Superconductivity: Further Outlook Warmer

by George Short

London's Science Museum recently acquired a new exhibit. It is not much to look at : a cylinder of black ceramic material. But the small company from the London suburbs which make it is proud to claim that it is the world's first high-temperature superconducting solenoid.

Superconductivity is the property of certain materials to lose all electrical resistance. The phenomenon was discovered by the Dutch physicist Heike Kammerlingh Onnes, who announced in 1911 that mercury becomes superconductive when cooled to a very low temperature, about four degrees above absolute zero (4 K).

It soon emerged that a number of metals become superconductive when cold enough. In every case the temperature required was only a little above absolute zero, attainable in practice only by immersing a specimen in liquid helium, which boils at 4.2 K at atmospheric pressure.

Having to reach such a low temperature was inconvenient but did not preclude what seemed at first to be an ideal application of the discovery, making electrical motors and generators of high power and efficiency. A great deal of the energy wasted in electromagnetic machines is in heat generated through the resistance of their windings by the flow of current. Removing the resistance by making the windings out of superconductive wires eliminates the loss.

Unfortunately, this hope was dashed by the discovery that superconductivity is destroyed when the wire is immersed in a strong magnetic field. Because motors and generators need strong fields to operate properly, the hoped-for improvement seemed unattainable.

Further Research

Nevertheless, superconductivity was a fascinating and unexpected effect. For that reason alone it became an important subject for physical research, and more was discovered.

What makes a superconductor lose its resistance? At first it seemed likely that at the very low temperatures involved the atomic structure of the material arranged itself in a perfectly ordered form, electrons could then, it was argued, move through the empty space between the atomic nuclei without colliding with anything and losing energy. But the explanation is far more complex.

One interesting aspect is that the electrons which mediate superconductivity appear in what are known as Cooper pairs, with opposite spins. Subtle quantum effects are involved, too.

Loss of electrical resistance is only one of several changes that take place when a superconductor is cooled below the critical temperature at which resistance disappears. There are striking magnetic effects : the permeability of the material drops to zero and magnetic flux in the material disappears; the thermal conductivity increases sharply.

The phenomenon of electron tunnelling, whereby electrons are able to penetrate barriers which classical physics once deemed impassable, is particularly important. Professor Brian Josephson at Cambridge University, who gained a Nobel Prize for his work, predicted and demonstrated that when two superconductors are separated by a very thin insulating layer electrons are able to pass through the insulation even when there is no electromotive force to drive them. If a driving voltage is applied, oscillations are produced at a frequency which depends only on the voltage and two well-known physical constants, Planck's constant and the charge on an electron. One implication is that if the frequency is measured the applied voltage can be calculated. This means that a Josephson junction, as it is now known, could provide for the first time an absolute measure of the volt.

A piece of yttrium barium copper oxide superconductor floats above a strong permanent magnet.

Niobium Tin

About half a century after superconductivity was discovered another finding suddenly renewed hopes of putting the effect to practical use. This was the possibility of making metallic alloys that would stay superconductive in very high magnetic fields. Alloys of niobium and tin are now used in powerful electromagnets.

An electromagnet of normal construction has the unenviable quality of manifesting zero efficiency, for all the energy in the driving current is dissipated in the resistance of the coil wire. If this resistance were reduced to zero by using superconductive wire, the ends of the winding could be connected together, leaving the energising current to circulate for ever without external help.

The idea is so attractive from the engineering point of view that it is worth going to the expense of installing liquid helium refrigeration to keep the coil cold. The energy saved by abolishing coil resistance more than pays for the cost of refrigeration. At any rate, that is so in the applications for which superconducting solenoids are used. These include field coils for nuclear magnetic resonance body scanners, chemical microwave spectrometers and large particle accelerators. The wires used for the windings are composite : the superconductive alloy parts are bonded to copper conductors. If, as can happen, a small part of the superconductor is overloaded and reverts to ordinary conductivity the copper acts as a temporary low-resistance bypass until it cools down. Suitable alloys are being made in the UK by IMI.

Superconducting coils have been proposed for use in hovertrains. The idea is to use superconductive electromagnets to suspend the train in the air only a short distance below an overhead track. In this way friction could be minimised and the train would glide along smoothly at high speed.

