A team of researchers at the National Institute of Standards and Technology (NIST) has successfully created fermion-like particles from Bose condensed atoms, or bosons, by trapping the atoms in a two-dimensional (2D) optical lattice. Fermions are particles that tend to avoid each other; this property is integral to a fundamental law of quantum physics which asserts that two identical fermions cannot occupy the same quantum state. Electrons, protons and neutrons are all examples of fermions. Bosons, on the other hand, act like long-lost friends in that they prefer to exist in the same quantum state.

William D. Phillips, winner of the 1997 Nobel Prize in Physics, and his team of researchers at NIST created patterns of light—in this case, a 2D lattice—that made an array of very thin, tightly confining tubes of light, forming 1D traps for neutral atoms. Bosonic atoms were then loaded into the tube and trapped in one dimension. Confinement of the atoms in 1D light structures changed the spatial correlation of the bosons, causing them to exhibit fermionic properties. The rate at which they collided to form molecules decreased because they began to avoid each other. The bosons did not actually become fermions; they simply began to exhibit fermion-like properties. Related experiments on the fermionization of bosons are being conducted at Universität Mainz, Germany, the Swiss Federal Technical University Zurich (ETH) and Pennsylvania State University.

The behavior was observed when the atoms were chilled to -273 degrees C to slow them down and allow the researchers to observe their interaction. At room temperature, atoms move at a dizzying pace of about 1,000 km/hour. Chilling them reduces their speed to less than 0.02 km/hour. Phillips says the fermion-like effect produced in this ultracold environment is an example of “the sort of thing that the combination of ultracold atoms and optical manipulation can yield.”

In atom traps, Phillips and his team have been able to view the changes bosons exhibit in 1D space. This unusual effect was observed through “shadow pictures,” which are produced by absorption imaging: the NIST team shined near-resonant light onto the cloud of atoms and then imaged the light with a camera. The atoms absorbed the light so that a dark shadow was cast at the location of the atoms, allowing the researchers to see the size, shape and number of atoms in the cloud.

According to Trey Porto, a senior researcher on the NIST team, in the past few years in cold atom physics a trend has developed toward conducting an “increasing number of condensed-matter experiments, which produce systems that are more strongly correlated and strongly interacting. …We’re moving into a time when very well-defined systems that have well-studied theoretical models can be produced with cold trapped atoms.” These results are particularly interesting for two reasons. Researchers can now explore interesting condensed matter systems that are very clean, in that they have fewer lattice defects, impurities and other imperfections. Since neutral atoms can be used as quantum bits, the experiments will help researchers explore the use of such atoms in quantum information processing.

Phillips, Porto and others are working with large numbers of atoms trapped in 1D space; eventually, researchers will conduct such experiments one atom at a time. The results could include advances in cryptography and very-high-speed database searching in quantum computers.
Bending Toward The Light

Researchers have known for over 150 years that plants will grow toward a blue light source, but until the 1990s, they did not understand the photoreceptive mechanism that allowed plants to sense light. Winslow Briggs, professor emeritus at Stanford University and the Carnegie Institution’s Department of Plant Biology, discovered in 1998 the gene responsible for photoreception in mouse-ear cress as well as the two proteins, phototropin 1 and phototropin 2, which enabled the plant to absorb light and caused it to bend toward it (phototropism).

Until recently, however, the biochemical and biophysical processes underlying phototropism were not completely understood. In July 2004, Briggs announced the results of research that showed how the biochemical process causing phototropism takes place. Phototropin 1 and 2 bind to flavin mononucleotide (FMN), a coenzyme contained in plants that is synthesized from riboflavin. When Briggs began investigating where FMN might be attached to the phototropic receptors, he found that two stretches of protein—termed LOV1 and LOV2 for Light, Oxygen, Voltage sensitive—form “cages” that bind the FMN. According to Briggs, “Within each of these cages is bound a single molecule of FMN in a very tight structure.” When the plant is in the dark, the tight structure is retained. But when the phototropin photoreceptors absorb blue light, an alpha helix in one of the cages unfolds, much like the opening of a door, and protein enzymes are activated. The enzymes add phosphate (a process termed autophosphorylation) to the phototropin receptor facing the light.

Autophosphorylation signals the plant to transport different amounts of the growth hormone auxin to its light and dark sides. According to Emmanuel Liscum, associate professor in the Division of Biological Sciences at the University of Missouri, “the side of the plant getting the most light tells cells on the darker side to ‘modify your growth; do something new.’” Auxin levels increase on the shaded side of the plant and decrease on the illuminated side, increasing the growth rate on the shaded side. Since the plant grows faster on the shaded side, its stem bends toward the light.

Briggs and Liscum say the findings could help agricultural researchers improve the heartiness of crops and their adaptability to different environments and geographic locations.

Nd:YAG Laser Treats Gum Disease

For the treatment of periodontal disease the Food and Drug Administration (FDA) approved first-generation dental lasers, which use one-pulse technology, in 1998. A new Nd:YAG laser, manufactured by Millennium Dental Technologies (Cerritas, Calif.), uses two types of pulses. The first pulse lasts 100 microseconds (similar to first-generation dental lasers). This short pulse allows removal of necrotic tissue without causing excessive thermal damage. The second pulse, which lasts 650 microseconds, is used at the end of the procedure. It causes just enough thermal damage to spur coagulation, providing homeostatic balance more quickly than do one-pulse lasers. According to David Harris, Ph.D., director of Bio-Medical Consultants & Associates, initial clinical trials of pulsed Nd:YAG in the treatment of gum disease show that it “selectively kills bacteria, leaving the surrounding tissue intact.” Harris says the “Nd:YAG [laser] has higher selectivity than other types of dental lasers.” The device was cleared by the FDA and is being used by periodontists in the United States and abroad.