LASER SPECTROSCOPY OF HYDROGEN AND ANTIHYDROGEN: TOWARDS A DIRECT CPT TEST BEYOND 14 SIGNIFICANT FIGURES

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The Doppler-free $1S_d$-$2S_d$ spectroscopy of trapped hydrogen at 400 μK obtained at MIT[1] in 1995 can be compared (see figure below) to that of trapped antihydrogen at $\approx$ 300 mK obtained in 2018 at the ALPHA experiment[2] at CERN. The frequency measurement of the trapped antihydrogen transition compared to that of hydrogen obtained in a beam at Garching[3], extrapolated to the ALPHA conditions of magnetic field in the trap sets a comparison of the two species to 2 parts in 10^{12}. This is the most precise comparison of matter and antimatter to date. Observing the figures below it is clear that this comparison can be pushed beyond 14 significant figures if systematic effects – such as the magnetic field environment, laser intensity and its AC Stark shift – are controlled. Since this comparison is meant to a test of the Charge-Parity-Time symmetry, even being in the same geographical position symultaneously is relevant.The route for this is to introduce hydrogen atoms in the same antihydrogen trap and let it be subjected to the same magnetic fields, and laser. I will discuss a prospective solution for loading hydrogen atoms in the ALPHA trap by a recently developed technique where we produce trapped cold hydrogen anions[4]. These H^- anions, at ultra-high vacuum condition, can be guided to the ALPHA trap – a Penning and superposed magnetic trap – and can then be neutralized by near-threshold photodetachment resulting in a fraction of trapped low temperature hydrogen atoms. A scheme for detecting laser spectroscopy on H atoms trapped in the ALPHA experiment has already been presented[5].

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[2] doi:10.1038/s41586-018-0017-2, M. Ahmadi, B. X. R. Alves, et al., Characterization of the 1S?2S transition in antihydrogen, *Nature* **557**, 71 (2018)

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[4] doi:10.1038/s42005-023-01228-7, Azevedo, L.O.A., Costa, R.J.S., Wolff, W. et al., Adaptable platform for trapped cold electrons, hydrogen and lithium anions and cations, *Commun. Phys.* **6**, 112 (2023)

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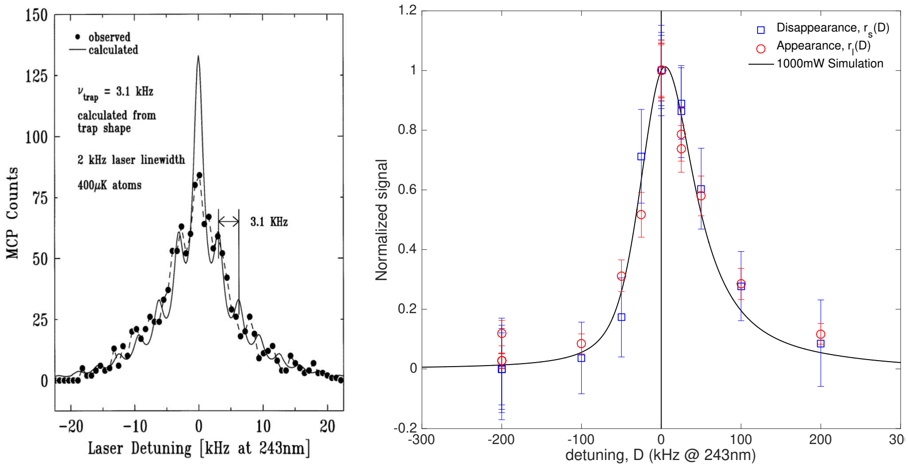

Figure 1: Doppler-Free 1S-2S spectrum of trapped hydrogen[1] (left) and antihydrogen[2] (right).