A less futuristic use of magnetic levitation is in a superconductive bearing. One consequence of the magnetic properties of a superconductor (or, rather, its anti-magnetic properties) is that a magnet brought near to a piece of superconductor experiences a repulsive force. Given a suitably shaped superconductor, this repulsion can keep the magnet floating in the air. So, if the magnet is an axle, it can be rotated virtually without friction. On a small scale such a low-friction bearing could be very useful in gyroscopes for navigational instruments, where frictional drag is a source of error. On a larger scale, a combination of superconductive coils and floating axles would be useful in electric motors and generators.

Electronic Applications

It is hoped that with the arrival of 'high-temperature' superconductors many of the possible low-power applications worked out with liquid-helium-cooled devices will become much more practicable.

The new superconductors work at temperatures above the boiling point of liquid nitrogen (77 K or — 196 C). Liquid nitrogen is relatively cheap and safe. One litre of liquid helium costs around four US dollars, is expensive to store and tricky to handle. Liquid nitrogen in Britain is cheaper than beer and easy to handle. At a recent demonstration at the Royal Society in London, researchers on superconductivity from Birmingham University, in the English midlands, stored it in ordinary vacuum flasks of the kind used at picnics and poured it out for use into throwaway plastic cups.

Extremely Sensitive

Resistance in communications engineering brings with it another penalty : noise. Any resistance in an amplifier generates noise, which sets a lower limit to the amplitude of signal which can be detected. Below that limit the resistance noise drowns the signal. For satellite and deep space communications it would be attractive to reduce amplifier noise by incorporating superconductors into the early stages of receivers. Some liquid-helium-cooled devices are in use now; liquid-nitrogen-cooled amplifiers should enable the cost to be reduced and the field of application widened.

One amplifying device already achieved in liquid-nitrogen 'high-temperature' form, at Strathclyde University, Glasgow, is the superconductive quantum interference device, or SQUID. A SQUID is essentially an extremely sensitive detector of changes in magnetic field strength. Its uses range from military to medical. A SQUID can, for instance, detect submarines by monitoring the changes they produce in the Earth's magnetic field in their vicinity. It can monitor blood flow (blood is magnetic) when placed near a blood vessel.

In radio, superconductors could by used to reduce the size of aerials which are usually made in dimensions that bear a simple relation to the wavelength. The ubiquitous half-wave dipole is an example.

Attempts to reduce the size to a very small fraction of a wavelength are vitiated by a sharp reduction in the aerial's ability to radiate signals. This ability is described in engineering terms by saying that an aerial has a certain radiation resistance. A resistance absorbs energy and the radiation resistance of an aerial is really a fictitious quantity which describes the aerial's ability to launch energy into the space around it. Aerials much shorter than a wavelength have very low radiation resistance.

—Spectrum

CORRECTING THE AGE OF THE UNIVERSE

COSMOLOGY as the science of the creation, development and dynamics of the universe has in this century made the decisive step out of the world of speculation into the empirical world of scientific testability. The first scientist to tackle the question of the creation of the universe was none other than Albert Einstein. The Bonn model has now caused a surprise by providing a new hypothesis in this area.

Recognized as a genius and one of the century's greater minds, Einstein, provided with his equations the first scientifically testable model of creation in his 1917 general theory of relativity, which is based on the equivalence of gravitational and inertial masses. The physicist maintained that this model described a steady-state universe throughout eternity, in which the cosmic dust clouds, galaxies and stars are spread homogeneously throughout infinite space. Since then, all cosmic standard models have been based on Einstein's undisputed, famous field equations, because a multitude of experiments have always confirmed them; to date however, these equations have not been applied in their full forms.

The new "Bonn model" now goes further than just correcting an incorrect assessment made by the great physicist. Professor Wolfgang Priester from the Institute for Astrophysics and Extraterrestial Research of the University of Bonn, together with his colleagues, Dr. Hans-Joachim Blome graduate physicist Josef Hoell have developed a model of the universe which provides a surprising answer to the previously unsolved questions concerning the creation of the star systems and the time this probably required. According to their hypothesis the universe is twice as old as the previously accepted 13 to 20 billion years; it has been in existence for 30 plus or minus 5 billion years.

In the opinion of the three cosmologists the galaxies — those giant star systems to which our own Milky Way belongs — required this length of time to become what they are today. All of these galaxies were born in the Big Bang, which set in motion the creation of matter and which led to a very rapidly expanding universe. In this universe the elements hydrozen and helium, which were formed directly one after the other, must have spread out homogeneously, becoming ever less dense in the process. It must also have been due to this rapid expansion that matter in the form of gas clouds was prevented from amassing in large spiral nebulae or galaxies in which star systems could be formed.

