VII. NUCLEAR MAGNETIC RESONANCE AND HYPERFINE STRUCTURE

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RESEARCH OBJECTIVES

The aims of this group are twofold; first, the investigation of chemical structural problems by nuclear magnetic-resonance techniques, and second, the investigation of the structure of atomic nuclei, particularly of radioactive nuclei, by nuclear magnetic-resonance techniques and by the investigation of atomic hyperfine structure and isotope shift. In order to get information from the relatively small numbers of atoms with radioactive nuclei that can be prepared, the emphasis in this group has been on the optical properties of atomic vapors. In addition to straightforward spectroscopic investigations that make use of gratings and interferometers, and especially designed light sources requiring very few atoms, techniques have been developed for eliminating Doppler broadening, especially by the use of radiofrequency and microwave absorption, and also of atomic-beam light sources.

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A. ISOTOPE SHIFT IN THE SPECTRUM OF CESIUM*

Cesium has a single stable isotope, A = 133, and two long-lived isotopes that occur as fission fragments, A = 135 and A = 137. In order to study the isotope shift in the spectrum of cesium, we have examined the resonance line, $\lambda 8944$ A $\left(6^2S_{1/2}\text{-}6^2P_{1/2}\right)$, of cesium, obtained from fission products supplied by Union Carbide Nuclear Company. We used approximately 0.05 mg of CsCl, which we reduced to metallic form by heating in the presence of sodium metal and introduced into an electrodeless discharge tube with neon gas at a pressure of approximately 2 mm.

Using a Fabry-Pérot interferometer, with a spacer of 3 cm, in conjunction with the 40-ft Fastie-Ebert grating spectrograph in the Spectroscopy Laboratory, M.I.T., we were able to resolve the hyperfine structure of this line, in both natural cesium and radioactive cesium. The structure observed in the latter corresponded to the known splitting (1) in Cs^{135} (N=80), with an isotope shift relative to Cs^{133} (N=78) of 3.3 ± 0.3 mK.

The smallness of this shift is somewhat difficult to understand. From the usual relation,

$$R = 1.2 \times 10^{-13} A^{1/3}$$

*This research was supported in part by the Alfred P. Sloan Foundation.

we would predict a shift of 25 mK; the distortion computed from the known quadrupole moment (2) of Cs^{133}, $0.003 \pm 0.002 \times 10^{-24}$ cm^2, is expected to reduce (3) this only approximately one part in 10^5. The most likely inference would seem to be that as one approaches a closed shell of neutrons (N=82), the nuclear density increases somewhat, although it may be that the mass effect contributes a significant amount (4).

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References

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B. ATOMIC-BEAM ABSORPTION CELL

An atomic-beam apparatus has been constructed for the purpose of studying more precisely the hyperfine structure of the thallium 3776 A $\left(7^2S_{1/2}\text{-}6^2P_{1/2}\right)$ resonance line, and, eventually, the 5350 A $\left(7^2S_{1/2}\text{-}6^2P_{3/2}\right)$ line. The results are expected to yield information on the isotope shifts in the $^2P_{1/2}$ and $^2P_{3/2}$ states, as well as a possible hfs anomaly in the $^2S_{1/2}$ state between the two stable Tl isotopes. Absorption has been observed only in the strongest component of the 3776 A line by using a Fabry-Pérot interferometer. The beam, however, was not completely satisfactory because the absorption was less than was expected, and the linewidth greater. In order to overcome these difficulties, a more intense atomic beam with a channel oven has been constructed. Further details are given in M. Çiftan's thesis (1).

