Laser spectroscopy of hydrogen

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Tunable lasers and coherent light techniques have made possible dramatic improvements in resolution in the spectrum of atomic hydrogen, opening new opportunities for precision measurements of fundamental constants and for stringent tests of quantum electrodynamic theory.[1]

Saturated absorption spectroscopy, polarization spectroscopy, and optical-rf double quantum spectroscopy with tunable dye lasers has been used to study visible Balmer lines in glow discharges.[2-6] An improved value of the Rydberg constant has been determined from the absolute wavelength of H-alpha.[4] Future improvements are possible by observation of a beam of metastable atoms or by laser excitation of the absorbing 2S state in a cool gas of ground state hydrogen atoms.

Transitions from the 1S ground state to the metastable 2S state are being studied by Doppler-free two-photon spectroscopy. Past experiments with a frequency-doubled pulsed laser were limited in resolution to about 100 MHz.[7,8] Present efforts to observe 1S–2S with a low-power source of cw radiation near 243 nm promise a thousandfold improvement in resolution.[9] They should yield an even better Rydberg and a new value of the electron / proton mass ratio. Moreover, they will confirm the predicted relativistic correction due to the recoil of the nucleus, and they will make possible a much more precise determination of the 1S Lamb shift. Future experiments approaching the 1 Hz natural linewidth of 1S–2S may well lead to some surprising fundamental discovery.

References

[1] T. W. Hansch, A. L. Schawlow, and G. W. Series, Sci. Am. 240, 94 (1979).
[2] T. W. Hansch, M. H. Nayfeh, S. A. Lee, S. M. Curry, and I. S. Shahin, Phys. Rev. Letters 32, 1336 (1974).
[3] C. Wieman and T. W. Hansch, Phys. Rev. Letters 36, 1707 (1979).
[4] J. E. M. Goldsmith, E. W. Weber, and T. W. Hansch, Phys. Rev. Letters 41, 1525 (1978).
[5] E. W. Weber, and J. E. M. Goldsmith, Phys. Rev. Letters 41, 940. (1978).
[6] E. W. Weber and J. E. M. Goldsmith, Phys. Letters 70A, 95 (1979).
[7] T. W. Hansch, S. A. Lee, R. Wallenstein, and C. Wieman, Phys. Rev. Letters 34, 307 (1975).
[8] C. Wieman and T. W. Hansch, Physical Review A, Submitted for publication.
[9] A. I. Ferguson, J. E. M. Goldsmith, T. W. Hansch, and E. W. Weber, in *Laser Spectroscopy. IV*, Springer Series in Optical Sciences, Vol. 21, H. Walther and K. W. Rothe, eds., Springer Verlag, Berlin, Heidelberg, New York 1979, pp. 31.

氢的激光光谱学

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可调谐激光和相干光技术使得氢原子光谱的分辨率有极大的提高，为精确测定基本常数以及严格检验量子电动力学理论提供了新的可能。

利用可调谐激光器的饱和吸收光谱术、偏振光谱术和光学—射频双量子光谱术已经研究了辉光放电中的可见的巴耳末线系。根据 H_2 谱线的绝对波长已经确定了里德伯常数的改进数值，对亚稳态原子束观察，或者在处于基态氢原子的冷却气体中用激光激励吸收的 2S 态有可能进一步改进上述的数值。

正在用无多普勒双光子光谱术研究从 1S 基态到 2S 亚稳态的跃迁。先前用倍频脉冲激光作的实验使分辨率限制为100兆赫左右。目前用243毫微米附近的低功率连续辐射源观察1S—2S，可望使分辨率提高千倍。从而应该获得更好的里德伯常数和新的电子—质子质量的比值、此外，还将证实由核反冲所预言的相对论修正，以及有可能更精确地确定 1S 兰姆位移。趋近到 1S—2S 的 1 赫自然线宽的进一步实验必将导致某些惊人的基本发现。