

Quantum modelling of the mind

Some of the best minds in biophysics have been divided on the question of how to model the workings of the human brain. Mainstream research has concentrated on developing complex neural networks to perform the cognitive processes that we call consciousness. However, others, including Roger Penrose at Oxford, have argued that consciousness is in fact a quantum effect and can only reasonably be simulated by a quantum computer.

The big issue in quantum consciousness is coherence time: how long can a superposition of quantum states in the brain persist? For the brain to be a true quantum mechanical system, the coherence time must be at least

1 s. Some say that it is, while others, including Stephen Hawking, say that it isn't. Now, Mark Tegmark of Princeton has weighed in with new calculations of coherence times for two cognitive models.

The first model describes the thought process as "neuron firing", where brain impulses are caused by neurons pumping out sodium ions and absorbing potassium ions. In the quantum picture, a neuron can exist in a superposition of firing and non-firing states.

In Penrose's alternative model, consciousness resides in microtubules – hollow cylinders of protein that act as "scaffolding" to maintain the shape of brain cells. Using techniques from string theory, thoughts can be

modelled as the collapse of a quantum superposition of electrical excitations propagating in a microtubule.

Whether the model involves neuron firing of charged ions or propagating excitations in microtubules, Tegmark calculated that the influence of nearby ions, by collision or coulomb interaction, will destroy the coherence of the superposed states on very short timescales (10^{-20} s for neurons and 10^{-13} s for microtubules) – too short for a quantum system.

"There is nothing fundamentally quantum mechanical about the cognitive process in the brain", said Tegmark. For the neural network community "it's business as usual". AIP

Only 18 clicks of hyperlink separation

Two randomly selected Web pages are on average 18 hyperlinks (or clicks) apart. So says a group of US scientists who used a technique based on power law distributions, borrowed from statistical physics, to investigate the topology of the Internet. The team also predicted that, even if the number of pages on the Web grows by 1000%, any two pages will still be only 20 clicks apart.

Symptoms of supersymmetry

Some particle physicists were excited when they heard rumours that supersymmetry had been found. The rumours were true. However, the supersymmetry in question is not the duality that boldly predicts that every known half-integer spin ("fermion") particle should have an as-yet-unseen integer spin ("boson") partner and vice versa.

A Swiss-German team has analysed in depth the energy level spectrum of gold-196, which has an odd number of protons (79) and an odd number of neutrons (117). Adding

this information to their existing knowledge of neighbouring even-even and even-odd nuclei, the experimenters were able to find correlations in the energy levels that showed that nuclear forces are fermion-boson symmetric – a property known in the physics world as supersymmetry.

This is good news for nuclear physicists, who now have an additional tool to help them to understand complex nuclear spectra. However, particle physicists are still waiting for their supersymmetric day to come.

Quantum non-demolition is demonstrated on a single photon

The first repeated measurement of a single photon has been reported at Ecole Normale Supérieure, Paris. Usually light detection is a destructive process, because photons are absorbed and converted into electrical signals. However, it doesn't have to be that way – the rules of quantum mechanics do actually allow repeated measurements of a quantum object without destroying it. This is called quantum non-demolition (QND) and has been demonstrated for large photon fluxes, but never before for a single photon.

After many years of effort, the Parisian researchers have now mastered the tricky QND technique and have made repeated measurements of a single photon trapped in a niobium cavity. In the experiment, a rubidium atom is passed through the cavity and the photon causes a phase shift in the atom's wavefunction. The phase shift is detected by interferometry. Sending atoms through the cavity again and again repeats the measurement, because the photon remains undisturbed (although it does suffer a phase

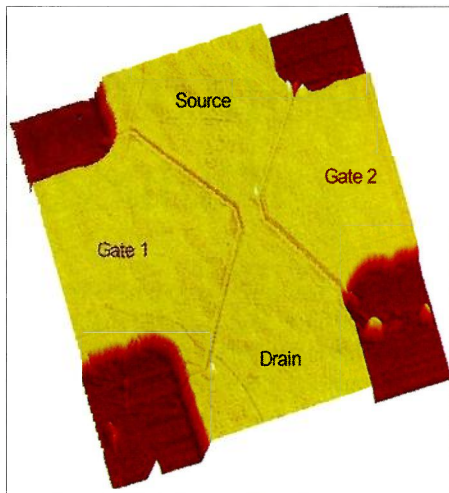
shift – Heisenberg's Uncertainty Principle won't let you have it every way).