According to Priester's interpretation, the galaxies could never have come into being within the time assumed up to now to be the age of the universe if it had expanded since its explosive starting phase at the same rapid rate. The model based on computer calculations thus predicts an almost quiescent phase, a certain "freezing " of the expansion of the universe. This gave matter time to condense to star systems, before an even faster expansion set in. According to Priester, "In our model the universe will continue to expand forever into the future."

While physicists have, to date, exclusively used — in accordance with Einstein's recommendations — the shortened form of the equations for their calculations, the scientists in Bonn have been experimenting with the supplement they rediscovered a few years ago: the cosmological constant lambda. This constant was previously always equated with zero, because of its obviously extremely small value. The "power" of lambda now, however, according to the experience of the Bonn research team, describes the decisive effect on the temporal course of the expansion speed of the cosmos and determines the expansion rate, which is known in the scientific community as the Hubble constant in honor of the American astronomer Edwin Hubble.

In 1929, Hubble showed that the star systems move through the universe in an astounding fashion: the further away from the earth a star is, the faster it moves away from our planet. The Hubble constant is the proportional factor between the speed with which an object in the universe moves away from an observer and its distance from that observer. This speed is given in kilometers per second, the distance in megaparsecs, whereby a single unit equals 3.3 million light years or 30×10^{12} kilometers.

The exact value of this constant is to be determined using the American Hubble Space Telescope which was put into orbit in the spring of 1990. The "Bonn model" assumes that this Hubble constant has the value 90. It is based on American measurements, the results of which agree within error limits with those of an investigation carried out in Bonn.

—(GRS)

Electronic Mouse Nibbles into Art

by Prakash Chandra

NEW DELHI : It was inevitable. Computer art had to arrive one day.

Now India's famous painters are all using computer graphics software.

Two years ago Abhay Mangaldas — who runs a computer graphics unit — and Sonal Zaveri, an art enthusiast, initiated computer-aided art projects. It was endorsed by the country's leading artists.

They say that the project has been conceived and executed over two continents. The painters have now before them a formidable array of possibilities and an unimaginable freedom on screen to draw, apply colour, animate, smudge, invert, blend and distort.

Now the first canvases have arrived from England. What the painters had created on a Macintosh 2 personal computer in Bombay was encoded on to diskettes and taken to another computer unit in London where the image was transferred onto large canvases.

The result is a unique collection of 24 acrylic paintings which were recently unveiled. It was called "State-of-the-Art."

The artists say that computer art on canvas has never been done before. "Painters in Europe and the US have been using the computer to create works on paper, but what we have done here is something new."

One of India's famous painters, Akbar Padamsee, is one of the prime movers of the project and shuttles between studios in Paris and Bombay. "We have a great future," he says.

"Only the computer's graphic potential has been utilised by painters in the West till now. But Indian painters have done something unique. We have used the computer to create actual canvases," says another well-known painter, M. F. Hussein.

This unique art project was born out of sheer boredom. Both Mangaldas and Ajay Sharma, who owns Prism Graphics, were troubled by routine assignments like designing graphics and setting type for publishers and other commercial clients.

Nothing exciting about that, they said. No great future in it either.

So they came up with the idea of roping in painters to create computer-aided art. Hussein admits: "In the beginning I just wanted to run away. Gradually, however, more and more Indian artists overcame their hesitation. This unusual project took off."

Mangaldas combined elements from a number of graphic software programs to create a hard disc program for use by artists.

The painters were reluctant to use computers for creating a work of art. Eventually, they agreed to experiment on a computer screen.

According to another painter, Laxman Shrestha, "I was very suspicious in the beginning. For three days I just sat and watched my wife Sunita work on a computer."

The artists needed cajoling and guidance. Their frayed tempers had to be calmed down. They were used to facing a blank canvas with a handful of colours.

But they have now 16 million colour shades, a menu under half a dozen categories, a tool box with 32 basic functions and an endless variety of permutations and combinations.

As one artist summed it up, "We had unimaginable freedom while working on the screen — to draw, apply colour, animate the drawing, multiply the image, scan another drawing or painting onto it, smudge, distort, invert, blend colours, introduce screens, and so on.

"The possibilities were endless to experiment at every stage, store what had already been done, or even go back to the original if the experiments were unsuccessful."

There also a choice of controls — a pen-like joystick on a magnetic board or an electronic "mouse" on a rubber pad. "It was so fascinating, the computer was like a toy in our hands, and sometimes we accidentally got effects we hadn't even visualised," observes Navjot, a respected painter.

