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TUNABLE LASERS AND COHERENT LIGHT TECHNIQUES FOR HIGH RESOLUTIO--ETC(U)
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Tunable Lasers and Coherent Light Techniques for High Resolution Ultraviolet Spectroscopy

Final Technical Report

1 April ~~1975~~ 1975 -- 31 March 1978

~~Contract No.~~ N00014-75-C-0841

GL-2812

~~G. L. Report No.~~ 2812

May 1978

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A. Technical Summary

Under the sponsorship of ONR we have explored and developed new coherent light techniques and instrumental systems for high resolution laser spectroscopy in the ultraviolet spectral region. This work has benefited from the interaction with another research program, sponsored by the National Science Foundation. A detailed summary can be found in the Technical Reports No. 4, 5, and 6 (1-3)*, which have been submitted to the U.S. Office of Naval Research Physics Program Office. The reports and technical papers published during the contract period and credited to ONR support are listed in section B. This section summarizes the most important technical accomplishements:

a) A dye laser oscillator-amplifier system has been developed, which combines high monochromaticity, a good spatial beam quality, and a wide linear tuning range with high peak power. This laser permits the efficient generation of narrowband tunable ultraviolet radiation by second harmonic generation and frequency mixing in nonlinear crystals and gases.

b) We have studied the 1S-2S transition of atomic hydrogen by Doppler-free two-photon spectroscopy with the frequency-doubled output of the pulsed dye laser oscillator-amplifier system. The experiments have provided the first accurate measurement of the Lyman alpha isotope shift for hydrogen and deuterium. We have also compared the 1S-2S interval with the n=2-4 interval, by simultaneously recording a Doppler-free saturation spectrum of the visible Balmer beta line with the fundamental dye laser output. This comparison has yielded the first precise measurement of the 1S ground state Lamb shift (5).

c) We have developed the technique of laser polarization spectroscopy, a new method of Doppler-free spectroscopy which can greatly exceed the sensitivity of saturated absorption spectroscopy (6).

d) We have demonstrated the possibility of unraveling complex molecular absorption spectra by polarization labeling. This new method identifies all absorption lines with a common lower level (7).

e) The high power, monochromaticity, and wide tuning range of our gas pressure tuned dye laser oscillator amplifier system has permitted us to record Doppler-free two-photon spectra of normal and deuterated benzene with unprecedented resolution. Computer fits of the observed rotational contours have provided new accurate molecular constants (8).

f) We have developed a tunable dye laser system with improved spectral brightness and output power by combining a single frequency cw dye laser oscillator with a multistage pulsed dye laser amplifier (12)

g) Using this new laser for Doppler-free spectroscopy of atomic hydrogen and deuterium, we have obtained new precision values of the 1S-2S isotope shift and the 1S Lamb shift, and have qualitatively confirmed the existence of the theoretically predicted relativistic nuclear recoil shift (12).

h) We have demonstrated a novel technique of high resolution laser spectroscopy, using coherent two-photon excitation with multiple light pulses. Quantum interference effects result in narrow resonances, similar to Ramsey fringes. The method holds promise for Doppler-free spectroscopy in the vacuum ultraviolet (9,13,14).

*) Footnote: the references in parentheses refer to the list of reports and publications in section B.

B. Reports and Publications

1) "Ultranarrowband Tunable Dye Laser for New Approaches to Atomic Spectroscopy," by T. W. Hansch, ONR Technical Report No.4, M.L. Report No. 2511, Stanford, December 1975.

2) "Ultranarrowband Tunable Dye Laser for New Approaches to Atomic Spectroscopy," by T. W. Hansch, ONR Technical Report No.5, G.L. Report No. 2648, Stanford, December 1976.

3) "Tunable Lasers and Coherent Light Techniques for High Resolution Ultraviolet Spectroscopy," by T. W. Hansch, ONR Technical Report No.6, G.L. Report No. 2756, Stanford, December 1977.

4) "Powerful Dye Laser Oscillator Amplifier System for High Resolution Spectroscopy," by R. Wallenstein and T. W. Hansch, Opt. Communications 14, 353 (1975)

5) "Hydrogen 1S-2S Isotope Shift and 1S Lamb Shift Measured by Laser Spectroscopy," by S. A. Lee, R. Wallenstein, and T. W. Hansch, Phys. Rev. Letters 35, 1262 (1975)

6) "Doppler-Free Laser Polarization Spectroscopy," by C. Wieman and T. W. Hansch, Phys. Rev. Letters 36, 1170 (1976)

7) "Simplification of Spectra by Polarization Labeling," by R. Teets, R. Feinberg, T. W. Hansch, and A. L. Schawlow, Phys. Rev. Letters 37, 683 (1976)

8) "High Resolution Two-Photon Spectroscopy in the 1B2u State of Benzene," by J. Lombardi, R. Wallenstein, T. W. Hansch, and D. M. Friedrich, J. Chem. Physics 65, 2357 (1976)

9) Applications of High Resolution Laser Spectroscopy," by T. W. Hansch, in "Tunable Lasers and Applications," A. Mooradian, T. Jaeger, and P. Stokseth, Eds., Springer Series in Optical Sciences, Vol. 3, pp. 326 (1976)

10) "Lasers, Light and Matter," by A. L. Schawlow, J. Opt. Soc. Am. 67, 140 (1977)

11) "New Methods of Laser Spectroscopy," by T. W. Hansch, in Proceedings of Laser 77 / Optoelectronics Conference, W. Waidelich, Ed., IPC Science and Technology Press, 1977, pp. 108

12) "Precision Measurement of the Ground State Lamb Shift in Hydrogen and Deuterium," by C. Wieman and T. W. Hansch, in "Laser Spectroscopy III.," J. L. Hall and J. L. Carlsten, Eds., Springer Series in Optical Sciences, Vol. 7, pp. 39 (1977)

13) "Multiple Coherent Interactions," by T. W. Hansch, in "Laser

Spectroscopy III.," J. L. Hall and J. L. Carlsten, Eds., Springer Series in Optical Sciences, Vol. 7, pp. 149 (1977)

14) "Coherent Two-Photon Excitation by Multiple Light Pulses," by R. Teets, J. Eckstein, and T. W. Hansch, Phys. Rev. Letters 38, 760 (1977)