Spin ups sending speed

Data transmission is set to get a whole lot faster,

THE fastest thing before the Internet was the Fax. This could transfer data in a foolscap page in about a minute. The Internet multiplied the speed by some thousands and modern optical fibre networks carry 100 channels of widescreen pictures many times a second. And yet, with business, services, even devices, now in the market for ever-growing data and image transfer, limitations of even the fibre optic highways may prove the bottleneck.

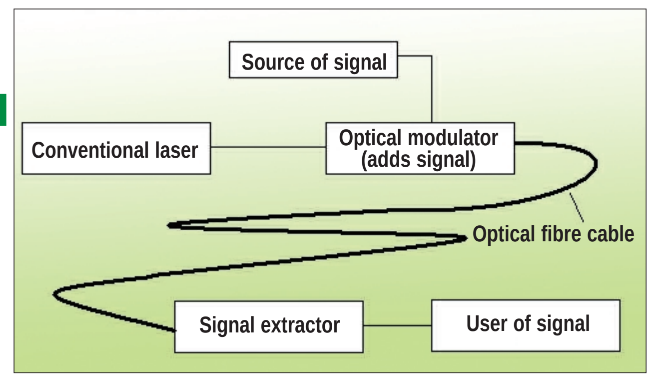
Scientists NC Gerhardt, MY Li, H Jähme, H Höpfner, T Ackemann and MR Hofmann at Ruhr University in Bochum, western Germany, report in *Applied Physics Letters* – a journal of the American Institute of Physics — that they have found a way to boost fibre-optic throughput by many orders!

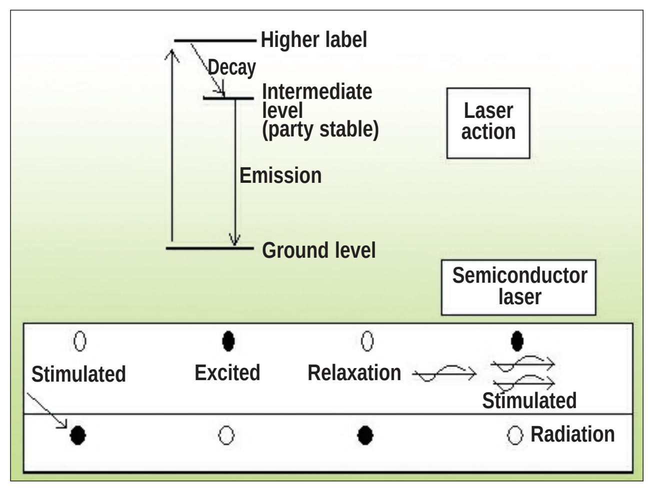
The old telephone and telegraph wires and, later, coaxial cables, carried data by creating *bumps and pits* in electric currents and then reading them at the receiving end. But with the electric and magnetic properties of wires and cables, there were great limits to the number of data streams that could be carried. And then there was the cost of cabling.

The Optical Fibre Cable took care of both deficiencies. Physically, the OFC is a fine glass strand that transmits a beam of light over hundreds of kilometres. While it needs precision construction and protection, the material is just silica, in place of copper, and, in economics, it wins hands down. In working, what the OFC carries is not an electric current but beams of light. The data to be transmitted is superimposed on the light signal, usually as variations in the intensity of the beam, and there can be many frequencies, as carriers of data, on a beam, different colour beams in a fibre and many fibres in a cable! And the signal moves at the speed of light, which is faster than current in wires, and the delay in sending a signal over 1,000 km and getting a response is as little as 11 milliseconds.

For the best efficiency, a the light used is a laser beam is generated using special crystal material at the ends of the cable. Laser light is better, first because it is of uniform frequency. This makes sure that the speed of all components of the beam is the same and there is no distortion. The other reason is that laser light is highly parallel and this also helps pack more information into a carrier beam. And then, when the laser beam is there, the data is loaded on by passing the beam through special materials that can be made more or less opaque by the electrical signals to be transmitted.

Thus, as the electrical signals strike the encoding material, it makes the beam alternately weaker or stronger – at the same pace as the signal – which is what can be detected at the other end to reconstruct the original signal.





