Physics

Light-induced current in a quantum well

Researchers can construct a variety of semiconducting materials by laying down thin, flat layers of different substances to create a stacked structure. Such structures often harbor quantum wells, which keep electrons confined to layers sometimes only 100 angstroms thick. Scientists at the State University of New York at Buffalo now suggest that laser light can direct the motion of electrons within a quantum well to produce a high-density electric current in that particular layer of material. If laboratory experiments confirm the existence of this phenomenon, then researchers could use it to design and build miniature devices in which light pulses interact with electrons to carry information.

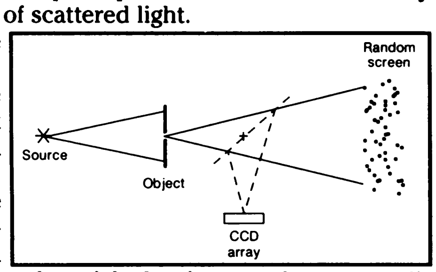
In their theoretical paper in the Dec. 31, 1990 PHYSICAL REVIEW LETTERS, Mark I. Stockman, Lakshmi N. Pandey and Thomas F. George treat the electrons confined in a quantum well as a kind of gas consisting of electrons moving randomly at various speeds. They argue that laser light at the right frequency can slightly alter the velocities of these electrons so that their collective behavior adds up to an electric current in a particular direction. "Researchers usually try to control the movement of electrons between layers," George says. "Here, the electrons stay in the same plane, and we're trying to control their movement in that plane."

Because the current is confined to such a small region of the material, theory suggests that the current density attainable far surpasses that achieved in present-day optoelectronic devices. "That would make it possible to produce much smaller devices," George says.

A rough road to lensless imaging

Unlike a mirror, a rough surface reflects light in random directions. But that scattered light can still carry information. Researchers have now discovered that they can retrieve an image from the light scattered by a rough surface, without using a lens or a curved mirror to focus the light.

To demonstrate the effect, Paul Rochon and Daniel Bissonnette of the Royal Military College in Kingston, Ontario, shine light on a slide (see diagram). Light emerging from the slide's transparent areas diverges and passes through a beam splitter, which allows about half the light to reach a screen with a rough surface. The beam splitter intercepts light scattered back toward the slide and redirects it to a detector, where the researchers find a reasonably faithful image of the object originally depicted on the slide. This image appears as a bright, somewhat fuzzy region superimposed on a dimmer, relatively uniform background of scattered light.



Rochon, Bissonnette/NATURE

"We found we could do it quite easily," Rochon says. "We started with a point source reflected off a white piece of paper. We could actually see the image." With a detector known as a charge-coupled device, they picked up images of more complicated objects, such as letters of the alphabet. Rochon and Bissonnette describe their findings in the Dec. 20, 1990 NATURE.

The researchers are now investigating what factors influence image resolution. They have already experimented with a variety of light sources, including lasers and tungsten lamps, and with different rough reflectors, such as diluted latex paint and microscopic polystyrene spheres suspended in water. Rochon and Bissonnette are also looking into the possibility of detecting an analogous effect when a rough surface scatters sound waves.

Space Sciences

From ring particles to whole planets

Researchers have informally dubbed it the "Velcro effect," referring to the clingy commercial material whose entangling fingers close pocket flaps and serve in a host of familiar applications. But as Artie P. Hatzes of the University of Texas at Austin and his colleagues use the term in the January ICARUS, it describes the effect they think holds together frost-covered ice particles in the rings of Saturn.

In laboratory tests, Hatzes – together with Frank Bridges, D.N.C. Lin and S. Sachtjen of the University of California, Santa Cruz – studied the influence of tiny frost particles on the ability of solid ice chunks to stick together until they build up into larger bits. The scientists used 2.5-centimeter ice balls, swinging them on a pendulum at different speeds to hit an ice block about the size of a brick. Lin notes that separate frost particles may exist in space either because they somehow failed to coagulate into a larger lump, or as the result of previous collisions that broke up larger chunks.

"Collisionally induced cohesion is one process by which small particles may coagulate and large particles may grow in size," the researchers suggest. If the surfaces of both the ice ball and the ice brick are frost-free, the two objects rarely stick together, they found. Using a chilled test chamber, the group produced frost on the two objects by blowing a stream of water-saturated nitrogen gas past both ball and brick.

Even with frost on them, the icy chunks would not stick together at all if they hit at speeds of less than about 0.02 centimeter per second or greater than about 0.1 cm per second, Hatzes says. Within that range, however, the objects almost always stuck together.

Lin thinks the sticking effect may also have played an important part in the origin of the solar system. The cores of the giant planets probably began when particles – either ice or dust – aggregated by sticking together, he says. This suggests that the sticking effect is significant in lumping together small chunks of other materials, such as rock. Lin adds that gravity provides the only other likely way of combining rocky bits into larger chunks, but he says the mass of the particles initially would be too low to start pulling them together to begin the planetary birthing process.

Lithium masquerading as the solar wind

In reanalyzing measurements of lithium ions released in 1984 from an Earth-orbiting satellite, scientists have found that the ions apparently distorted or perturbed the structure of the planet's magnetic field in a way that was earlier attributed to density changes in the solar wind.

Researchers originally had hoped to use the ions as "tracers" of Earth's magnetic field lines after the charged particles were ejected from a satellite called the Active Magnetosphere Particle Tracer Experiment. They failed, however, to detect the ions.

Earth's magnetic field lines often change with fluctuations in the pressure of the solar wind, and they changed during the lithium release. However, the solar wind's density was "very stable" at the time of the ion release, according to a report in the December 1990 GEOPHYSICAL RESEARCH LETTERS by Thomas A. Potemra of the Johns Hopkins University Applied Physics Laboratory in Laurel, Md., Hermann Lühr of the Institute for Geophysics and Meteorology in Braunschweig, Germany, and Wolfgang Baumjohann of the Max Planck Institute in Munich, Germany.

The researchers thus conclude that the increased density of the lithium ion "cloud" distorted the field lines. Potemra says the distorted field was "the first positive indication" inside Earth's magnetosphere of the experimental ion release, which occurred outside the magnetosphere.