip power should result with the combined effects of incorporation of Josephson junctions into the chips and the realization of the first generation of Josephson junction supercomputer.

### SDI applications: plasma electronics

While more conventionally minded physicists have been increasingly perplexed by the new high-temperature superconductors, one community of scientists—plasma hydrodynamicists—have had their full expectations realized. These scientists have long predicted that "quantum phenomena" are not fundamentally acausal; that eventually, man could master




ner. Sometimes oxygens are found at other, unexpected positions in the lattice. Distortions also occur, such as in the case in which the yttrium "cube" is crushed relative to the barium cubes. This appears to occur because yttrium is smaller than barium. And that may explain why the oxygens are missing from the yttrium horizontal plane. That is, there is no room for them.

Many other interesting crystal lattice "defects" and "distortions" have also been found. For example, the unit cells normally are stacked in a Ba-Y-Ba—Ba-Y-Ba fashion, but sometimes a yttrium is inserted between them. Sometimes the smallest face of the unit cell, most usually a perfect square, is distorted very slightly into a rectangle. This particular distortion occurs when the ceramic is processed at high temperatures and then cooled. And it would appear that for the first time macroscopic geometry is seen to determine quantum behavior, i.e., the so-called crystal imperfections are producing superconductivity.

quantum phenomena with a sufficiently advanced hydrodynamics. And this hydrodynamics would be closely related to that found in energy dense plasmas, such as those explored for hydrogen thermonuclear fusion energy generation.

In fact, Dr. Robert Moon of the University of Chicago and editor of the *International Journal of Fusion Energy,* has long held that these type of materials, the doped ceramic oxides and rare earth doped ceramic oxides in particular, held great promise for high-temperature superconductivity. Dr. Moon pioneered the use of these materials in a more limited application in terms of developing materials for "cold cathodes." Dr. Moon has developed an extensive theory for a causal, "hydrodynamic" quantum theory derived from the early 20th-century work of Louis de Broglie and the later work of David Bohm.

Dr. Moon's work is also based on the most provocative applications of plasma hydrodynamics to "elementary" particle physics carried out by Prof. Winston Bostick of the New Jersey Stevens Institute and Los Alamos National Laboratory. In fact, the new high-temperature superconductors appear to function in a manner completely analogous to that of energy-dense, self-organized plasma pinches. When intense electrical currents are passed through a plasma, the plasma transforms itself into filamentary, "force-free" vortex structures. This permits the plasma to conduct huge current densities without significant dissipation—like that of a superconductor.

Within the high-temperature superconductor, it appears that internal waveguides are self-generated by the flow of the electron current. These waveguides appear as slight distortions in the lattice and form into a multi-layer, filamentary geometry—like that seen in the plasma pinch.

But this similar behavior goes much further than that of a simple analog. The new superconducting materials offer the ideal external and internal interfaces for operating both delicate diagnostics and sensors, and, monstrously powerful relativistic beam weapons systems. The new superconducting materials offer potentialities for electromagnetic "machine" interfaces similar to that seen for the application of teflon to "greaseless" pumps and no-stick cookware. But in this case, it is high-temperature plasmas, and high-energy particle and laser beams that are interfaced with the minimum of "stick" and resistance.

More specifically, the new high-temperature superconductors would provide the ideal materials for all essential interfaces in high-energy particle accelerators and lasers. The