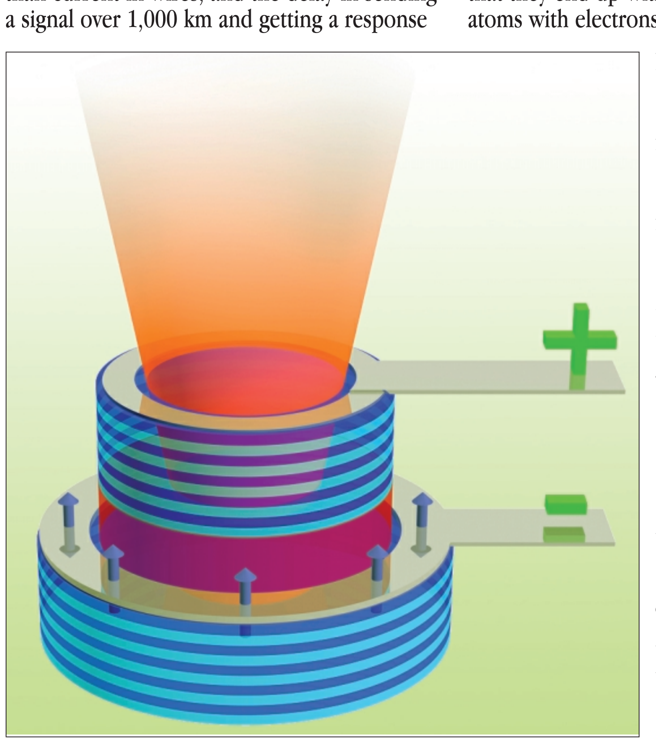
Semiconductor laser

The laser works by making use of special "landings" in the energy staircase of atoms. The electrons, which are negative particles that orbit the massive positive nucleus, can gain energy and jump to more energetic orbits. And once in the higher orbit they quickly "decay" by emitting a photon of light and falling to a series of lower energy levels. In materials that can work as lasers, some of these energy levels are slightly more stable — and the electron may stay there a wee bit longer than usual. Now, if the atoms in such a material are "pumped" by some stimulus so that they end up with a good number or atoms with electrons in these slightly more long-lived states, then there could be an "inversion" – with more particles in a higher state than in the lower states!

In such a condition, if a photon of the energy of the higher state strikes an atom it will decay, emitting both photons — the one that struck and the one emitted — as if generated together; that is, their wave patterns will move forward exactly "in step". If the material is configured so that the emitted light partly reflects back to provoke more of the atoms to decay, there can be a *cascade* of decay and a powerful pulse of photons all in step, which is the laser pulse.

In semiconductor materials, the configuration is such that electrons of atoms in the crystal are loosely bound and can wander about within the lattice. When an electron that has gained some energy leaves an atom like this, it will leave behind an atom with one electron less, which is the opposite of an electron. Like electrons excited to higher energy orbits, such an electron can also fall back to the bound state and release energy by emitting a photon. And in like manner, this emission can be stimulated by a photon of the same energy, in which case the two photons go forth "in step", as in a laser.

With a suitable choice of materials, semiconductors can be made to show "population inversion" and "cascading emission", to work as a laser. The stimulation is usually a stream of electrons in the form of the electrical current that the semiconductor junction carries and semiconductor lasers can be very compact and efficient sources of light for use in OFC.



By injecting spin-polarised electrons in semiconductor based microlasers, modulation speeds can be reached that are far superior to any conventional lasers.

The spin laser

The Ruhr-Universitaet-Bochum scientists used a feature of the generation of light in semiconductor lasers to double up as the signal loading mechanism as well. As mentioned earlier, in the usual course the laser light is generated by the semiconductor laser and this light is loaded with the signal by passing the light through a material whose opacity changes with the signal to be applied. As a result, the speed with which the material responds to the electrical signals becomes the limit of the signals that can be loaded. The time of response is about half a nanosecond, or half a billionth of a second, and this puts the cap on data transfer with the conventional method at well below 50 billion cycles a second.

