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ABSTRACT

A change in laser axial beat-note amplitude has been observed when the mode separation becomes equal to an integral multiple of twice the Zeeman frequency. The effect was observed in both He-Ne and Ar^+ lasers. Application of the method to spectroscopy of excited states is discussed.

In this letter we report observation of a change in the amplitude of the beat note between axial modes of a laser when the mode separation becomes equal to an integral multiple of twice the Zeeman separation of either the upper or lower lasing levels of the atoms. The magnitude of the effect decreases with increasing order, and becomes effectively zero by the fourth order.

In this experiment it was our purpose to develop a method for rf spectroscopy of excited states. In principle, this method may be extended to the measurement of g_J's and hyperfine-structure separations of any lasing states in an atom. Because the linewidth is independent to first order of the Doppler effect, this technique should enable the study of excited-state lifetimes under lasing conditions.

The effect was observed in both a 50-cm-long He-Ne and a 35-cm-long Ar^+ laser. These lasers had Brewster-angle windows and external spherical mirrors. The mirror separation was always much smaller than the focal length. The lasers were placed in an axial magnetic field and operated in the TEM_{00} mode. A schematic diagram of the apparatus is shown in Fig 1. Since the phototube is a square-law detector, its output is modulated at the difference frequencies between modes. The tuned receiver passes only the portion of the phototube output which contains the desired beat frequency.

Resonances were observed at a fixed cavity length by sweeping the magnetic field. Figure 2 shows the beat-note amplitude for the 6328-A transition in the He-Ne laser. The resonance takes the form of a dispersion curve because a phase-sensitive detector is used with field modulation. Because both the upper and lower lasing levels of Ne have the same g_J, only one resonance is obtained in this case.

The dependence of the resonance on cavity length was verified by changing the cavity length and observing the shift in the field value of the resonance. The width of the line shown in Fig. 2 is of the order of 35 MHz. Similar results were obtained for the 4880 A transition in the Ar^+ laser. The estimated width of the resonance corresponding to an overlap of the upper levels was of the order of 70 MHz; resonances due to an overlap of lower levels were small and poorly defined because the lower levels are only partially resolved at the field values used. In both cases, no attempt was made to frequency-lock the laser, or to achieve a field homogeneous to more than approximately 10%; the linewidths are therefore broader than they would be under optimum conditions.

The observed effects can be qualitatively explained by the following simple consideration. As the magnetic field is swept through the point of overlap between the Zeeman splitting and the axial-mode separation, the atom can be stimulated to emit into two modes. This has the effect of coupling the two axial modes and is analogous to the strong-coupling case in Lamb's theory.[1] At this strong-coupling point, one mode tries to quench the other, and a change in beat-note amplitude is expected.

The effect that we observed is similar to that reported by Kannelaud and Culshaw.[2] We believe, however, that our method allows easier observation of resonances and clearer determination of line shapes and widths, with corresponding gains in accuracy of spectroscopic measurements. In addition, by using a tuned receiver to select the axial modes to be studied, one no longer needs to operate the laser in a single transverse mode.

FOOTNOTES AND REFERENCES

[*] Work done under the auspices of the U. S. Atomic Energy Commission.

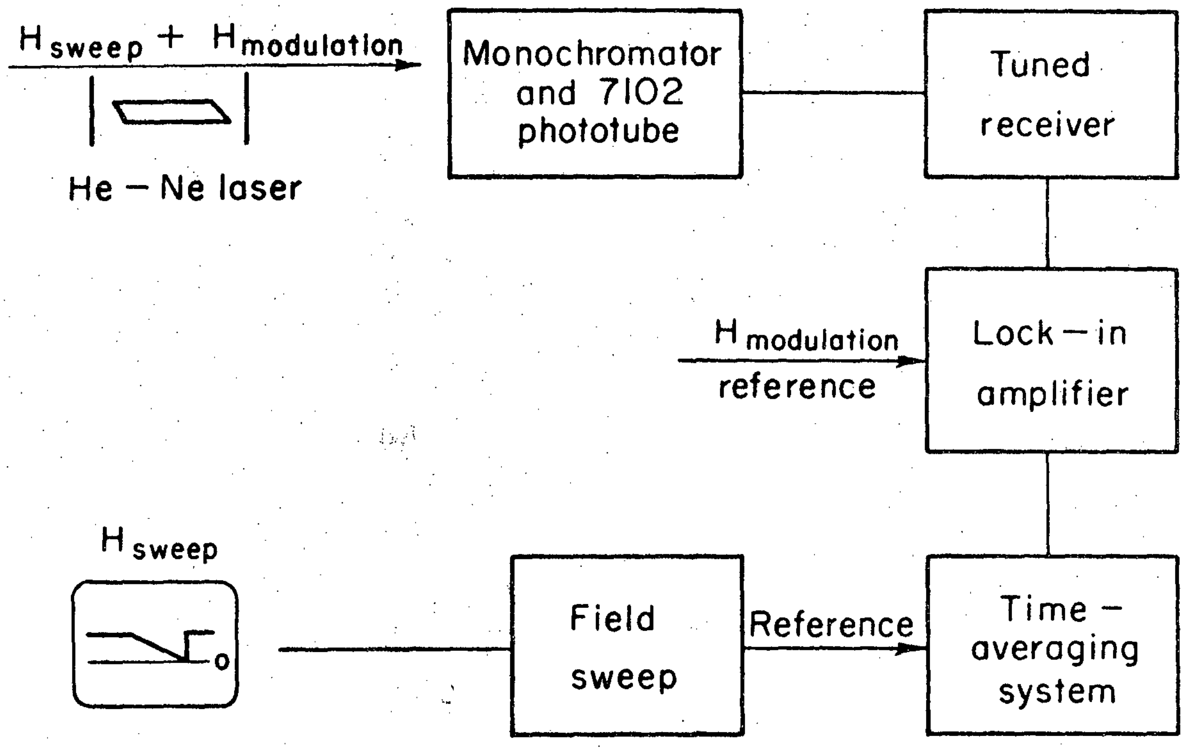
[†] National Academy of Sciences Research Associate.

