

Laser Spectroscopy VI

Proceedings of the Sixth International Conference,
Interlaken, Switzerland,
June 27 - July 1, 1983

Editors

H. P. Weber and W. Lüthy

With 258 Figures

Springer-Verlag
Berlin Heidelberg New York Tokyo 1983

Laser Magnetic Resonance Spectroscopy of Atoms

K.M. Evenson and M. Inguscio*

Time and Frequency Division, National Bureau of Standards
Boulder, CO 80303, USA

Laser magnetic resonance (LMR) using optically pumped far-infrared lasers is a powerful spectroscopic technique for investigating molecules. It has been already proven by applying it successfully to detect and study the rotational spectra of transient molecular species, including metastable levels and ions (1). The applicability of LMR to atoms, however, meets with some difficulties. The main one is that a CW laser line in near coincidence with a suitable atomic transition may not be available on account of the much smaller number of atomic energy levels relative to those of even a simple molecule. Besides this, since atomic transitions in the far infrared are mostly magnetic dipole in nature, the sensitivity of absorption spectroscopy to atomic transitions is greatly reduced. To date only atomic oxygen (2,3), atomic carbon (4) and atomic silicon (5) have been measured. On the other hand, there are many reasons for investigating atoms: the fractional accuracy of the frequency determination using LMR is of the order of 10^{-7} and is about two orders of magnitude more accurate than data for the fine structures derived from optical spectra. The high accuracy of direct fine structure measurements can expedite astrophysical searches for the species, as for the case of atomic carbon (6). Furthermore in cases where more than one Zeeman coincidence is observed, LMR data also produces atomic g_f factors with enough accuracy to test the complex corrections to Russell-Saunders values which have been recently computed for complex atoms.

Briefly, the experimental apparatus consists of a far-infrared gain cell pumped transversely by a grating-tuned CO₂ laser and separated from the intracavity sample region by a polypropylene beam splitter at Brewster angle to the far laser beam. The sample region is placed between the ring-shimmed Hyperco 38 cm pole caps of an electromagnet producing a 7.5 cm diameter homogeneous field region. Two coaxial flow tubes extend to the perimeter of the laser beam where the atom to be investigated is produced. As a transition in the atom is tuned into coincidence with the laser frequency by the magnetic field, the total far-infrared power inside the laser cavity changes and is modulated at 10 KHz by a pair of Helmholtz coils. The laser output is detected with a helium-cooled germanium bolometer and the signal is fed to a lock-in amplifier. The demodulated output signal is approximately equal to the first derivative of the absorption signal.

The powerfulness of the technique is demonstrated for atomic silicon, where to all the difficulties, also that related to the production of enough den-

Permanent address: Dipartimento di Fisica dell'Università, piazza Torricelli 2, I-56100 Pisa, Italy

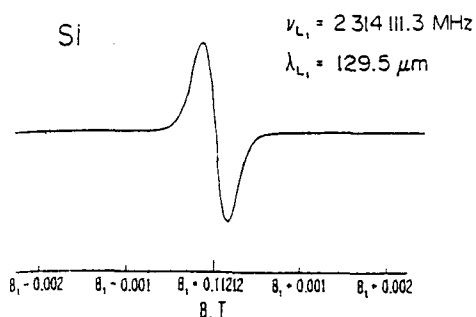


Fig. 1 - LMR signal of Si from the 129.5 μm (2314111.3 MHz) line of CH_3OH at 0.11212 T. This signal was recorded with a 0.1 second time constant. The linewidth is 0.00032 T corresponding to about 6 MHz

sity of a refractory element must be added. The atom is produced in a reaction between F atoms and silane (SiH_4). Fluorine atoms are produced in a 2450 MHz discharge through a dilute mixture of F_2 in He. In Fig. 1 is shown the LMR recording of the $^3P_0 - ^3P_1$ fine structure transition of Si in its ground state resonant with a CH_3OH laser line. The signal-to-noise ratio is excellent in spite of the relatively low atomic transition probability ($A=8.25 \times 10^{-6} \text{ sec}^{-1}$). Extra resonances have also been observed with laser lines from CD_3OH and $^{13}\text{CD}_3\text{OH}$ yielding g_J factor - 1.500830 (70) - and fine structure separation (2311755.6 MHz) with one of the highest accuracies ever obtained by LMR.

References

- (1) K.M. Evenson, R.J. Saykally, D.A. Jennings, R.F. Curl, and J.M. Brown : in "Chemical and Biochemical Applications of Lasers" vol. 5, ed. C.B. Moore, Academic Press, N.Y. 1980
- (2) P.B. Davies, B.J. Handy, E.K. Murray - Lloyd and D.K. Russell: J. Chem. Phys. 68, 3377 (1978)
- (3) R.J. Saykally and K.M. Evenson: J. Chem. Phys. 71, 01564 (1979)
- (4) R.J. Saykally and K.M. Evenson: Ap.J. Letters 238, L107 (1980)
- (5) M. Inguscio, K.M. Evenson, V. Beltran-L, and E. Ley - Koo: Ap.J. Letters to be published
- (6) T.G. Phillips, P.J. Huggings, T.B.H. Kuiper, and R.E. Miller: Ap.J. Letters 238, L103 (1980)