Trapping cold atoms in microwave webs

Dramatic progress in the use of laser light along with various combinations of magnetic and electric fields to cool and trap neutral atoms has opened the possibility of studying exotic forms of matter.

For example, theorists have postulated that a gas of hydrogen atoms at high enough densities and low enough temperatures may undergo a transition known as Bose-Einstein condensation. The result would be a peculiar substance — unlike any known form of matter — in which a large fraction of the atoms are in the same quantum state.

Now, researchers have demonstrated that microwave radiation can trap neutral cesium atoms. The success of this particular type of atomic trap offers the possibility of capturing sufficiently large numbers of hydrogen atoms at temperatures near 1 microkelvin to achieve Bose-Einstein condensation.

Physicists Isaac F. Silvera and M.W. Reynolds of Harvard University and their collaborators at the National Institute of Standards and Technology in Gaithersburg, Md., report their results in the May 16 PHYSICAL REVIEW LETTERS.

According to quantum mechanics, particles come in two varieties. Fermions — which include electrons, protons, and neutrons — have spins measured in fractions of a quantum unit. Bosons, which include photons and certain atoms such as hydrogen, have whole-number spins.

Whereas no two interacting fermions can occupy the same quantum state, no such restriction limits bosons. Therefore, a sufficiently cold, dense collection of bosons, losing their individual identities, should undergo Bose-Einstein condensation to a single quantum state.

For more than a decade, physicists have struggled to create this state, and various groups throughout the world have tried different methods of chilling and capturing hydrogen atoms. These efforts have so far proved inadequate for achieving Bose-Einstein condensation.

In a test of a new approach, Silvera and his coworkers load neutral cesium atoms cooled to approximately 4 microkelvins into a small spherical cavity machined from steel. The slowly moving cesium atoms fill a trap defined by a web of laser light and magnetic fields at the cavity's center. This trap is then switched off and replaced by a new magnetic field and microwaves of a certain frequency, which keep the atoms in their lowest-energy spin state.

"You find that the atoms don't escape," Silvera says. "We've demonstrated that the microwaves can actually confine atoms and work as a new type of trap. We want to do it for atomic hydrogen now."

— I. Peterson

The social brain: New clues from old skull

Phineas Gage died in 1861, about a dozen years after surviving a horrifying accident in which an iron rod hurtled through his face, skull, and brain. More than 130 years later, brain imaging techniques have provided a new look at Gage's wounds that adds to emerging evidence on how the brain's frontal lobes facilitate social decision making and a sense of responsibility toward others.

"The damage involved left and right prefrontal [areas] in a pattern that, as confirmed in Gage's modern [brain-damaged] counterparts, causes a defect in rational decision making and the processing of emotion," argue Hanna Damasio, a neurologist at the University of Iowa Hospitals & Clinics in Iowa City, and her colleagues.

The 25-year-old Gage envisioned no such contributions to science in 1848 as he directed the controlled blasting of uneven terrain in Vermont prior to the laying of new railroad tracks. He mistakenly triggered one explosion before an assistant had covered the strategically placed explosive powder with a buffer of sand; the force of the blast threw a 3½-foot-long tamping iron through his head.

Remarkably, Gage regained consciousness almost immediately and walked away from the site with the help of his work crew. Although he remained as able-bodied and intelligent as before the accident, his personality changed irrevocably. Formerly a top-flight worker and popular with peers, Gage began to behave in irresponsible ways. He refused to honor commitments on the job and with friends. He offended others with his sudden tendency to sprinkle profanities throughout his conversation and to otherwise depart from social conventions of the time.

Gage lost his job soon after the accident

Clementine's spin may cancel asteroid visit

Lost and gone forever? Not quite, but the Clementine spacecraft isn't likely to keep an August date with the near-Earth asteroid 1620 Geographos.

A computer problem 2 weeks ago set the craft spinning at 80 revolutions per minute (rpm), says mission manager Lt. Col. Pedro L. Rustan of the Defense Department's Ballistic Missile Defense Organization in Arlington, Va. Engineers can probably slow the spin to 30 rpm, but that would still be too fast to image the asteroid clearly, Rustan says.

