Using an optical tweezer array of laser-cooled molecules to observe ground state collisions

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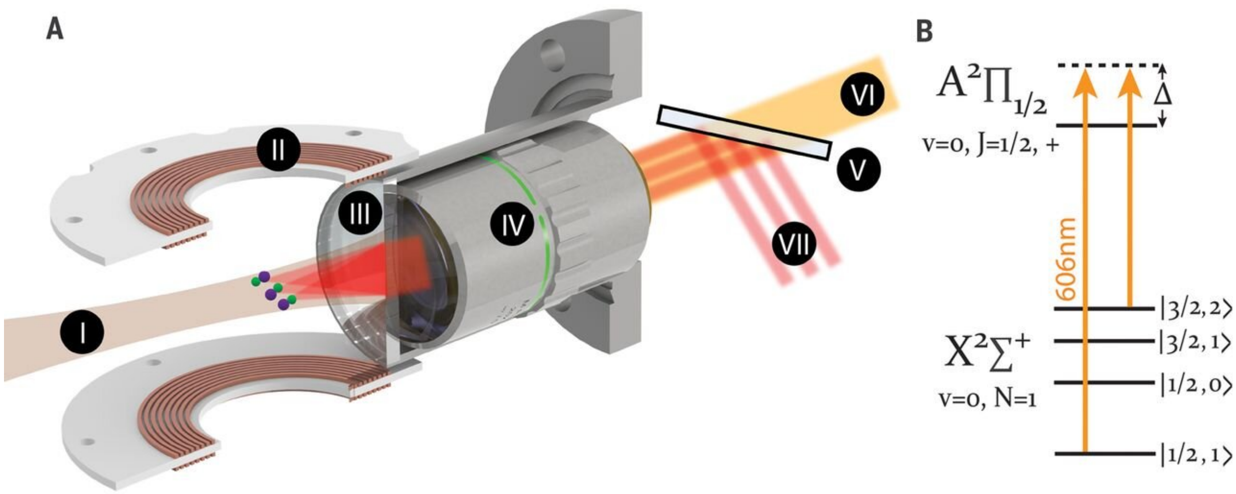

Molecular energy diagram and experimental setup. (A) An optical dipole trap formed by a focused beam of 1064-nm light (I) intersects the MOT and is reflected off the re-entrant window (III) at an angle to prevent the formation of a lattice. A microscope objective (IV) is placed inside a re-entrant housing between the MOT coils (II). Fluorescence from the molecules (VI) is collected through the objective and imaged onto a camera. The optical tweezer traps are generated by using an AOD (VII) and are combined into the imaging path by using a dichroic mirror (V). (B) CaF level structure of relevant states used in the Λ-cooling process. The cooling is operated at a detuning $\Delta = 2\pi \times 25$ MHz. Credit: *Science* (2019). DOI: 10.1126/science.aax1265

A team of researchers from Harvard University and Massachusetts

Institute of Technology has found that they could use an optical tweezer array of laser-cooled molecules to observe ground state collisions between individual molecules. In their paper published in the journal *Science*, the group describes their work with cooled calcium monofluoride molecules trapped by optical tweezers, and what they learned from their experiments. Svetlana Kotochigova, with Temple University, has published a Perspective piece in the same journal issue outlining the work—she also gives an overview of the work being done with arrays of optical tweezers to better understand molecules in general.

As Kotochigova notes, the development of optical tweezers in the 1970s has led to groundbreaking science because it allows for studying atoms and molecules at an unprecedented level of detail. Their work involves using laser light to create a force that can hold extremely tiny objects in place as they are being studied. In more recent times, optical tweezers have grown in sophistication—they can now be used to manipulate arrays of molecules, which allows researchers to see what happens when they interact under very controlled conditions. As the researchers note, such arrays are typically chilled to keep their activity at a minimum as the molecules are being studied. In this new effort, the researchers chose to study arrays of cooled calcium monofluoride molecules because they have what the team describes as nearly diagonal Franck-Condon factors, which means they can be electronically excited by firing a laser at them, and then revert to an initial state after emission.

In their work, the researchers created arrays of tweezers by diffracting a single beam into many smaller beams, each of which could be rearranged to suit their purposes in real time. In the initial state, an unknown number of molecules were trapped in the array. The team then used light to force collisions between the molecules, pushing some of them out of the array until they had the desired number in each tweezer. They report that in instances where there were just two molecules present, they were able to observe natural ultracold collisions—allowing a clear view of the action.

More information: Loïc Anderegg et al. An optical tweezer array of ultracold molecules, *Science* (2019). DOI: 10.1126/science.aax1265