The Rub scientists used a special feature of electrons, which are used to stimulate the semiconductor laser. Electrons have a property known as *spin*, which is something like the polarity of a magnet. Now, in the conventional laser, the material was stimulated by electrons with jumbled up spin, leading to exciting bound electrons and the emission of photons on relaxation. The Rub scientists used electrons with only one predetermined direction of spin. The result was that electrons in the material were stimulated to two distinct levels of higher energy, with the electrons in the higher level being either with spin "up" or spin "down".

As the two levels have different energies, when there was relaxation there were two frequencies generated — or two laser modes. The two frequencies, when combined, resulted in an oscillation with a new frequency — the difference of the two frequencies. Using the spin polarised electrons, it is possible to create oscillations in the emitted laser light which enable loading signals, which could, in principle, be faster than 100 billion cycles a second.

While this would mean a huge increase in the rate of data transfer possible, it also amounts to shifting the stage of loading the laser with data from after generation to the moment of generation itself!

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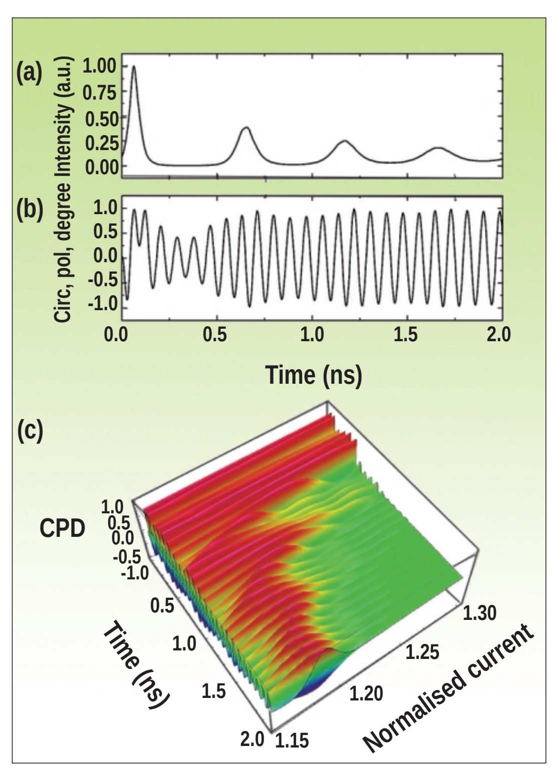


Relaxation oscillations, as shown in (a) mark the maximum speed achievable in conventional semiconductor lasers. By using spin-polarised electrons, oscillations are generated in the polarisation of the light field, which can be much faster than the relaxation oscillations (b). Since the oscillation lifetime can easily be tuned via the current (c), such spin lasers are ideally suited for optical data transmission.

Looking at woodpeckers

Their bone structure could shape design of new headgear, says michael mccarthy

BEING a headbanger doesn't have to be a damaging way of going about things, according to new scientific research on woodpeckers. When they rapidly "drum" on tree trunks, the birds experience enormous stress to the head that would gravely injure humans, yet they are completely unscathed. Now Chinese researchers have, in the hope of finding new approaches to prevent and treat human head injury, investigated how the birds protect their brains from impact damage while pecking wood.

Head trauma is one of the major causes of death across the world. Brain injuries may be caused by an impact or a sudden change in the velocity of the head. However, woodpeckers experience no ill effects even though their beaks hit tree trunks at six to seven metres a second, with deceleration producing enormous forces of up to 1,000G.

The study — led by Yubo Fan of Beihang University in Beijing and Ming Zhang of Hong Kong Polytechnic University — examined how the birds did it, concentrating on great spotted woodpeckers that occur across Eurasia and are the most common species in Britain. Their results — published in the online science journal *PLoS ONE* — show they have complex shock absorbers inside their skulls. The researchers used high-speed video cameras and took scans of the birds' heads to examine bone structure. They found details of the cranial bones and beak — such as the "sponginess" at different places in the skull and the unequal lengths of the upper and lower parts of the beak — were crucial for preventing impact injury. They concluded that the shock absorption system was not based on a single factor but was a result of the combined effect of different morphological features.

They have suggested this combination may be useful in guiding design for new protective headgear.

