Ketterle demonstrated a new laser trap that could yield higher densities. This variant is called the Dark SPOT trap, for dark SPontaneous force Optical Trap. This new trap works by hiding most of the atoms in a "dark" state, in which they can't absorb photons and thus can't be pushed apart by scattered light. The concealment scheme takes advantage of the atoms' two ground states, one in which the spins of the nucleus and the electrons are parallel and the other, slightly lower energy state in which they are anti-parallel.

The cooling and trapping lasers are tuned to the higher of these "hyperfine" states, so that the atoms can be cooled only when they are in that state. A very weak laser tuned to the lower, "dark" state sometimes lifts an atom into the upper state, where it undergoes a brief bout of cooling. "Every atom gets its turn and is cooled," says Ketterle. Afterward, it settles back into the lower state, in which it is oblivious to light. "By doing this," he continues, "we can get a high enough density to do evaporative cooling."

At IQEC, both Ketterle's MIT group and the Colorado group led by Cornell and Wieman reported that they had managed to combine dark SPOT traps and evaporative cooling. Reaching the threshold for BEC, however, will require an improvement of another three or four orders of magnitude in density and temperature. "The big excitement now," says Ketterle, "is that we saw the first step of cooling, and people expect this will carry us down by several more orders of magnitude." Cornell isn't so upbeat; he notes that the results so far are "not even in the ballpark" for BEC. But when he was told that Ketterle is optimistic, he said, "Well, I'm plenty optimistic. I'd just hate to open up *Science* magazine and read myself saying that three or four orders of magnitude is close."

One reason for not abandoning the caution traditional in this field is that nobody has ever approached BEC with metal atoms, only with hydrogen. As Wieman explains, "the whole business of laser-cooled atoms for Bose condensation is at an early enough stage that the kinds of problems encountered by people doing hydrogen have not yet shown up." And that complicates the betting about which technique, if any, will reach BEC first.

Greytak, for instance, notes that the evaporative cooling technique developed by his group is still closest in terms of combined cooling and density; if they can get their extremely complicated apparatus to work properly, he says, they still have the best shot. But the laser cooling/evaporation strategy, he adds, is moving fastest, and one more breakthrough could put that technique even closer. As for Chu, he takes the view that the past is prologue: "I'm betting on nature to hide Bose condensation from us. The last 15 years she's been doing a great job."

–Gary Taubes

AGRICULTURAL BIOTECHNOLOGY

Developing Nations Adapt Biotech for Own Needs

On 18 May, the biotechnology industry in the United States marked a major milestone: The first product of a genetically engineered plant—the Flavr-Savr tomato, which was modified to retard spoilage and improve flavor—received approval from the Food and Drug Administration (FDA). But as some presentations at a recent meeting of the National Agricultural Biotechnology Council (NABC)* made clear, developed countries like the United States aren't alone in applying gene transfer and other biotechnology techniques to the improvement of crop plants.

Despite early concerns that developing countries would reap little benefit from these technologies because they lacked the advanced research facilities needed to apply them to native crops, those countries are in fact aggressively adapting advances made in the West to local needs, says Robb Fraley, group vice president and general manager for new products at Monsanto Corp. in St. Louis. "What has stunned me is the energy developing countries are putting into biotechnology" in agriculture, Fraley asserts. "The progress made in the last 18 months has been breathtaking."

One significant sign of that progress is the speed with which biotech crops are moving through the research pipeline in developing countries. Many—including potatoes, cotton, rice, and tomatoes, as well as native species such as papaya—are currently in or near field tests. Some have gone into commercial production well ahead of similar crops in the United States. In China, for example, vegetables such as tomatoes, which have been genetically engineered for resistance to viruses, have been on the market for about 18 months, while comparable plants are only now reaching the final stages of approval at the U.S. Department of Agriculture (USDA).

