A method for producing 3-D Bose-Einstein condensates using laser cooling

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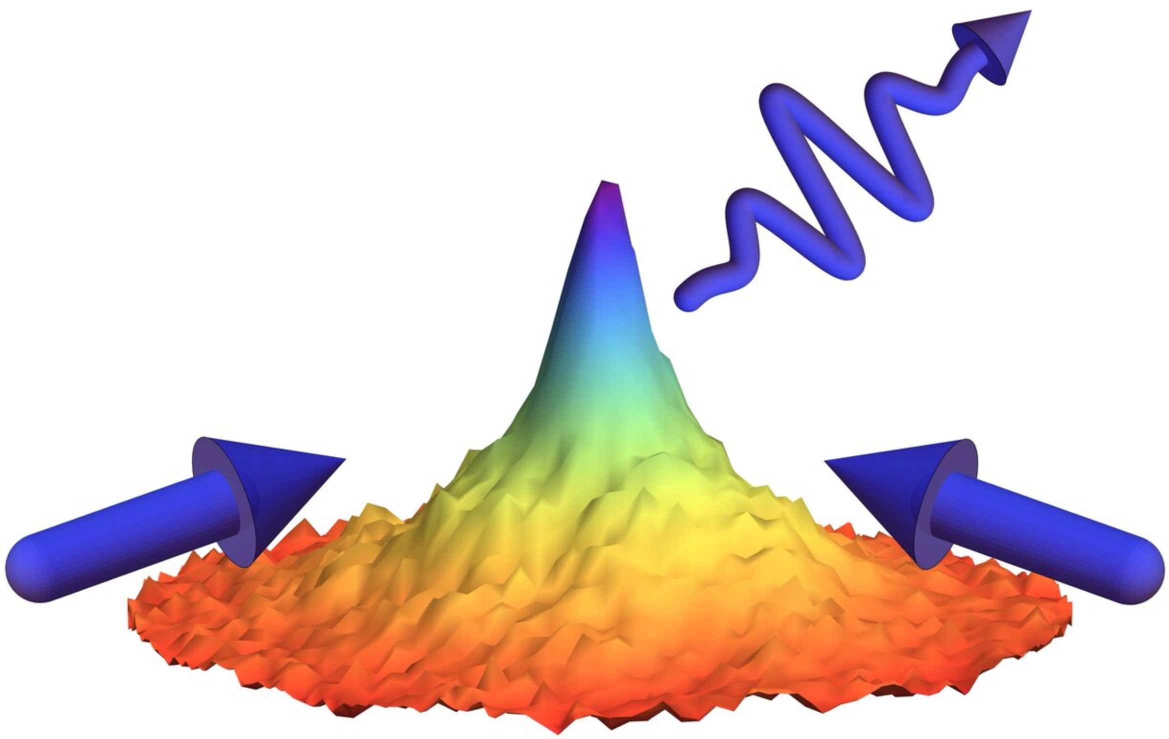

Credit: Urvoy et al.

Researchers at the MIT-Harvard Center for ultracold atoms and research laboratory of electronics have proposed a new method for producing 3-D Bose-Einstein condensates using laser cooling only. In their study, featured in *Physical Review Letters*, they demonstrated the efficacy of their technique in producing Bose-Einstein condensates, achieving temperatures that are well bellow the effective recoil temperature.

In past physics research, Bose-Einstein condensation (BEC) by direct laser cooling was an often pursued, yet highly elusive goal. It was first attempted by Steven Chu, who won the Nobel Prize for laser cooling, and around 1995 by Mark Kasevich, who did not succeed at the time. Other groups led by Carl Wieman and Eric Cornell, and by Wolfgang Ketterle, all Nobel Prize laureates for BEC, succeeded in achieving BEC using evaporative cooling instead. Eventually, most researchers gave up on trying to produce BEC using laser cooling alone, up until this ground-breaking new study.

"A few years ago, I had an idea of how to reduce the main obstacle to laser cooling of atoms, the light-induced formation of molecules from atoms, by using specific laser frequencies," Vladan Vuletić, one of the researchers who carried out the study, told Phys.org. "Compared to cooling through evaporation, laser cooling had the potential to be faster and more efficient, resulting in reduced constraints for the experimental setup."

Laser cooling atoms entails carefully positioning a set of lasers and tuning them to slow down the motion of the atoms by kicking them with photons. This technique is commonly used to create cold clouds of atoms, but using it to create samples of cold atoms with a high enough density for BEC had so far proved very challenging. A key reason for this is that laser light can photoassociate neighboring atoms into molecules, which then leave the atom trap.

"We found that we could dramatically reduce atom losses by deliberately choosing the energy of the pumping laser to mismatch the amount of energy required to form molecules," Vuletić explained. "Combined with a carefully optimized sequence of so-called Raman cooling (first demonstrated by Chu and Kasevich), this allowed us to produce a cold cloud of atoms with a density high enough to create a moderately sized BEC in about one second of cooling."

In their study, Vuletić and his colleagues trapped atoms in a crossed optical dipole trap and cooled them using Raman cooling, with far-off-resonant optical pumping light to reduce atom loss and heating. This technique allowed them to reach temperatures significantly below the effective recoil temperature (the temperature scale associated with the recoil momentum of a photon), on a time scale that is 10 to to 50 times faster than the typical evaporation time scale.

"Such a fast production of BEC is already on par with the very best evaporation techniques, which were optimized for speed, highlighting the potential of the new laser cooling technique," Vuletić said. "Our laser cooling method should be applicable to other species of atoms in the future, as well as to cooling of molecules. Our faster method yields better signal-to-noise ratio, and enables new experiments to study quantum gases that were difficult to perform before."

The new method introduced by Vuletić and his colleagues could have numerous implications for future physics research. For instance, it could enable the fast production of quantum degenerate gases in a variety of systems, including fermions. In their current work, the researchers are using their system to study 1-D quantum gases with attractive interactions, which should theoretically collapse but are instead stabilized by quantum pressure.

"In the future, we would like to apply the same technique to fermionic atoms," Vuletić said. "Fermionic atoms do not condense, but avoid each other, and instead form a so-called quantum degenerate Fermi gas at low temperatures. Such systems can be used to study electrons (which are also fermions) in solid-state systems, e.g. in order to understand the nature of magnetism and high-temperature superconductivity."

More information: Alban Urvoy et al. Direct Laser Cooling to Bose-Einstein Condensation in a Dipole Trap, *Physical Review Letters* (2019). DOI: 10.1103/PhysRevLett.122.203202

H. J. Lee et al. Raman Cooling of Atoms in an Optical Dipole Trap, *Physical Review Letters* (2002). DOI: 10.1103/PhysRevLett.76.2658

K. B. Davis et al. Bose-Einstein Condensation in a Gas of Sodium Atoms, *Physical Review Letters* (2002). DOI: 10.1103/PhysRevLett.75.3969

M. H. Anderson et al. Observation of Bose-Einstein Condensation in a Dilute Atomic Vapor, *Science* (2006). DOI: 10.1126/science.269.5221.198

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