Physical Science
Ultracold molecules

Sandia opens up new research in the physics of molecules at temperatures near absolute zero

Beam scattering technique produces ultra-cold molecules that will provide insight into the wave-like nature of molecules.

When an atom or molecule is cooled to a temperature below 10 milliKelvin (mK, 1/100 of a degree above absolute zero), its wave-like nature or "wavelength" becomes larger than the particle itself. It thus behaves as a wave as well as a particle. This quantum mechanical effect has many consequences for interaction of particles at these temperatures, such as the formation of new states of matter like Bose Einstein condensates and degenerate Fermi gasses. Although cooling of atoms is now routinely done, no general technique has been available for the production of ultracold molecules.

The added complexity found in molecules—including permanent dipoles and quadrupole moments, and complex rotational and vibrational structure and chemistry—offer the possibility of rich areas of investigation. Moreover, the wave-like nature of ultracold molecules is predicted to lead to a new understanding of weak interactions between molecules, and lead to novel technologies such as quantum computers. All of these possibilities have generally remained unexplored until now.

Sandia researchers have recently produced measurable amounts of ultracold molecules having temperatures ranging from 10-100 mK, using a unique molecular beam scattering technique. The cold molecules are formed at the intersection of an atomic beam and a molecular beam (see figure). The collisions between the beams produce the cold molecules. The researchers have recently demonstrated the ability to produce samples of cold molecules that survive for 100s of microseconds, thereby opening the door to further trapping and detailed studies.

There are four or five techniques in the world that have been able to produce as cold a sample of molecules as has been achieved at Sandia; however, none are as versatile. The technique being developed at Sandia will become general and will lead to the ability to study the wave-like nature of molecules that occurs only at ultracold temperatures.

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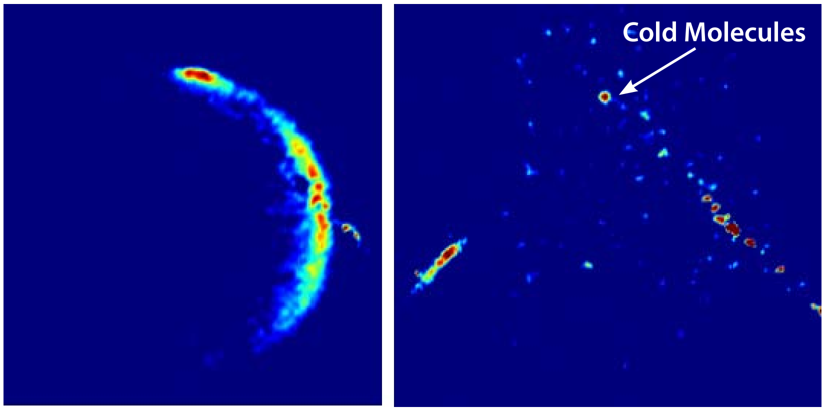

(Left) The production of cold molecules while the atomic and molecular beams are present. (Right) The cold molecules(small spot in the center of the image) remain even 100 microseconds after the atomic and molecular beams have been shut off, indicating a temperature of approximately 30 mK.