Trapping Erbium Atoms: The Impossible Made Possible

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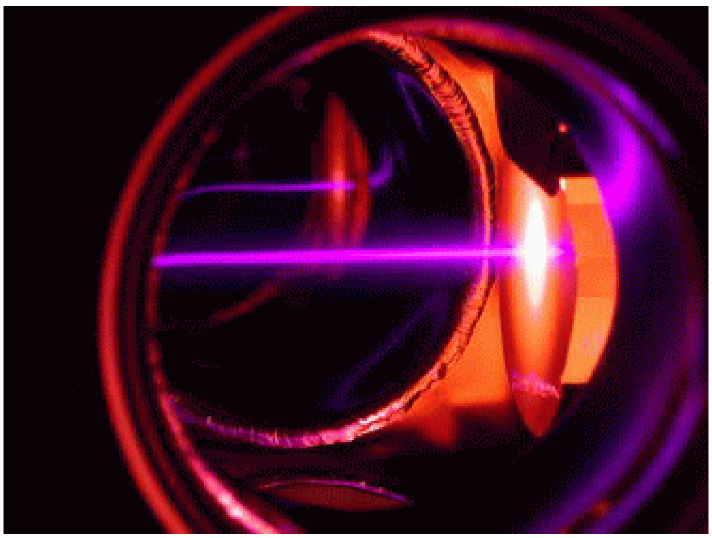

An Er beam emerging from a hot oven (orange glow on right) being slowed by a violet laser beam. Credit: Jabez McClelland

Recycling atoms? Can they *do* that? In a world where nearly everything can be reused, scientists are moving forward with a novel approach to using Magneto-Optical Traps (MOTs) to, in effect, recycle atoms. In a Letter published April 14th in *Physical Review Letters*, Jabez McClelland and James Hanssen, his colleague at the National Institute of Standards and Technology, published the results of a new way to use a MOT to trap erbium atoms.

"With erbium, anyone doing laser trapping would say it would never work," McClelland tells *PhysOrg.com*. But McClelland and the members of the Electron Physics Group at NIST's Center for Nanoscale Science and Technology managed to do the unfeasible.

McClelland explains that for laser trapping a scientist needs two things: a magnetic field and laser light. When an atom is in its ground state, it can absorb light from a laser, causing it to go up a level in its state. When the atom loses the excitement caused by the laser light, it falls back down, heading for the ground state and feeling a push as a result. The laser can then be trained on the atom again. The magnetic field makes sure atoms feel a push toward the center of the trap that gets bigger as they move away from the center. "Ordinarily," says McClelland, "the atoms go up and come down, and they are always hit and stay trapped." But, he continues with his explanation, this method, in existence since the 1980s, was thought to work only with limited classes of atoms, such as alkalis, alkaline earths, and metastable rare gases, as well as a few other atoms scattered through the Periodic Table of Elements.

The reason for the assumed narrow application of MOTs lies in the number of levels atoms have. "Everybody thought that other atoms—most atoms—are impossible to trap because of their electronic structure. They are very complex and have lots of levels. The thinking was that if you try to trap them, they fall into other metastable states and are lost."

Elements like chromium, which have a few levels, can still be used in MOTs with the help of a process called repumping. With repumping, another laser is used to excite the atom when it looks as though it might become "lost" as it tries to return to its ground state. The second laser re-excites the atom, keeping it trapped. The problem with using repumping on rare earth atoms like erbium, says McClelland, is the fact that there are so many levels that the number of lasers needed for repumping would be prohibitive.

But, McClelland points out, he, along with Hanssen, discovered that the metastable states do not “float away.” Rather, “they hang around and they aren’t lost. That’s the discovery.” But how are these atoms kept in place? The answer lies in the magnetic field. The field, an integral part of the MOT, has a strong confining effect on atoms with spin, and with erbium, the intermediate levels have very high spin. “This way,” explains McClelland, “there’s a magnetic field that holds them, even without the extra laser. Eventually they fall back to the ground state and we can hit them again.” He pauses. “There’s a recycling mechanism here.”

So, what can be done with complex atoms trapped in MOTs? “Actually,” says McClelland, “there’s a lot you can do.” Scientific uses of such atoms have to do with making these atoms very, very cold. “Once you’ve trapped them,” he explains, “you can get them incredibly cold with laser cooling—the coldest you can possibly get them.” These cold atoms can help scientists in experiments regarding Bose-Einstein condensations, as well as observing dipole interactions between colliding ultra-cold atoms.

McClelland’s interests, however, lie in another direction. “We are in the business of using these Magneto-Optical Traps to make single atom sources,” explains McClelland. He goes on to say that single atoms have applications in things like photonic devices. Erbium is a very optically active element that is used in telecommunications. McClelland also points out the high technology possibilities in areas such as encrypted telecommunications and measurement methods on the nanoscale. “There is also a possibility of making nanoscale sensors out of individual ions if you embed them on scanning tips.”

As the Letter points out, this new use of MOTs opens many doors for the future, “greatly expanding opportunities for practical applications and fundamental studies using laser-cooled atoms.”

More information on the Electron Physics Group and its work can be found at http://physics.nist.gov/epg.

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