

# Laser Cooling

Laser cooling refers to the number of techniques in which atomic and molecular samples are cooled through the interaction with one or more laser light fields. The first example of laser cooling, and also still the most common method of laser cooling (so much so that it is still often referred to as 'laser cooling') is Doppler cooling.

## Doppler cooling

Doppler cooling, which is usually accompanied by a magnetic trapping force to give a magneto-optical trap, is by far the most common method of laser cooling. It is used to cool low density gasses down to the doppler cooling limit, which for Rubidium 85 is around 150 microkelvin. As Doppler cooling requires a very particular energy level structure, known as a closed optical loop, the method is limited to a small handful of elements.

In Doppler cooling, the frequency of light is tuned slightly below an electronic transition in the atom. Because the light is detuned to the "red" (i.e. at lower frequency) of the transition, the atoms will absorb more photons if they move towards the light source, due to the Doppler effect. Thus if one applies light from two opposite directions, the atoms will always scatter more photons from the laser beam pointing opposite to their direction of motion. In each scattering event the atom loses a momentum equal to the momentum of the photon. If the atom, which is now in the excited state, emits a photon spontaneously, it will be kicked by the same amount of momentum but in a random direction. The result of the absorption and emission process is to reduce the speed of the atom, provided its initial speed is larger than the recoil velocity from scattering a single photon. If the absorption and emission are repeated many times, the mean velocity, and therefore the kinetic energy of the atom will be reduced. Since the temperature of an ensemble of atoms is a measure of the random internal kinetic energy, this is equivalent to cooling the atoms.

## Other methods of laser cooling

Several somewhat similar processes are also referred to as laser cooling, in which photons are used to pump heat away from a material and thus cool it. The phenomenon has been demonstrated via anti-Stokes fluorescence, and both electroluminescent upconversion and photoluminescent upconversion have been studied as means to achieve the same effects.

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