The project grew in scope even as work was in progress, Zaveri and Mangaldas, who set up the new company Brahma to promote computer-aided art, at first attracted painters with the promise of creating low-priced, multiple-edition graphic art on paper.

But Mangaldas stumbled onto a new process developed by an Australian computer engineer and used till now mainly for creating theater or shop window backdrops — transferring an image from a diskette to a canvas by spraying water-based acrylic inks through computer-controlled jets.

The spray jets contain only the four primary colours, which combine according to the electronically-coded data on the diskette to create a variety of colours and shades.

The acrylic ink is guaranteed not to face or crack for 100 years, an unprecedented assurance in an art market where complaints are heard about deteriorating oil paintings. The result, as Zaveri describes it : exclusive electronic canvases.

Some of the painters sell their work for no less than 200,000 rupees (US $16,000) for a large-size painting. The minimum is something like 15,000 rupees (US $1,200) or 20,000 rupees (US $1,600)

The question is whether the buying public will accept computer-created art.

The artists are quick to explain that the use of computers has raised costs. Prices have been pushed up. And they believe that computer-aided art will sell at prices even higher than what the artists' normal canvases fetch.

Some painters like Padamsee and Shrestha have emphasised the pixilated qualities of the image, introducing an abstract element in the nudes and mountainscapes.

Others like Manjit Bawa and Atul Dobiya have used contrasting luminous and dark or flat colours to recreate images reminiscent of their oil canvases.

Hussein has utilised the computer to let loose a miasma of rich, dark imagery, while Navjot has taken advantage of the facility to reproduce images in her brooding figurative studies.

Prabhakar Barve is the only painter who used the computer just to visualise the image, transferring it onto canvas by hand with enamel paint.

Of the other painters, some refused to touch the canvas after it was painted except to sign their names, while some worked on it further with a brush.

A gallery owner here told me : "This art has vast potential. It will try to cater to the middle class. But if it remains uppish, then why talk of computer graphics?"

Younger artist are rather exited. The electronic mouse may probably nibble its way into the history of art.

— Depthnews Asia

Libya Tackles Screw-Worm Fly

THE new world screw-worm fly, which has heavily infested livestock in Libya, may soon see its days ended.

The fly attacks all warm-blooded animals with any form of open wound, even a small tick bite. It causes infection, leading to sickness, debilitation and, if left unchecked, death.

In North Africa alone the pest, if it continues to spread, could affect some 70 million head of livestock, with disastrous consequences. Previously confined to the Americas, the screw-worm fly made its first appearance in North Africa in 1988.

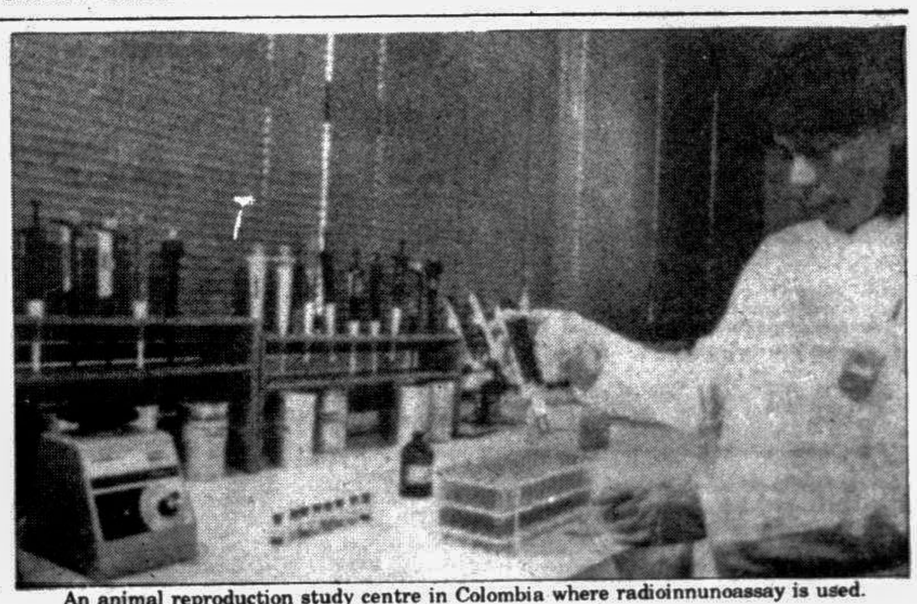
So far, over 10,000 cases have been detected and are being treated. In addition, 12 human cases have also been reported.