Clementine, originally scheduled to pass within 100 kilometers of Geographos on Aug. 31, would have been the first craft to photograph a near-Earth asteroid.

BMDO/Naval Research Laboratory

Clementine spacecraft before launch.

Ironically, the glitch occurred just after the joint military-NASA mission got a last-minute reprieve. Acting under congressional pressure, the Pentagon came up with the $3.2 million needed for the craft to continue on to Geographos after its just-completed moon-mapping mission.

DOD didn't want to pay for the asteroid visit because the flyby deals more with astronomy than military testing, Rustan says. He notes that the department has given less attention to the astronomical parts of the mission. "I feel a lot like a neglected stepchild."

NASA has given little publicity to the low-cost project — in part, apparently, because of the perceived taint of a project that has its origins in the Stars Wars program.

Though Clementine carries 23 new devices, the malfunction occurred in the flight-proven main computer. During a brief communication loss with the ground, the computer accidentally directed four attitude control thrusters, which help steer Clementine, to fire. This emptied the propellant from one of two fuel tanks and set the craft spinning.

Plenty of fuel remains in the other tank, which powers the main engine. But even if scientists can use this engine to slow the spinning to 30 rpm, the probe could take only blurry images of the asteroid and would have trouble even pointing at the rocky body. Clementine may not get any closer to Geographos than several thousand kilometers.

Rustan says his team will try instead to steer Clementine toward Earth's radiation belts. If they succeed, this should further test the durability of the craft's miniaturized detectors. *— R. Cowen* and spent years wandering. He died in the custody of his parents.

The physician who treated Gage in the months after his injury, John Harlow, learned of his former patient's death and convinced Gage's family to have his body exhumed in 1866 so his skull could be removed and kept as a record of this unusual medical case. The skull and the offending tamping iron, which had been buried with Gage, have since resided in a Harvard University museum.

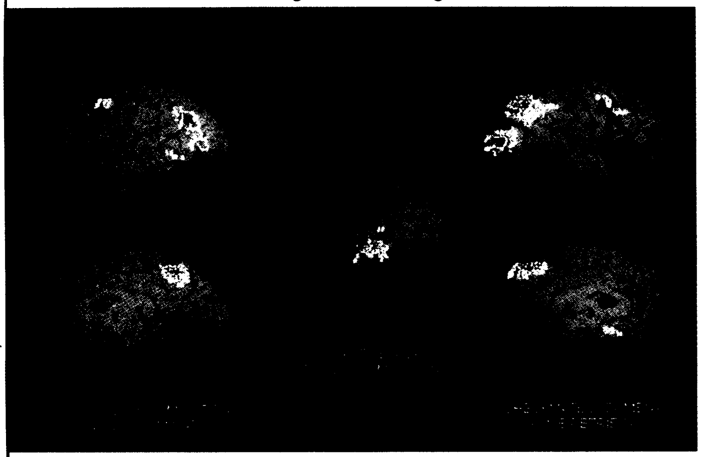
Harlow wrote a paper in 1868 arguing that Gage suffered localized damage to the frontal lobe, an indication that the brain contained structures responsible for "rational" personal and social behavior. But the exact position of Gage's injury could not be determined from his skull alone, and researchers generally dismissed Harlow's theory.

Enter modern technology. Damasio's group created a three-dimensional computerized skull from X rays and measurements of Gage's skull. Their digital version included the tamping iron's entry and exit holes. They then simulated possible trajectories of the projectile through a reconstruction of a human brain that closely matched Gage's estimated brain dimensions.

The rod's most likely path ran diagonally through the middle of the frontal lobes, missing structures involved in language production and muscle control, the scientists report in the May 20 SCIENCE. Gage's injury closely resembles brain damage documented for 12 patients at the University of Iowa, they contend. Like Gage, these individuals display pervasive irresponsible behaviors, as well as difficulty in expressing and interpreting emotions.

