Antihydrogen 1S-2S laser spectroscopy

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I review the developments in the ALPHA collaboration leading to the first laser spectroscopy of an anti-atom [1] and resulting in the most precise measurement ever achieved on antimatter. The $1S_d$–$2S_d$ transition was excited via Doppler-free two photon absorption from a 243 nm laser coupled into a cryogenic optical enhancement cavity [2]. The sample consisted of magnetically trapped antihydrogen with an average kinetic energy around 300 mK. The obtained lineshape (see Fig. 1) allowed a frequency measurement with 12 significant figures, compatible with the hydrogen frequency projected and simulated at this environment and conditions. This is a direct test of the Charge-Parity-Time (CPT) symmetry to 2 parts in 10^{12}. As a comparison, in Fig. 2 we show the MIT spectrum on trapped hydrogen at 400 μK obtained in 1995 where a fractional resolution of 2 parts in 10^{12} was achieved [3]. It shows the prospects for improvement in these measurements with trapped species which could largely surpass [4] the present record accuracy of parts in 10^{15} using a 5.5 K beam of hydrogen [5]. We discuss the limitations in this initial measurement and ideas to proceed towards parts in 10^{15} by employing different techniques such as: (i) larger laser beam waist decreasing time-of-flight broadening and AC Stark shift with a lower intensity; (ii) larger samples or further cooling of the sample by Lyman–α [6], microwave [7], or other; and (iii) trapping hydrogen [8] in the same trap as antihydrogen allowing a direct comparison between the species in the same electromagnetic and gravitational environment.

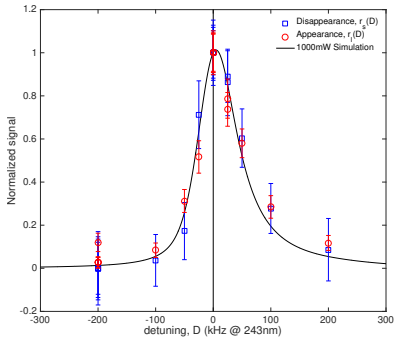

Figure 1: Lineshape obtained with trapped anti-hydrogen lineshape [1].

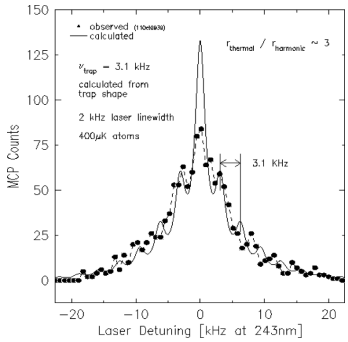

Figure 2: Lineshape from MIT's experiment [3] using trapped hydrogen at 400 μK

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