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Trapped laser-cooled molecules: From quantum simulation to particle physics to chemistry

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Due to the versatility of cold polar molecules, they are a powerful platform for both precision measurement searches of physics beyond the standard model (BSM) and for quantum science. This has led to intense efforts to control molecules at the quantum level. We report on new methods to cool and trap molecules and the creation of optical tweezer arrays of ultracold CaF molecules. We have also conducted preliminary collision studies using optical tweezers, demonstrating the potential for exploring state-selective ultra-cold quantum chemistry. These methods can be extended beyond diatomic molecules to polyatomics, which have new features advantageous for quantum computation and precision measurement. Already, a cold diatomic molecular beam experiment (ACME) provides the best limit to the electrons EDM, which is a 3-30 TeV probe of BSM physics. Polyatomic molecules such as YbOH and $YbOCH_3$, when laser-cooled and trapped optically, will provide longer coherence times, opening the possibility for future experiments to probe BSM physics at the PeV scale. We report on preliminary progress on this front.