The Independent, London

Questioning Einstein

New experimental results seem to cast doubt on his famous theory of relativity, writes saswato r das

ALBERT Einstein is a near-mythic figure among scientists, regarded as a god in a branch of human endeavour where gods are rare. (He may well be the most famous scientist of all time.) His fame rests on his theory of relativity, which he began developing in 1905 and completed a decade later. Relativity says that the speed of light in a vacuum, approximately 186,282 miles per second, is the ultimate speed limit. Nothing in the universe can travel faster.

A recent experiment contradicts the "great one" and raises the prospect that he could have been mistaken. In the experiment that has excited the scientific community, physicists at Cern, the giant particle accelerator near Geneva, fired a beam of neutrinos towards a detector in Gran Sasso, 454 miles away. Neutrinos are ghostly particles with a very small mass created in nuclear reactions. They are electrically neutral and don't interact much with other matter; only rarely will one of them be captured in a detector. Using sensitive equipment, the Cern physicists tracked some 15,000 neutrinos over a period of three years. The neutrinos seemed to be reaching the detector 90 nanoseconds (a nanosecond is one-billionth of a second) faster than light.

While this seems like a small discrepancy, it should not occur if Einstein's theory of relativity is correct. Longstanding scientific theories are usually overthrown when results from an experiment prove to be at odds with its predictions. Philosopher Karl Popper called this the notion of falsifiability of scientific theories, and said it was the basis for scientific progress. Such was the case with medieval geocentric astronomy, which was supplanted by a heliocentric worldview, thanks to Galileo's observations.

Einstein himself was motivated by an experiment that disproved a 19th century scientific belief. Back then, it was widely held that light, like sound, needed a medium to travel. Physicists called it the "luminiferous ether". Since the earth revolved around the sun and the sun revolved around the centre of the galaxy, they reasoned that the presence of ether would cause the speed of light to be different in different directions. Albert Michelson and Edward Morley set out to measure this difference. Instead, they found that the speed of light was the same in every direction. In 1887, they published a paper, which went on to influence Einstein.

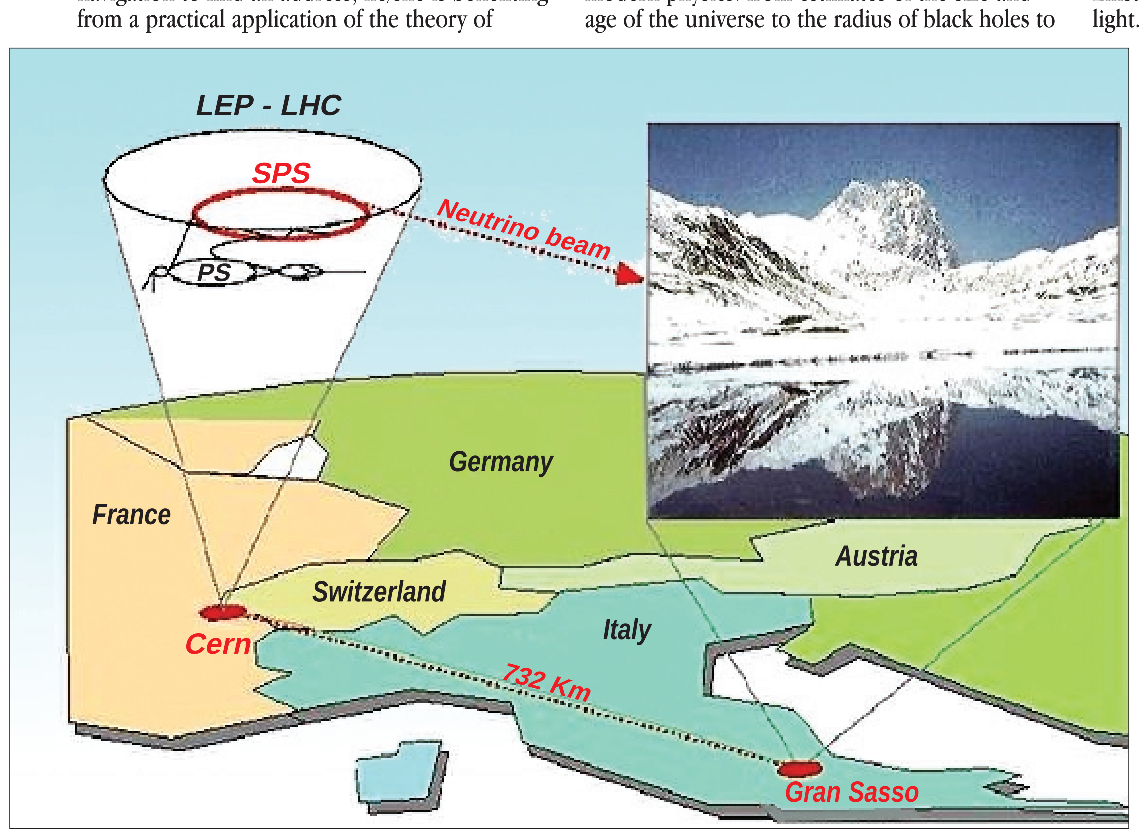
Sometimes a new theory becomes accepted because it makes a seemingly outrageous prediction that is borne out by observations. Einstein had predicted that the gravity of a massive object such as the sun would bend light. In 1919, two teams of astronomers led by Sir Arthur Eddington went to the Southern Hemisphere to observe a total solar eclipse. Normally, given the brightness of the sun's disc, this bending is impossible to observe.

