TOWARDS COOLING AND TRAPPING MOLECULAR HYDROGEN

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The hydrogen molecule, the simplest neutral chemically bound system, provides an ideal benchmark for testing quantum theory. Precise determination of energy intervals between rovibrational states in hydrogen, with relative accuracy reaching the sub-ppb level,[1,2] allows for performing stringent tests of molecular quantum electrodynamics for molecules[3] and for putting constraints on the strength of hypothetical beyond-Standard-Model interactions.[4]

To maintain progress in accurate metrology, it becomes necessary to trap a cold H_2 sample. However, this task presents a challenge: molecular hydrogen lacks a permanent electric dipole moment, which makes it difficult to manipulate using electric fields. Moreover, H_2 molecule in its ground electronic $^1\Sigma$ state interacts with magnetic field very weakly, primarily due to its nuclear spin, and even weaker rotational magnetic moment.

We investigate the potential for trapping molecular hydrogen using intense laser and magnetic fields. Recent progress in laser technology already gives capabilities for generating a 1 mK optical-dipole trap with a continuous-wave (CW) laser coupled to a high-finesse cavity.[5] Consequently, we examine the possibility of eliminating the AC Stark effect caused by the trapping laser field. Taking advantage of the anisotropy of the dipole polarizability in H_2 and the weak contribution from electric quadrupole polarizability near resonances, we identify a magic wavelength for the 1-0 S(0) line in the H_2 isotopologue.[6] For the *ortho*-H_2 spin isomer, we identify states amenable for trapping using magnetic fields and study the inhomogeneous broadening of the 1-0 Q(1) line due to misalignment of Zeeman shifts in the ground and excited vibrational levels. Finally, we explore the potential for sympathetic cooling of *ortho*-H_2 through collisions with ultracold lithium atoms, which could facilitate bringing trapped hydrogen closer to the micro-kelvin regime.

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