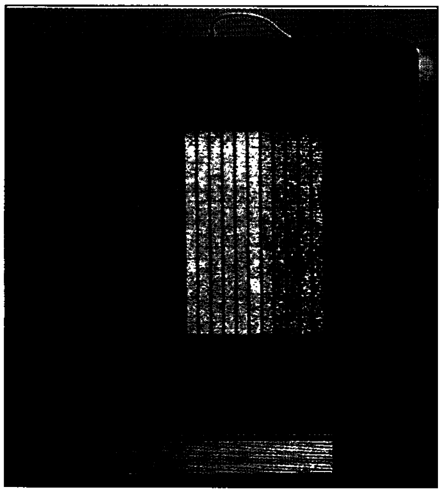
leagues at the Samsung Advanced Institute of Technology in Suwon, South Korea, is the first full-color field-emission display using carbon nanotubes as the electron emitters. "It's an important step forward," says Yahachi Saito, an associate professor of electrical and electronic engineering at Japan's Mie University, who is also working on carbon nanotube field-emission displays.

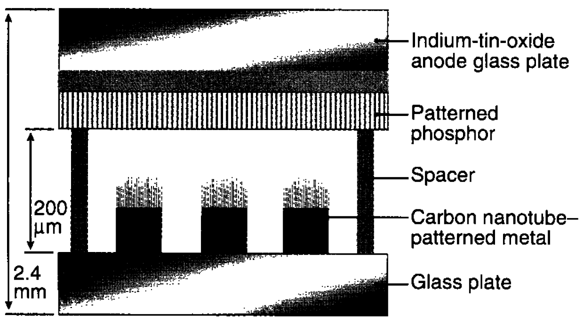
The carbon nanotubes, cousins of the soccer ball–shaped fullerene carbon-60 molecule, are created by passing an arc discharge between graphite electrodes in a chamber filled with helium. The Samsung team mixes a conglomeration of single-walled carbon nanotubes into a paste with a nitrocellulose binder and squeezes the concoction through a 20-micrometer mesh onto a series of metal strips mounted on a glass sheet. As the nanotubes emerge from the mesh, they are forced into a vertical position. The researchers then heat the arrangement to burn off the nitrocellulose binder and melt metal particles in the paste. When the metal solidifies, it binds the nanotubes to the metal substrate. "Getting the nanotubes perpendicular to the substrate and evenly spread out is the key to getting even brightness in the finished panel," Choi notes.

The metal strips with the carbon nanotubes sticking out of them serve as cathodes, running from top to bottom of a glass sheet that serves as the back of the finished display. The front of the display is a glass sheet containing red, green, and blue phosphors and strips of a transparent indium-tin-oxide anode running from side to side (see diagram). The glass sheets are separated by spacers. Once assembled, the edges are sealed and air is pumped out of the display. Each intersection where a vertical cathode and a horizontal anode cross forms a pixel. Each pixel is turned on or off by applying a voltage to its defining vertical cathode and horizontal anode. As with a CRT, an image is formed by setting the individual brightness and color for each pixel. "It's a very impressive display," says Sumio Iijima, a microscopist at NEC Corp.'s Fundamental Research Laboratories in Tsukuba, Japan, who discovered carbon nanotubes in 1991.

Samsung's 4.5-inch (11.4 centimeters) display could be the precursor of a new generation of more energy-efficient, higher performance flat panel displays for notebook computers and wall-hanging televisions. The carbon nanotubes appear to be durable enough to provide the 10,000-hour lifetime considered to be a minimum for an electronics product, and the panel uses just half the power of an LCD to produce an equivalent level of screen brightness. They should also be cheaper to produce than LCDs or other types of field-emission displays being developed, Choi says, adding that the technology also permits larger, more defect-free screens to be made than is possible with LCDs.

Although the Samsung group has earned bragging rights with its full-color field-emission display, which it demonstrated earlier this year at a conference, it's only a step ahead of the competition. Ise Electronics Corp. of Mie Prefecture in Japan has since then shown a similar display based on Saito's work. At least five major Japanese electronics manufacturers are working on the technology, notes Saito, but their progress is a secret. "Only Samsung and Ise Electronics are [being] open about their research," he says.





Flat-out success. A cross section of a flat-panel display, with carbon nanotubes that generate the full-color image shown.

CREDIT: W. B. CHOI *ET AL./APPL. PHYS. LETT.*

Iijima praises the technical advances in the use of carbon nanotubes, but he says that "commercialization is another question." Nanotubes must overcome the huge investment in the manufacturing of LCDs, which continue to fall in price. "LCD technology is improving very rapidly," Choi admits. His field-emission displays are at least 3 years away from stores, he estimates.

