Variance Measurement of m_p/m_e Using Cold Molecules

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This paper discusses the possibility of measuring the variance in the proton-to-electron mass ratio using the $|n_v = 0, N = 0, F = 1, M = 1\rangle \to |n_v = 1 \text{ or } 2, N = 0, F = 1, M = 1\rangle$ transition frequency of magnetically trapped cold XH (X: even isotope of alkali-earth atoms) molecules. The energy structure of XH molecule is shown in Fig. 1. The spectrum is observed by two-photon absorption using two counterpropagating laser beams, so that the spectrum is observed without the Doppler broadening. The Zeeman energy shift on the $|N = 0, F = 1, M = 1\rangle$ state is strictly linear to the magnetic field with the coefficient $Z(n_v) = \mu_B (g_e + g_I(\text{H}))/2$, where μ_B is the Bohr magneton and g_e and $g_I(\text{H})$ are the g-factors of electron and H-nuclear spins. The Zeeman shift on the vibrational transition frequency is less than 2 mHz/G, because of $|Z(1 \text{ or } 2) - Z(0)|/Z(0) < 10^{-10}$. The uncertainty on the transition frequency was estimated considering not only the Zeeman shift, but also the light shift, the blackbody radiation shift, the quadratic Doppler shift, and the collision shift. When molecules are trapped with temperature lower than 1 mK, uncertainty in this transition frequency is less than 10^{-15}, which makes it possible to measure the variance in the proton-to-electron mass ratio [1].

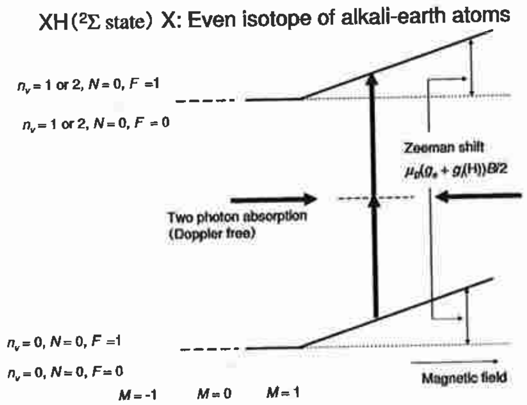

Figure 1: Energy structure of XH molecules (X: even isotopes of alkali-earth atoms) in $^2\Sigma$ $N = 0$ state. Zeeman energy shift of molecules in the $(F = 1, M = 1)$ state is also shown.

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[1] Masatoshi Kajita, Phys. Rev. A **77**, 012511 (2008).