1. W. E. Lamb, Jr., Phys. Rev. 134, A1429 (1964).
2. J. Kannelaud and W. Culshaw, Appl. Phys. Letters 9, 120 (1966).

FIGURE LEGENDS

Fig. 1. Schematic of apparatus. The frequency of $H_{modulation}$ is about 400 Hz. The frequency of H_{sweep} equals 0.005 Hz.

Fig. 2. Intensity of beat-note amplitude vs magnetic field. The cavity is about 120 cm long; the beat frequency is 122 MHz.



$H_{sweep} + H_{modulation}$
He – Ne laser
Monochromator and 7102 phototube
Tuned receiver
$H_{modulation}$ reference
Lock – in amplifier
H_{sweep}
o
Field sweep
Reference
Time – averaging system

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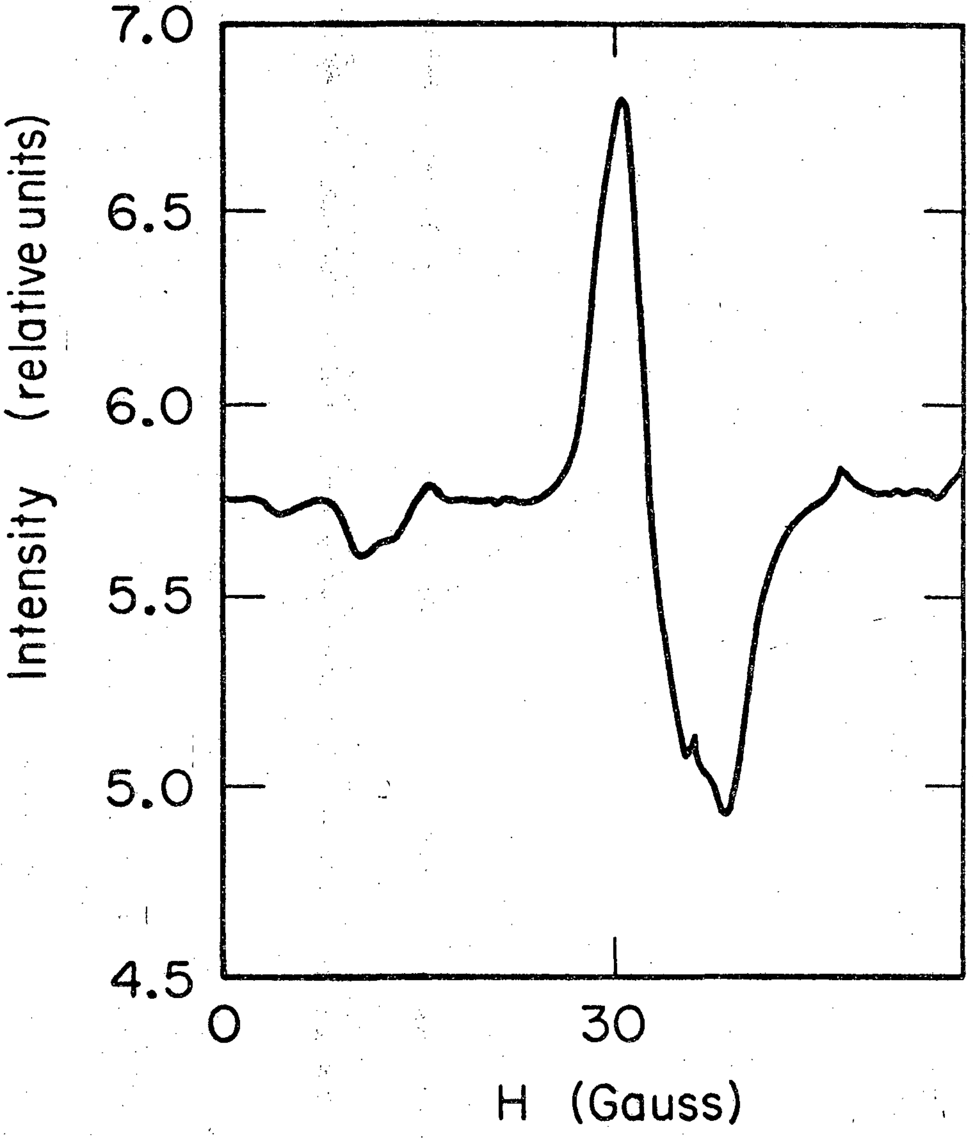

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