–DENNIS NORMILE

HUMAN GENOME RESEARCH

German Effort Stuck In Minor League

MUNICH—When Germany finally began making a contribution in the mid-1990s to the worldwide effort to sequence the human genome and utilize its information, the prevailing thinking in the scientific community was "better late than never." Germany's research ministry stepped gingerly onto the human genome bandwagon in 1996 with a modest \$23-million-a-year program for an initial 3-year period. The investment has resulted in some notable achievements, and several recent reports have recommended major increases in genome research funding. But at a meeting here last week that aimed to celebrate the results of the first phase of the German Human Genome Program (DHGP), researchers seemed to be already suffering from a hangover: Phase two of the DHGP officially began last month with an unchanged budget.

"There's a lot of disappointment [in the community]. This is far from being enough. Compared to what we said we required, we're about 10-fold underfunded," says geneticist Rudi Balling of the National Research Center for Environment and Health in Munich, adding that the pharmaceutical industry in Germany is "adding close to nothing" to the project. Hans Lehrach, a molecular geneticist at the Max Planck Institute for Molecular Genetics in Berlin, says that "Cambridge, Massachusetts, is spending more money than Germany, and just the construction of the Sanger Centre [Britain's main sequencing center near Cambridge, U.K., funded by the Wellcome Trust] was worth about 8 years of German genome research."

Despite its meager resources, the DHGP has made its mark on the international genome program. German and Japanese groups are the driving force behind the sequencing of chromosome 21, which is expected to be the next one finished after chromosome 22, whose sequence was published last week. DHGP researchers are also working hard to unravel the role of the thousands of previously unknown human genes by testing their function in model organisms such as mice or fruit flies. "In many ways, Germany is ahead of us because it centers not just on sequencing but also on how [the sequence information] functionally integrates," says David Cox, a geneticist at Stanford University.

In light of these successes, Germany's main granting agency, the DFG, last June recommended that an additional \$550 million be spent on genome research over the next 5 years. And recently the Association for the Promotion of Human Genome Research, an industry group, together with the DHGP's scientific coordinating committee, argued for an overall annual budget of $280 million. The research ministry's refusal to heed this advice has plunged Germany's genome community into despondency. "There's a real danger that with genomics, just like with microelectronics, Germany is going to miss out on another scientific revolution—which will seriously jeopardize its future as a high-tech country," says Lehrach. "It's like we're on the *Titanic* and nobody's interested in icebergs." Balling admits that the scientific community has to take part of the blame. "Obviously we weren't able to communicate the prime importance of genome research. Space scientists, for instance, succeeded in speaking with one voice. That's something we still have to learn," he says.

At last week's meeting, researchers did express some hopes that, when the genome effort moves from brute sequencing to sifting through the data to tease out the roles genes play in cells and organisms, the DHGP's vice—a watering-can approach to funding—may turn into a virtue. "In the U.S. there are fewer and fewer people with bigger and bigger institutes [that get most of the funding]. For functional genomics that is not the way to go; you don't need gigantic institutions for that," says Cox. But even small, specialized functional genomics groups need funding, and making this point loud and clear in Munich was a big step for the genomics community. Says Cox, "If policy-makers still don't understand [the impact of genome research], there's no hope for them."

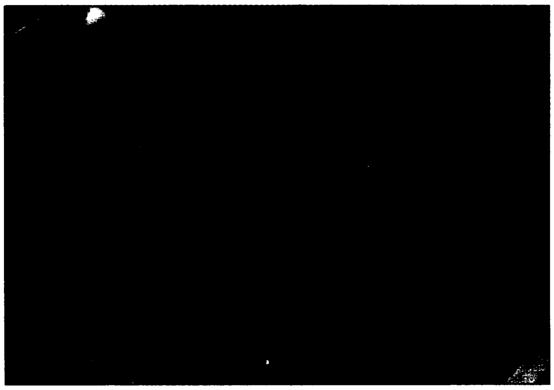
–MICHAEL HAGMANN

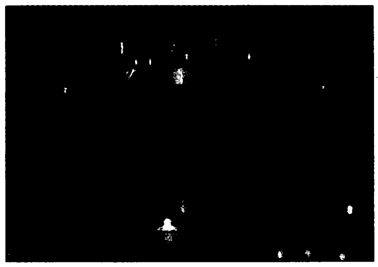
ASTROPHYSICS

Z Mimics X-rays From Neutron Star

When a massive object such as a neutron star or a black hole steals matter from a companion star, the process is anything but stealthy. Material cascading from the star to its greedy partner forms a disk and heats up, illuminating the in-falling material and surrounding gas with a blaze of x-rays in one of the cosmos's more spectacular displays. The spectrum of the x-rays could reveal the temperature and density of the accretion disk and the forces that shape it—if only astrophysicists knew how to read the spectral clues. Computer models are de rigueur, but until recently astrophysicists had nothing on Earth against which to check their results. Now, thanks to an earth-shaking experiment at Sandia National Laboratories in Albuquerque, New Mexico, they do.