Biotech crops may be moving into commercialization faster in the developing world partly because some of the countries do not have tight regulatory mechanisms like those imposed by agencies such as the FDA and USDA. But there's also a more fundamental reason: hungrier populations. "Genetic engineering has more potential for developing nations than for the First World," says Luis Herrera-Estrella, a molecular biologist at the Centro de Investigación y Estudios Avanzados (CINVESTAV) in Irapuato, Mexico. "In developed countries [agricultural] biotechnology's main value will be to reduce costs. But in the developing world it will allow us to produce more food."

The developing countries are adopting several strategies to achieve this goal of greater food production, several of which were on view at the annual meeting of the NABC, an organization of agricultural research centers established in 1989 to provide a forum for exploring the pros and cons of agricultural biotechnology. In some cases, the countries have reorganized established labs such as CINVESTAV, veterans of the classical plant breeding work that produced the high yielding crops of the "Green Revolution," to handle biotechnology. In others, they've set up new labs, such as the Agricultural Genetic Engineering Research Institute (AGERI) in Giza, Egypt. And they've been forging collaborations with Western researchers who bring their own biotech expertise to bear on foodstuffs of the developing world.

DENNIS GONSALVES/CORNELL UNIV.

Papaya protection. A gene introduced into the papaya plant on the left makes it resistant to ringspot virus, while the control plant *(right)* has a damaging infection.

Among these are local variants of the same species previously genetically engineered by the Western researchers. For example, in the late 1980s, scientists in Europe and the United States showed that they could "immunize" potatoes and other vegetable species against viruses by giving them

*The meeting was held on 23 and 24 May in East Lansing, Michigan.

the gene for a viral coat protein, which interferes with the replication of invading viruses in ways that are not fully understood.

Herrera-Estrella, with Rafael Rivera and other CINVESTAV colleagues, has now applied that technique to immunize "Alpha" potatoes, a variety common in Mexico, against infection by two potato viruses, simply known as X and Y. Field testing of these transgenic potatoes began last year, and it has shown promising results, according to Rivera: Average potato crop losses to the viruses range from 15% to 20%, but the transgenic varieties had losses ranging from 0% to 15%.

In addition to working on traditional crops, developing nations are using biotechnology to improve native species, including sweet potatoes, papaya, banana, and palm—the plants on which many subsistence farmers depend. Richard Sawyer, president of the International Fund for Agricultural Research in Arlington, Virginia, says that, in the West, researchers and farmers "have a cereal mentality, but there are alternative crops, such as fruits and vegetables, that are of more interest to small farmers in developing nations."

Take papaya. This staple of tropical diets is infected almost worldwide by the ringspot virus, an RNA virus that is transmitted by aphids to papaya, squash, and related plants and greatly reduces their yields. About 7 years ago, Dennis Gonsalves of Cornell University's Agricultural Experiment Station in Geneva, New York, began a collaboration with Richard Manshardt and Maureen Fitch of the University of Hawaii and Jerry Slightom of Upjohn to see whether genetically engineering papaya plants to express ringspot viral coat proteins could make them resistant to the virus. Field trials with the genetically modified plants began in 1992. The results, Gonsalves says, are dramatic: "We had 100% protection. It's one of the most impressive field trials you will see."

A problem remains, however. The protection conferred by the coat-protein gene appears to be specific to the viral strain from which the gene came. This may mean, Gonsalves says, that transgenic papaya plants will have to be specifically tailored to resist strains indigenous to the areas where they will be grown.

Papaya isn't the only developing-world crop that's being modified to protect it from disease. International Services for the Acquisition of Biotech Applications, a not-for-profit international organization based at Cornell University that encourages the transfer of agricultural biotechnology to developing countries, is funding efforts by Marto Valdez and Gabriel Macayo of the University of Costa Rica to genetically engineer resistance to viruses into several varieties of the criollo melon, grown by small farmers in Costa Rica, Mexico, and Guatemala. And Magdy Madkour and his colleagues at AGERI are using transgenic techniques to improve disease resistance and nutritional qualities of the fava bean, a food eaten in many Mediterranean countries.

