Direct laser cooling of molecules

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Cooling molecules with lasers is harder than cooling individual atoms with lasers. The very process of laser cooling, in which atoms are buffeted by thousands of photons, was thought by many to be impossible for molecules since photons, instead of slowing and cooling the molecules, could actually excite internal motions such as rotations and vibrations. Consequently, to get cold molecules one method is to first cool atoms and then combine them into molecules.

Now Yale physicist David DeMille and his team have developed a way to cool molecules directly with laser light using three lasers instead of the two typically needed for atoms. By choosing the molecular species carefully --they experiment with SrF molecules-- and choosing the photon energies to avoid unwanted excitation of rotational motion, the cooling process can proceed.

In this way, molecular temperatures of 300 micro-K have been achieved, the lowest ever for direct cooling of molecules. This temperature pertains so far to motion along one selected dimension only, much as for the initial demonstrations of laser cooling for atoms.

While these temperatures are less than a thousandth of a degree above absolute zero, they are for now orders of magnitude hotter than the cold molecules that can be made by first chilling individual atoms and then combining them. With the latter approach, however, the choice of molecules is presently limited to only those that can be made with alkali atoms. The SrF molecules used in the Yale experiment, by contrast, possess an unpaired electron. This makes them potentially useful as quantum bits or in various studies of fundamental physics. In addition, the results from DeMille’s group indicate that laser cooling to yet lower temperatures is likely possible for SrF and other, similar molecules.

"The technique of laser cooling," says DeMille, "which has led to a revolution in atomic physics, has now been shown to also apply to (at least some) molecules. This significantly expands the range of molecules for which ultracold temperatures can be reached, which in turn opens a route to many new scientific applications."

David DeMille presents the findings at Frontiers in Optics (FiO) 2010/Laser Science XXVI -- the 94th annual meeting of the Optical Society (OSA).

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