A turning point is now being reached in this threatening situation with the arrival in Tripoli on December 16 of 3.5 million sterile Mexican screw-worm flies.

As a result, the pilot programme of the International Fund for Agricultural Development (IFAD) for the biological eradication of the screw-worm infestation will go into action in Libya.

The US$2.9-million programme, co-financed by the African Development Bank (ADB) and the United Nations Development Programme (UNDP), is executed by the Food and Agriculture Organisation (FAO) as the technical agency. The International Atomic Energy Agency (IAEA) is cooperating in the programme.

The first shipment of screw-worm pupae which have arrived from Mexico have been mass-reared and sterilised through exposure to gamma rays at the Mexican Tuxtla Gutierrez Plant. The technology for screw-worm self-destruction through insect sterilisation is known as Sterile Insect Technique (SIT). Developed in the United States, it has been successfully applied there and in Central America.



An animal reproduction study centre in Colombia where radioinnunoassay is used.

A day or two after arrival to allow time for the flies to emerge from their pupae initial dispersal operations will be made on Aagilat Zone bordering Tunisia. The 5,000-square-kilometre area is one of the most heavily infested of the 20,000 sq. km. in northwest Libya affected by the pest.

In Jan. 1991 the international press will observe the first full dispersal operations by small engine planes and ground surveillance teams. Once completed in two months' time, the IFAD pilot programme will be immediately followed by a larger scale project. The estimated cost is about US$117 million for two years.

The pilot programme will test the effectiveness of this new technology in the conditions on North Africa.

— Depthnews Science

NEW "TEST BAY" FOR EINSTEIN'S THEORY

WITHIN an hour's drive from Hannover", a new "window" to the secrets of the universe is to be opened. At least this is the intention of a German-British research group, assuming that the Bundesministerium fur Forschung und Technology (Federal Ministry for Research and Technology") gives the "green light" for their project.

They plan to construct a gravity wave detector, with which the finest trembling distortion of the cosmic space-time continuum is to be detected; according to the predictions of Albert Einstein such a phenomenon can be triggered, amongst other events, by a violent stellar catastrophe.

The choice of location for this large experiment assembly, with its two perpendicular, diverging laser measuring sections, each three kilometers long, is the area around the capital of the state of Lower Saxony, although the exact location has not yet been decided.

The reason for this choice is the fact that the area is one of the least active seismic regions of the entire world. This subterranean inactivity is also absolutely necessary, according to Dr. Karsten Danzmann, the head of the gravity wave group of the Max Plank Institute for Quantum Optics in Garbing near Munich. This is because the effect being sought for is so small that it almost defies imagination, he reported to the Scientific Press Conference in Bonn.

Thus, according to the theory, something as catastrophic ad the death of a star in a supernova explosion produces compressions and extensions in the space-time continoum having such a small relative magnitude that they are like a single hydrogen atom when compared to the 150 million kilometer distance between the earth and the sun.

The effects of such gravity waves, assuming that they exist, is thus exceptionally small. However, they are also exceptionally penetrative. Because of this, according to Danzmann, it should be possible with their aid to look deep into the core of stellar catastrophes and to see back "to the creation of time and space". The plans for the new instrument have been developed by Danzmann's working group together with Brotish researchers, especially some colleague from Glasgow university.

The realization of the project will probably cost around 150 million DM. The largest portion of this amount is to be provided by the Federal Ministry for Research and Technology. The state of Lower Saxony will contribute 24 million DM, the Max Planck Society twelve million DM and the Brutish partners 18 million DM. The final decision regarding the project is expected to be made in the spring of 1991.

— (GRS)

Cinema-Quality Pictures on Television

ALTHOUGH a high-definition television set (HDTV) with an image quality approaching that on cinema screens was introduced as early as 1989 at the International Radio and Television Exhibition in Berlin, a major disadvantage of this new product was its elaborate, bulky electronics.

In this area too, the most important prerequisite for reducing the dimensions of components was the manufacture of appropriate chips.

These VLSI (very large scale integration) circuits, whose printed conductors are only 1.2 microns apart, allow this complex technology to be made more compact.

At the Heinrich-Hertz Institute of Communications Technology in Berlin, scientists engaged in a three-year research project in cooperation with American and Japanese companies produced the first of these multipurpose chips, modules for converting waves received by television sets into digital video signals.

The development of five more VLSI circuits is to be completed in early 1992. Thus, the key components for future digital HDTV sets have already been designed.