M. Çiftan, L. C. Bradley III, H. H. Stroke

References

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C. MECHANICAL IMPROVEMENTS IN A HIGH-POWER MICROWAVE ATTENUATOR

Movable water loads provide a practical means of obtaining variable microwave attenuation at power levels of 50 watts, and upward. The water load is a dielectric tank through which a mixture of ethylene glycol and water is pumped. When it is placed in a waveguide carrying rf power, the power is absorbed directly in the liquid. The

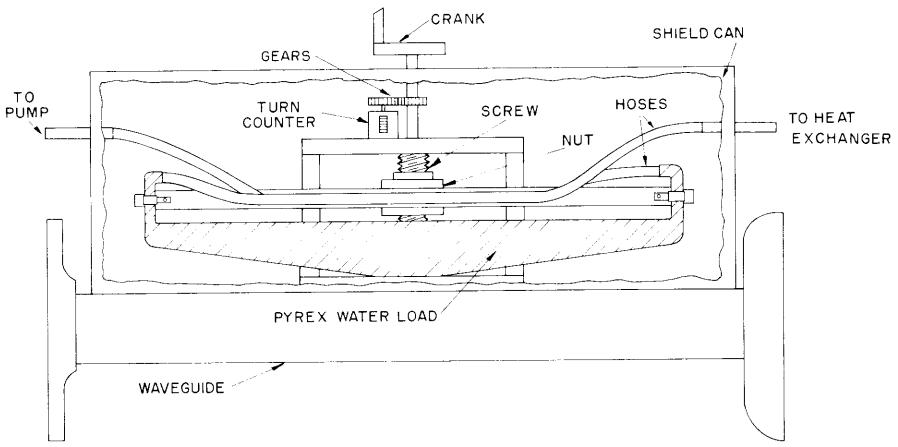

Fig. VII-1. Attenuator.

liquid is cooled by being pumped through an external heat exchanger. The attenuation is increased, either by moving the load from a low field to a high field region or by inserting it progressively through a slot in a wall of the waveguide.

Although variable water-load attenuators are ideal for high-power applications, they are not commercially available at the present time. Experience has shown that the polystyrene water loads, which have been used thus far, gradually deteriorate under the action of ethylene glycol, and warp badly if they are subjected to even a slight excess of heat. The useful life of a load is approximately 6 months, and replacements are far from easy to fabricate. Moreover, the necessity for minimizing stray radiation has led to complicated mechanisms for varying the attenuation, and these have failed to provide adequate protection for the delicate water load.

A 3-kmc attenuator has been constructed (Fig. VII-1) which is relatively simple, and obviates the difficulties mentioned. The load itself is made of Pyrex. A screw lowers it through a slot in the waveguide. A shield can encloses the entire mechanism, isolating it mechanically and electrically. Hoses from the water load are connected to brass tubes passing through the shield, so that tugs on the external hoses to the pump and heat exchanger cannot be transmitted to the Pyrex tank. It was conjectured that the shield might act as a resonant cavity coupled to the waveguide, but no difficulty from this source has been encountered.

H. R. Hirsch

D. HYPERFINE STRUCTURE OF Hg^{201} IN ZERO FIELD

The hyperfine structure of the $^3P_1$ state of Hg^{201} has three components: $F = \frac{1}{2}$, $\frac{3}{2}$, $\frac{5}{2}$. Optically detected microwave resonance between the $\frac{3}{2}$ and $\frac{5}{2}$ components has

been observed. The method is the same as that used to measure the $F = \frac{3}{2} \leftrightarrow F = \frac{1}{2}$ separation (1, 2). The results of both measurements are:

Transition	Frequency (mc)	Observed Lifetime (sec)
$\left(F=\frac{3}{2} \leftrightarrow F=\frac{1}{2} \right)$	7551.613 ± .013	0.7×10^{-7}
$\left(F=\frac{3}{2} \leftrightarrow F=\frac{5}{2} \right)$	13,986.557 ± .008	1.0×10^{-7}

R. H. Kohler

References

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E. HYPERFINE STRUCTURE OF THE $^3P_1$ STATE OF MERCURY

The $F = \frac{3}{2} \leftrightarrow F = \frac{1}{2}$ transition in the $^3P_1$ state of Hg^{199} has been observed in small magnetic fields (≈10 gauss). The methods employed are basically the same as those used by Kohler (1, 2).

The previous accepted value (22,118 ± 15 mc) was that obtained by Melissinos (3). Preliminary observations give the splitting as 22,129 ± 0.5 mc. With further modification of the apparatus, and an increase in sensitivity, it is anticipated that the error will be decreased by a factor of 10.

C. V. Stager

References

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