HIGH PRECISION MOLECULAR SPECTROSCOPY BY PHOTOASSOCIATION OF ULTRACOLD TRAPPED ATOMS

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Photoassociation spectroscopy provides a precision, high resolution tool for probing long range interatomic interactions in the ground and excited states of diatomic molecules of laser cooled and trapped atomic species. A number of groups are now exploiting one- and two-color photoassociation spectroscopy of trapped atoms. Photoassociation is a free-bound transition induced by light between colliding ground state atoms and a bound vibrational-rotational level of the molecule formed by the two atoms. High resolution is possible because of the very small spread in thermal energy of the atoms at $\leq$ 0.001 K. The asymmetric line shapes of the spectral lines show the influence of natural broadening and the quantum properties of the ground state wavefunction. Analysis of spectra of the 0_g^- state of the Na_2 molecule at NIST has been used to determing the long range resonant dipole interaction strength between ground and excited Na atoms, yielding the most accurate value to date of the Na $^2P_{3/2}$ atomic lifetime, as well as observation of relativistic retardation corrections to the long range interatomic interaction. In addition, since these spectra probe the ground state wavefunction in the $T \to 0$ limit, we have determined the scattering length for collison of two Na atoms in the $F = 1, M = -1$ hyperfine state. This is a critical parameter in the theory of Bose-Einstein condensation of this species.