Brain circuits that mediate emotion may participate in various types of social decision making, Damasio and her coworkers theorize. This collaborative effort may depend on the cerebral terrain Phineas Gage unintentionally blasted away, they assert. — *B. Bower*

Is this the way Bobby Fischer does it?



P. Nichelli et al./NATURE

These computer-generated images of the brain illustrate how—or actually, where — chess players think. The brightly colored regions reveal that the various mental tasks of chess require the activation of different neural pathways, says Jordan Grafman, a neuropsychologist at the National Institute of Neurological Disorders and Stroke in Bethesda, Md.

He and his colleagues imaged the brains of 10 experienced, active chess players using positron emission tomography (PET). During the PET scans, these right-handed men answered questions about a chessboard displayed on a computer monitor.

The researchers designed the questions to examine increasingly complex problem solving. With each new task, they ignored areas activated by earlier, simpler tasks. In this way, they sought to identify parts of the brain used uniquely for a particular type of thinking.

Players first had to decide whether black or white pieces lay on the board. Then they noted the color of the piece closest to their own, which was marked with an X — a test of spatial discrimination.

Next, they answered whether a particular piece, such as a pawn, could capture a nearby piece. The players had to both recognize the piece and remember how it moves. This so-called rule retrieval involved additional parts of the brain, including the hippocampus and other areas of the left temporal lobe, the researchers report in the May 19 NATURE.

Finally, the players decided whether one move remained to checkmate, based on the configuration of pieces on the computer screen. Only in that last task did they tap the prefrontal cortex, located in the front of the brain, Grafman notes. "We think that's because of its role in planning," he says.

This scheming also tapped an area toward the back of the brain not activated by the earlier tasks. The region seems to draw mental pictures of the chess-piece configurations being thought out by the prefrontal cortex, Grafman says.

These results bolster his contention that the prefrontal cortex is where the brain does its planning and processing of events or thoughts that must be considered as a unit instead of individually. — *E. Pennisi*

Seeing quantum leaps at room temperature

Scientists usually observe quantum effects only at temperatures close to absolute zero. But by looking at materials on a sufficiently small scale, some quantum effects can be detected even at room temperature, say researchers at the IBM Thomas J. Watson Research Center in Yorktown Heights, N.Y.

By and large, the energy levels of electrons in a solid are closely spaced. However, quantum mechanics predicts that these energy levels will become widely separated in certain regions where electron movement is restricted.

Researchers Phaedon Avouris and In-Whan Lyo report in the May 13 SCIENCE that tiny, naturally formed terraces on metal surfaces trap electrons and that these electrons exhibit quantum size effects. The researchers used a scanning tunneling microscope to map the surfaces of both gold and silver sheets on an atomic scale and simultaneously to observe the distribution and energy levels of electrons.

The movement of electrons on some metal surfaces is restricted to two dimensions. Like light, electrons can act as both particles and waves. When surface electrons get stuck on a terrace, they bounce back and forth between the edges in a standing wave; these electrons can still travel parallel to the edges, however. Electrons on the surface of an island, or isolated terrace, also are trapped in standing waves, just as the head of a drum vibrates in an enclosed area when struck.

To see quantum size effects, says Avouris, scientists must look at materials on approximately the same scale as the electron wavelengths. The smaller the terrace, the shorter the wavelengths and the greater the energy and frequency of the electrons trapped there.

If the terraces are small enough — as they are on these metal surfaces — the energy levels of the trapped electrons are so far apart that even the jiggling effects of thermal radiation can't prevent the quantum size effects from being detected at room temperature.

"We are going to have to be more careful when thinking that surfaces are smooth," says Avouris, since these quantum size effects may affect diffusion and surface chemistry. Understanding these effects may eventually lead to new devices and technologies, he adds. — *D. Christensen*

IBM Research

Topograph of 4.5-nanometer-wide silver island (top); image of standing (trapped) electron waves (bottom).