As these examples show, biotechnology holds great promise for improving many crops in developing countries. Yet, ironically, it also has the potential to harm economies of some developing countries—by reducing the demand for their specialized export crops. One negative impact could come from the efforts of companies in the developed world to use plant cell culture techniques to make high-value materials, such as vanilla and cocoa butter, that now must be extracted from tropical plants. Experts such as Michigan State University sociologist Lawrence Busch say that if it becomes economically feasible to make these materials by biotech methods, agricultural production in some developing countries will be harmed, much as the development of high-fructose sweetener from corn devastated the sugar industry in the early 1980s.

But biotech itself could provide an appropriate response, says Ralph Hardy, president of the Boyce Thompson Institute for Plant Research in Ithaca, New York, and an NABC founder. Developing nations could profit, he says, "by using biotechnology to export a more finished product instead of raw commodities." They might, for example, use genetically engineered coffee plants to produce beans that are naturally decaffeinated. Innovative products like these would help to ensure that the overall outcome of biotech on the developing world, where it is fast acquiring a firm foothold, will be positive.

–Anne Simon Moffat

ATOMIC PHYSICS

Making and Trapping the Ultimate Ion

Uranium likes to hang on to its electrons. By stripping away most or all of the 92 electrons surrounding a uranium atom, scientists can turn it into a valuable testing ground for atomic physics, but the 92 positive charges in its nucleus—the most of any natural element—exert a tenacious grip. The last few electrons, bound close to the nucleus, are exceptionally hard to dislodge. Until recently, the only way to do so was to whirl the uranium atoms at half the speed of light in a particle accelerator, smash them into a thin foil, and look for bare nuclei in the debris streaming out the other side. But Ross Marrs and his colleagues at Lawrence Livermore National Laboratory have a subtler strategy.

He and his colleagues Steven Elliott and David Knapp report in the 27 June *Physical Review Letters* that they suspended uranium atoms in a high-speed stream of electrons, which erodes away the uranium's own electrons like a sandblaster stripping paint, all the way down to bare nuclei. As a bonus, the beam conveniently traps the ions for study. "We're the first people to make [bare uranium] sitting still in the laboratory," says Marrs.

That achievement has already opened the way to measuring the rate at which collisions dislodge the last few electrons, a test of theorists' understanding of how high-speed electrons interact with massive nuclei. It's also a proof-of-principle of the Livermore workers' technique for studying heavy, highly charged ions, where quantum mechanical effects that are muted in lighter ions should come through loud and clear. As physicist Michael Prior of Lawrence Berkeley Laboratory puts it, if you can make and trap fully ionized uranium—"the ultimate ion," he calls it—"you've demonstrated the ability to ionize essentially anything."

The key, Marrs explains, is a device called the electron-beam ion trap (EBIT). Originally developed in 1984 to study atomic physics processes for Strategic Defense Initiative beam weapons (*Science*, 4 February, p. 620), the device is built around a tightly focused, high-energy electron beam. The beam not only strips away the electrons from any atoms it encounters but also generates a powerful electric field that holds the resulting positive ions dead center in the beam.

In the work Marrs and his colleagues reported last week, the electron beam also served a third purpose: probing the contents of the trap. An occasional high-speed electron from the beam recombines with a uranium ion, which signals the event by giving off an x-ray photon. The photon's energy depends on whether the ion was fully stripped or had one electron or more left. By measuring the number of photons at each energy, Marrs and his colleagues were able to do a census of their trap to find out the ratio of bare uranium ions to ions still clothed in a single electron. And from that ratio (about 1-to-50), the Livermore workers calculated the rate at which the electron-stripping collisions were taking place.

That rate is about 50% higher than theorists had predicted, which may imply that they need to do some tinkering, says Marrs. But he and his colleagues are just as excited about future EBIT experiments that will probe quantum electrodynamics (QED), the reigning theory of how charged particles interact. "We'd like to see how QED plays out in the environment of these highly charged ions," says Marrs, and the EBIT may give him a front-row seat.

–Tim Appenzeller