Toward a determination of the proton-to-electron mass ratio from a Lamb-dip measurement of HD

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Precision spectroscopy of the hydrogen molecule is a test ground of quantum electrodynamics (QED), and may serve for determination of fundamental constants. Using a comb-locked cavity ring-down spectrometer [1], for the first time, we observed the Lamb-dip spectrum of the R(1) line in the overtone of HD. The line position was determined with a precision of 90 kHz, which is the most accurate transition ever measured for the hydrogen molecule. Moreover, from calculations including QED effects up to the order $m_e\alpha^6$ [2], we obtained predictions for this R(1) line as well as for the HD dissociation energy, which are less accurate but signaling the importance of the complete treatment of nonadiabatic effects. Provided that the theoretical calculation reaches the same accuracy, the present measurement will lead to a determination of the proton-to-electron mass ratio with a precision of 1.3 parts per billion.

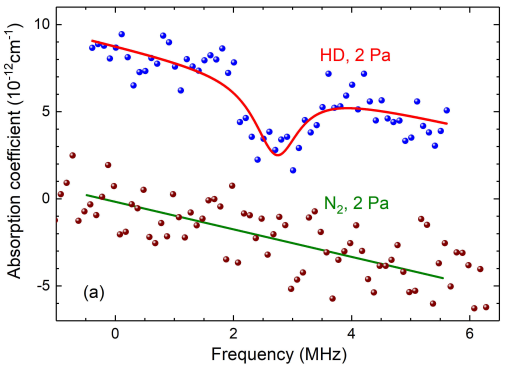

Figure 1: Lamb dip spectrum of the R(1) 2-0 line of HD

	D_0, (0,0)	2-0, R(1)
$E^{(2)}$	36406.510839(1)	7241.846169(1)
$E^{(4)}$	-0.531325(1)	0.040719
$E^{(5)}$	-0.1964(2)	-0.03743(4)
$E^{(6)}$	-0.002080(6)	-0.000339
$E^{(7)}$	0.00012(6)	0.000021
E_{FS}	-0.000117	-0.000021
Total	36405.7810(5)	7241.84912(6)
Expt.	36405.78366(36) [3]	7241.849386(3)
Diff.	0.0026	0.00027

Table 1: Calculated and experimental energies of HD (unit: cm^{-1}).

[1] J. Wang *et al.*, Journal of Chemical Physics **147** (2017) 091103.

[2] M. Puchalski *et al.*, Physical Review Letters **117** (2016) 263002.

[3] D. Sprecher *et al.*, Journal of Chemical Physics **133** (2010) 111102.