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RAPIFAX

DATE Dec 16

TO Andy Ruina, C/o Hermann Riedel.

FROM Meher Antia

FAX No. 49-761-5142-110

No. OF PAGES (inclusive) 3

Dr Ruina,

Please send me corrections, comments or suggestions by email (MeherAntia@economist.com) or fax to 44-171-839 4092

Thanks for all your help.

Meher.

Meher Antia
The Economist, ENGLAND
FAX: 0044 171 839 4092

Meher; 12/17/97

Your article is fun, nice, as clear as one could hope and generally accurate. Two things

1) Maybe check if Tad McGeer is a mechanical engineer. I think he may have degrees in aeronautical engineering.

2) The name "Mr. Fancy pants" is new to me. Using it as if that is a name we use is not accurate. I have always referred to the device as "The Tinkertoy Walker" since it is made of Tinker toys. ~~I think~~ I think you should get rid of "Mr Fancypants" entirely unless you can write it in as your name for the device. Or if Mike wants to say he calls it Mr Fancy pants he can put it in first person. I don't think he ever used that name while talking to me, so I doubt he does call it "Mr. Fancy Pants", however.

Thanks, ANDY RUINA

Talking Phone: 49 7633 50611

design the best artificial reefs.

Some surfers, however, seem less than grateful. Some, dedicated to a solitary search for the elusive perfect wave, object on philosophical grounds. Others worry about the effects on the ocean environment. Still others fear that the waves will be boring—a concern that Dr Black and his fellow reef-designers dismiss, citing the natural variation of surfing conditions.

Dr Black cannot predict how many days of good surf each year an artificial reef will permit. The vagaries of winds, tides and the size of the swell mean that even the best reef will not produce good waves all the time. But if Dr Black's calculations are correct, artificial reefs will be able to produce good waves more consistently than even the best natural reefs. Soon, everyone may have access to waves fit for a king.

Lasers

Seeing infra-red

THE semiconductor laser is best known for its contribution to the living room. Without a laser small enough to fit on a silicon chip, you would not be able to listen to music on your compact-disc player. In principle, similar lasers might be used for a different set of applications—notably to detect low concentrations of chemicals. But for this purpose they would have to shine not in the red (like the laser in a CD) but in the infra-red. And making semiconductor lasers of this sort is trickier.

To circumvent this obstacle, a group of scientists headed by Frederico Capasso at Bell Laboratories (part of Lucent Technologies) in New Jersey has been working on an alternative device altogether. It is called a quantum cascade laser.

In normal semiconductor lasers, the wavelength—and hence the colour—of the light emitted is directly related to the so-called "bandgap" of the semiconductor. The bandgap represents, for electrons moving about in the material, a range of forbidden energies—a sort of electronic hurdle. Applying a big enough voltage to the material gives the electrons an energetic push over this hurdle. But they soon fall back again, re-emitting the energy as light. Under the right conditions, the light waves emitted by the different falling electrons oscillate in lockstep, which is what gives laser light its unique properties. The smaller the bandgap—the less the energy an electron emits on falling back—the longer the wavelength of the resulting light. Infra-red light has much longer wavelengths than visible red light, and so requires materials with extremely small bandgaps.

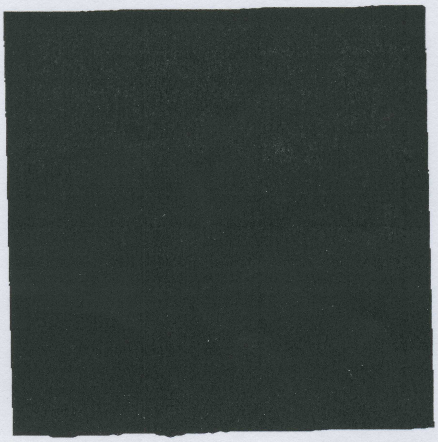
Such materials are difficult to engineer, so Dr Capasso chose another tack. Rather than trying to lift electrons over an energy hurdle and letting them drop back, he and his group designed a material in which electrons could be pushed down a series of small energy steps—hence the name "cascade laser". At each step, the electrons would emit a small amount of energy as infra-red light.

The trick in making lasers this way is to fabricate the individual steps of the cascade by spraying layers—just a few atoms thick—of gallium, aluminium, indium and arsenic on to a surface. In each layer, electrons exist at a different level of energy, determined by the layer's thickness. The differences between these levels are the energy steps in the cascade.

By carefully tailoring the semiconductor layers, the researchers can make lasers that shine in two bands of infra-red light to which the atmosphere is highly transparent—allowing the light to travel a long way. Moreover, such a laser can be fine-tuned over a smaller range of wavelengths simply by varying its temperature. This comes in handy for chemical-sensing applications. Almost all molecules absorb infra-red radiation at certain precise wavelengths; the wavelengths a given molecule absorbs are like a unique fingerprint for it. By tuning the quantum cascade laser and measuring how much of the infra-red radiation is absorbed on its way to a detector, hazardous gases in between can be identified.

In addition, since a single electron travelling through the device emits light not once (as in most other lasers), but many times, quantum cascade lasers are powerful: Dr Carpasso's group has recently shown that they beat conventional lasers by a factor of 20. Above all, they can be made intense even at room temperature, whereas competing technologies require bulky, expensive cooling systems. This gives the quantum cascade laser an edge for applications outside the laboratory.