The key is Sandia Laboratories' Z-pinch machine, known to its users simply as Z and ordinarily used for defense and fusion research. To anybody who has derived a perverse pleasure from shooting sparks across the terminals of a car battery, Z is the ultimate thrill, the world's greatest fuse blower. At the flick of a switch, an 18-million-amp current surges through a cylindrical array of 300 fine tungsten wires, each just 10 micrometers in diameter. The immense current creates a magnetic field that squeezes the wires toward the center of the cylinder at nearly the speed of light. When the wires collide, they vaporize to create a hot ionized gas, or plasma, that spawns a mighty 120-terawatt blast of x-rays—making Z the world's most powerful x-ray source.





Hell on Earth. At the heart of the Z machine, the world's most powerful x-rays vaporize a small iron foil *(below)* to simulate conditions found near a neutron star.

"When you set off Z the whole building shakes, the ground shakes. You can feel it for a few hundred meters in any direction," says Robert Heeter of Lawrence Livermore National Laboratory in California, a plasma physicist who will present the first results of the effort to mimic astrophysical x-rays with Z at a workshop at the Goddard Space Flight Center in mid-December. "It's very exciting."

Even more exciting for Heeter and his colleagues is what the x-ray blast does to an iron-foil target next to the cylinder. "Iron is a very popular element amongst astrophysicists," says Mark Foord, the Livermore plasma physicist who heads the Sandia-Livermore collaboration along with Sandia's James Bailey. Iron, Foord explains, is easy to spot at x-ray wavelengths and is abundant in space. "It's found in almost every astrophysical body."

As a result, researchers often study iron as a stand-in for cosmic matter in general. But features of the spectrum of highly ionized iron are "notoriously complex" to predict, says Andrew Fabian of the Institute of Astronomy in Cambridge, U.K., which makes it difficult to turn iron spectra gleaned from satellites such as the Chandra X-ray Observatory into astrophysical know-how. "We can't calculate the relation between temperature, density, and line brightness directly; we have to observe it," adds Stanford Woosley, an astrophysicist at the University of California, Santa Cruz.

That is where Z comes in. Literally in a flash, it rips anywhere from 10 to 16 of the 26 electrons off each iron atom, converting the foil into a thin, highly ionized gas whose spectrum mimics that of the iron in the gas cloud of the cosmic x-ray source. "Instead of having a neutron star, we're using the Z machine x-rays as our x-ray source," Foord says. "We're watching what the effects are of those x-rays on our target and trying to reach similar conditions that are found out in space."

The name of the game, says Woosley, is "to study how iron behaves in some of the most extreme conditions in the universe so that when we see emission lines of iron, we can use those lines to understand stars and black holes so dense and exotic that most of their emission comes out as x-rays." One prize, Foord says, will be the ability to work out the sizes, shapes, and compositions of the accretion disks in binary systems. And if astronomers can quantify the relation between the accretion rate and the x-ray brightness, they could estimate how hungrily one partner in a binary system is gathering in matter—a clue to whether it is, for example, a white dwarf or a neutron star.

Fabian thinks iron spectra may not bare all the secrets of neutron stars and black holes, because their motion and gravity will blur the x-ray emission. But he says the spectra "will be very important for modeling the gas in clusters of galaxies and stars." Astronomers would like to study the x-rays emitted by the gas for clues to where shock waves are heating it and where supernovae have exploded.

"What they're doing at Sandia couldn't be done elsewhere," says astrophysicist Francis Keenan, who with his colleagues at Queens University, Belfast, is part of the worldwide consortium of groups working with the Sandia-Livermore team. But the accretion disk of knowledge will grow if funding allows more earth-shaking astrophysics with Z, along with studies on Z's smaller sibling, Saturn. "I think this work in general, of using plasmas in the laboratory to mimic very faraway plasmas in astronomy, is going to be very important over the next few years," says Keenan. **–ANDREW WATSON**

Andrew Watson is a writer in Norwich, U.K.

CREDITS: SANDIA NATIONAL LABORATORIES