During a solar eclipse, however, the sun's disc is covered by the moon, and Eddington and his colleagues were able to observe the bending of light (it resulted in stars near the sun appearing out of place). If Eddington's observations had not corroborated Einstein's predictions, the theory of relativity, complex and abstruse as it was, would not have become popular. (When Einstein first published his complete theory, it was considered so difficult to understand that only three people in the world were supposed to have mastered it.

On being asked about the truth of this statement, Eddington is supposed to have quipped, "Who's the third?") But even though it is hard to grasp, relativity has proved to be very successful. Whenever someone uses GPS navigation to find an address, he/she is benefiting from a practical application of the theory of relativity. (The satellites that are used to get GPS coordinates have to account for the effects of relativity for GPS to work properly.) Einstein's famous formula about the relation between mass (m) and energy (E), E=mc2 — where the speed of light in a vacuum is denoted by the letter *c* — also comes from relativity. Note how a little matter can produce a lot of energy, since *m* is multiplied twice by *c*, a very large number. It is this formula that led to the nuclear bomb and explains how the sun and other stars produce energy.

In fact, the edifice of modern physics is built on the pillars of relativity and quantum mechanics (the latter explains the physics of the microscopic world). The speed of light shows up all over modern physics: from estimates of the size and age of the universe to the radius of black holes to the power generated by nuclear reactors. Over the years, careful experiments have rigorously tested relativity and quantum mechanics time and again and found no discrepancies — until now.

If it turns out that the Cern/Gran Sasso neutrino experiment is correct, then our scientific understanding is flawed. All sorts of strange things could happen if the speed of light can be exceeded. Causality — the relation between cause and effect — would be affected. Anyone travelling faster than the speed of light would be able to see not a vase breaking but fragments of a broken vase coming together. Faster-than-light travellers could go back in time — say, leave New York for Paris one evening and return the previous day. (To preserve causality, Einstein did not believe in speeds faster than light.)



The experimental team has scrutinised its results and hasn't been able to find any obvious sources of error. Physicists everywhere are scratching their heads. Could it be that another scientific revolution is at hand? Are we witnessing such a paradigm shift? Most scientists believe it is still too early to say. The Cern/Gran Sasso experiment needs to be independently verified. Measuring neutrinos is very hard and statistical methods were used by the research team. These have to be checked carefully. There could also be some hitherto undetected experimental error. What if this effect were limited to neutrinos, which are very exotic particles?

You can bet that physics' brightest minds are scrutinising the latest neutrino experiment results and experimentalists are seeking to replicate them. This is how science works. Should other experiments validate the claim that neutrinos are travelling faster than light, even Einstein will turn out to be fallible.

A version of this article first appeared in the International Herald Tribune.

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