It could, for instance, be particularly useful in environmental monitoring of smokestacks and car exhausts. The group is also looking into medical applications: the laser might, for example, help to detect molecules characteristic of ulcer formation in a patient's breath. Or any other molecule: if quantum cascade lasers become really cheap, you might never be in danger of leaving the house with halitosis again.



Mechanical engineering

Walk this way

EXCEPT perhaps after Christmas parties, grown-up humans take the ability to walk on two legs for granted. Yet with bipedal walking, evolution has pulled off an impressive feat of engineering, one human engineers have not been able to reproduce in a robot. This may be because the engineers have been barking up the wrong tree.

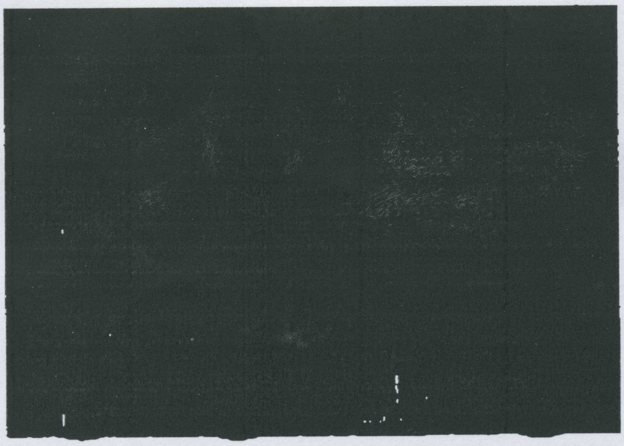
How humans walk has been pondered in great detail. A better understanding of the process could lead not just to more nimble robots but also to better prosthetic limbs and new treatments of muscular diseases that impair walking. But most research in the field has focused on the complicated interactions between the nervous system and the muscles. This may not be necessary.

In the late 1980s, Tad McGeer, a mechanical engineer, built a pair of leg-like objects with no control mechanism, and showed that they were capable of marching down shallow slopes all by themselves, powered only by gravity. This suggested that the design of the body might matter as much as the signal the legs receives from the brain.

Since then, more people have become interested in the mechanics of walking. With his colleagues, Andy Ruina, an engineer at Cornell University in Ithaca, New York, has been building a range of metal legs that can walk by themselves. The simplest model has two straight rods, joined at a "hip", with two semi-circular "feet" attached to the ends of the rods. These can walk down slopes without signals from any brain but without falling over.

But making toys that can walk is only part of what the group does to understand walking. A lot of the walking is "virtual". Mariano Garcia, a graduate student in the group, has written a number of computer simulations to see if a model of walking fits what legs do in practice. The equations that describe the motion of the walker take into account the mass of the feet and hips, the angle of the slope, the angle between the two legs and the force of gravity. Cranking through the calculations, the computer looks for motions that will be stable.

The results show that even a simple pair of legs is capable of a diverse array of gaits. There is the standard one leg in front of the other motion, called "period one" motion because it repeats itself after each step. Change the angle of the incline, and you get "period two" motion, which looks like limping: the same motion is repeated only after two steps. Make the slope even steeper, and the period of the motion keeps doubling—after limping comes staggering, and finally chaotic walking, where the legs take short and long steps at random, never settling down into a pattern but not falling down either. On the steepest slopes the legs finally succumb, and simply fall.



Caption to come

The latest toy from Dr Ruina's laboratory, however, is a walker with more complex behaviour. Named Mr FancyPants (owing to the pair of trousers it sports), it has no knees, but is stabilised with weights around its ankles. Mr FancyPants has the distinction of being the first walker that can walk, but cannot stand still.

This is important, because it means that Mr FancyPants is not stable because it has big, wide base, which is what makes most things stable. Rather, some aspect of the motion keeps it from falling over. In many ways, Mr FancyPants moves like a person who has stumbled, but instinctively knows where to put his leg to avoid taking a spill. Remarkably, Mr FancyPants seems to put its legs in exactly the right place to stop falling just because of the way it is constructed, not because of any complicated signals from a control mechanism like a brain.

The computer model that describes Mr FancyPants' motion shows that it walks in an unstable way. Unstable walking is only possible under the most ideal conditions—even the slightest change will cause the walker to topple over. But Mr FancyPants walks in the real world, where conditions are never ideal. How it does so while remaining stable is something of a mystery.

For a system to be stable, small disturbances must not affect it. For instance, friction acts to stabilise the motion of a pendulum through the air. But stability can also arise from what are known as "nonholonomic constraints". An ice-skater is nonholonomically constrained, for example, because he can move back and forth, but not side to side. So the skater is constrained in a way that a person on ice without skates who can slip and slide where he pleases is not. What Dr Ruina and ~~his colleagues~~ Michael Coleman his student are proposing in a forthcoming paper in *Physical Review Letters* is that Mr FancyPants may be constrained in a similarly nonholonomic way: Mr FancyPants cannot move by slipping and sliding, only by lifting its leg and making contact with the ground as it steps.

A complete model of how two-legged creatures walk will eventually have to include the muscular system, nerves, brains and skeleton. But Dr Ruina has shown that two legs can walk a long way alone, without the guidance of an active brain. Just occasionally, that can be jolly useful.

Title to come

HONG KONG

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