This QND technique could become the basis of a quantum logic gate.

Correction

The e-mail address printed in the advertisement for VAT Vacuum Products on p12 of the July issue of *CERN Courier* was incorrect. The correct address is "uk@vatvalve.com".

Flat transistor



Scratches on the surface of a semiconductor, made using an AFM, can influence the conduction of electrons in the material. Shown here are grooves of 110 nm width, which form an in-plane-gate transistor in a GaAs/AlGaAs sample.

Scientists at Hannover and Stuttgart have demonstrated a new nanomachining technique to make tiny electronic components. An atomic force microscope (AFM) was used to etch the surface of a semiconductor and form a micrometre-sized in-plane-gate (IPG) transistor - a device in which the source, drain and gate of the transistor all lie in a single plane rather than the usual sandwich structure.

First the group formed the semiconductor from layers of GaAs and AlGaAs, finishing with a hard layer of GaAs on top. In the plane between these semiconductor layers, a reservoir of electrons collects. Then, by carefully scratching grooves into the surface of the GaAs with the AFM, conduction channels for the electrons are defined.

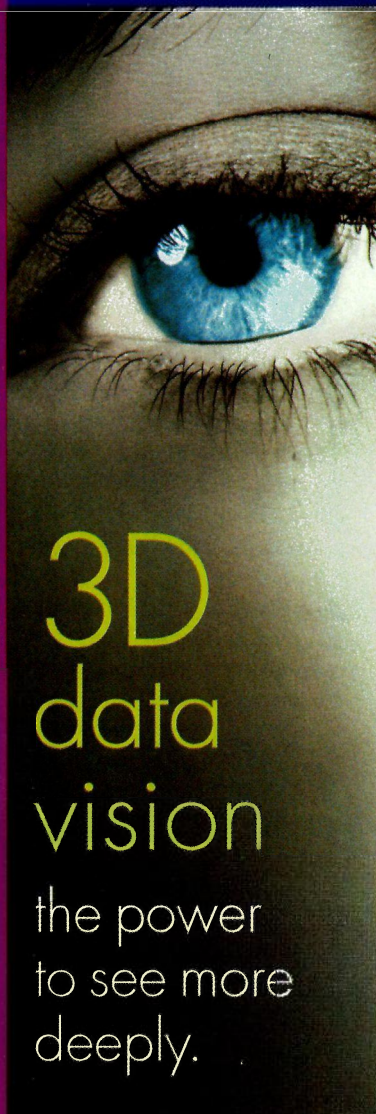
The experimenters were also able to monitor the resistance across the etched lines during fabrication, thereby allowing the characteristics of the electronic device to be tuned very accurately.

With a few more scratches (as tunnelling barriers across the conduction channel), the IPG transistor was transformed into a single-electron transistor that (as its name suggests) is capable of registering the movement of single electrons.

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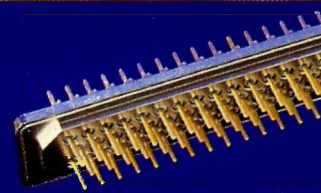
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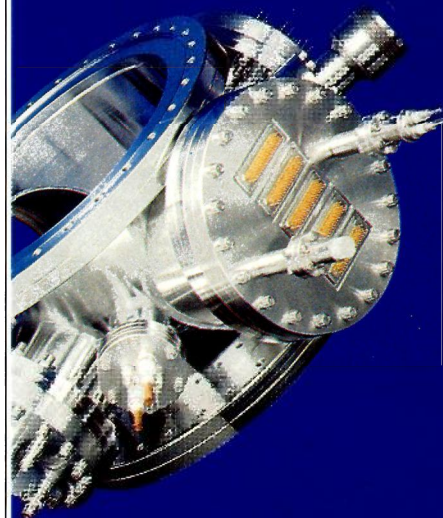
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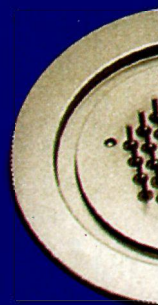


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