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Taming molecular beams; towards a molecular laboratory on a chip

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The motion of neutral molecules in a beam can be manipulated with inhomogeneous electric and magnetic fields. Static fields can be used to deflect or focus molecules, whereas time-varying fields can be used to decelerate or accelerate beams of molecules to any desired velocity. I will give an overview of the possibilities that this molecular beam technology presently offers, ranging from ultrahigh-resolution spectroscopy and novel scattering experiments to lifetime measurements on trapped molecules. I will report in particular on our recent experiments demonstrating trapping of carbon monoxide molecules on a chip using direct loading from a supersonic beam. Upon arrival above the chip, the molecules are confined in tubular electric field traps of about 20 micrometer diameter, centred 25 micrometer above the chip, that move along with the molecular beam at a velocity of several hundred meters per second. By using the 13-C carbon monoxide isotopologue, losses due to nonadiabatic transitions near the center of the tubular traps are prevented. An array of these miniaturized moving traps can be brought to a complete standstill over a distance of only a few centimetres. After a certain holding time, the molecules can be accelerated off the chip again for detection. This loading and detection methodology is applicable to a wide variety of polar molecules, and enables the creation of a molecular laboratory on a chip. Many of the gas phase molecular physics experiments that are currently being performed in large beam machines might be performed in a compact vacuum machine on a surface area of a few square centimetres in the future and new experiments will become possible.