Laser Cooling

EC - 5th
6-wk

Nobel Prize Extra Credit Assignment
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In 1997, the Nobel Prize in Physics was awarded to Steven Chu, Claude Cohen-Tannoudji, and William D. Phillips. The Prize was shared jointly among the three of them for development of methods to cool and trap atoms with laser light, more commonly known as laser cooling.

William Daniel Phillips is of Irish and Welsh decent and was born on November 5, 1948 in Wilkes-Barre, Pennsylvania. He graduated valedictorian of his high school class and after undergraduate college at Juniata College went on to get a physics doctorate from the Massachusetts Institute of Technology. He is currently a professor of physics at University of Maryland, College Park. Phillips is a Methodist and is one of the few scientists to be deeply involved in the "science versus religion" debate.

Steven Chu was born on February 28, 1948 in St. Louis, Missouri, with ancestry from Taicang, China. He earned both a Bachelor of Arts in mathematics and a Bachelor of Science in physics from the University of Rochester. Chu later earned his Ph.D. in physics from the University of California, Berkeley, in 1976. He taught himself how to play tennis from reading a book when he was in eight grade and learned to pole vault by practicing with bamboo sticks from a local carpet shop. He currently has two sons and has been the 12th United States Secretary of Energy since January 21st, 2009.

Claude Cohen-Tannoudji was born on April 1, 1933 in Constantine, Algeria to Jewish parents. He is working at his alma mater, the École Normale Supérieure in Paris. He worked in the army for 28 months during the Algerian War and received his doctorate afterwards in 1962. He became the first Nobel Prize winner born in an Arab country.

Laser cooling is the slowing down of atoms or molecules from 4000 kilometers per hour to speeds less than 1 kilometer per hour by the use of a laser whose frequency has been adjusted to remove momentum from the particles. In order to make atoms colder, you must make the light bounce off of them. In fact, light will bounce off the atoms with more energy than when it hit the atom. When the photons are bouncing off the atom, the electron in the atom absorbs the photon and jumps up to a higher level, and then it quickly jumps back down and shoots back out the photon. Each type of atom will react only to exactly one specific color. Lasers were needed that can adjust their color to almost non-measurable degrees. Just the vibrations in the floor of a normal building can make the color of a laser change so much that it won't match the atoms any more and the protons will go right through the atom. The Doppler Effect indirectly changes the frequency of the laser's light too. If an atom is moving towards the light, the light must have a lower frequency than that required for a stationary atom if it is to be received by the atom. What this process actually does is reduce the random motion of small particles. This consequently reduces the temperature. This can get atoms to millionths of a Kelvin away from absolute zero. The atoms then appear to be suspended, or trapped. This leads to the other term used for laser cooling, which is laser trapping.

This process allows individual atoms and their inner structure to be studied with great accuracy. Thanks to Chu, Cohen-Tannoudji, and Phillips our knowledge of the reactions between radiation and matter has increased. These methods may lead to the design of more precise atomic clocks for use in space navigation and accurate determination of position.

Steven Chu set out to cool atoms when he walked into his lab around 1985 at the Bell Laboratories in Holmdel, New Jersey. They used six laser beams opposed in pairs and arranged in three directions at right angles to each other. Sodium atoms from a beam in vacuum were first used. Because of the angles the lasers were positioned at, whenever the sodium atoms attempted to move, they were met by photons of the right energy and pushed back into the area where the six laser beams intersected. At that point there formed what to the naked eye looked like a glowing cloud the size of a pea, consisting of about a million chilled atoms.

William Phillips used magnetic fields to slow down atoms in the beginning of the 1980s. In 1985 with a device that would later be called a Zeeman slower, he stopped and captured sodium atoms in solely a magnetic trap. Claude Cohen-Tannoudji and co-workers at the École Normale Supérieure had already in theoretical works studied more complicated cooling schemes. He used Helium atoms and six laser beams to reach a temperature of 0.18 μK. The helium atoms moved at about 2 cm/s at this temperature.