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THE OPTICAL DETECTION OF STIMULATED EMISSION IN CN AT 20-CM WAVELENGTH

Kenneth M. Evenson
National Bureau of Standards
Boulder, Colorado 80301

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Six of the seven allowed electric dipole transitions between the hyperfine levels of the $J = 7/2$ lambda doublet in the 10th vibrational level of the $A^2\pi_{3/2}$ state of CN were observed. The transitions at frequencies between 1580 and 1650 MHz occur between the more populated negative parity levels and the positive parity levels. The stimulated emission was detected by measuring an increase in the intensity of the $B^2\Sigma^+ \rightarrow X^2\Sigma^+(0, 0)$ violet band of CN near 3875 Å.

In two previous papers[1,2] the optical detection of microwave transitions (double resonance) has been shown to be an extremely sensitive technique for measuring microwave transitions in electronically excited CN. This same technique has now been used to study stimulated emission at six frequencies between 1580 and 1650 MHz and also to indicate that none of the proposed mechanisms for the 337-μm "so-called" CN laser seem to be correct.

Previous measurements on both electric[1] and magnetic dipole[3] transitions within the $K' = 4$ perturbation complex of the $v = 10$ level of the $A^2\pi_{3/2}$ and the $v = 0$ level of the $B^2\Sigma^+$ states have shown the lambda doublet separation to be in the 1600-MHz region. Transitions reported here are between the upper negative parity, unperturbed hyperfine levels, and the lower positive parity, perturbed levels. A tunable coaxial cavity one-half wavelength long with a 6-in. diam and resonant in the 1600-MHz region was used to make the measurements. The cavity, with a Q of about one thousand, was fed with 2 to 3 W of microwave power 100% modulated at 1 kHz. A viewing port at the center of the cavity allowed the detection of this 1000-cps modulation in the optical emission at the $B^2\Sigma^+ \rightarrow X^2\Sigma^+(0, 0)$ violet band of CN near 3875 Å. The 3875-Å emission was isolated with a violet glass filter, and was detected by a photomultiplier connected to a 1-kHz phase-sensitive detector. Active nitrogen and methylene chloride (which react to form CN) entered the cavity on one side of the circumference of the cavity, and were pumped out on the opposite side.

The cavity frequency was varied with a motor drive while the microwave oscillator was manually held to the cavity frequency. The observed stimulated emission frequencies are listed in Table I along with the observed and calculated[4] relative intensities; the energy levels are illustrated in Fig. 1. The identity of the transitions was known from previous predictions[1,3] and measured frequencies were in agreement with these measurements. Differences between the observed and calculated relative intensities are most likely due to population and lifetime differences in the positive parity levels

Table I. Frequencies and Relative Intensities of the Observed Stimulated Emission in $K' = 4$ Rotational Level of the $A^2\pi_{3/2}$ Electronic State of CN.

Electron	Hyperfine Transition $F \rightarrow F^1$	Observed Frequency (MHz)	Observed Relative Intensity	Calculated Relative Intensity
$\pi(u) \rightarrow \pi(p)$	$5/2 \rightarrow 5/2$	1579.3 ± 0.3	76 ± 7	58
	$5/2 \rightarrow 7/2$	1590.0 ± 1.5	14 ± 5	5.3
	$7/2 \rightarrow 5/2$	(not observed)	–	5.3
	$7/2 \rightarrow 7/2$	1610.4 ± 0.3	83 ± 7	73
	$7/2 \rightarrow 9/2$	1623.0 ± 1.5	10 ± 7	5.3
	$9/2 \rightarrow 7/2$	1635.5 ± 1.5	10 ± 7	5.3
	$9/2 \rightarrow 9/2$	1649.1 ± 0.3	100 ± 9	100

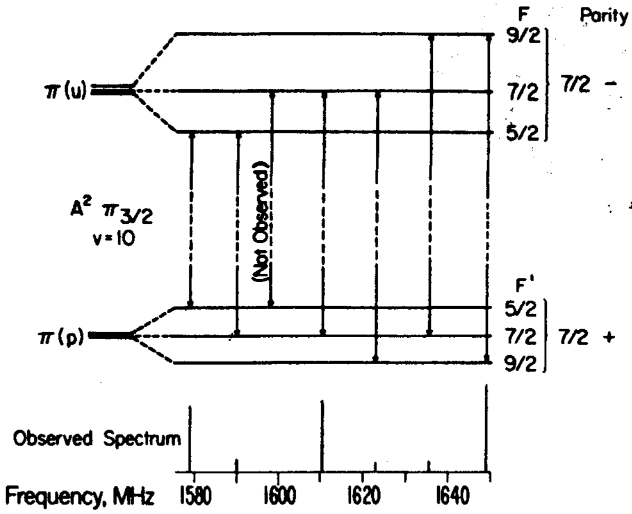

Fig. 1. Energy level diagram of $A^2\pi_{3/2}$, $v = 10$ state. The observed microwave spectrum is shown with the transitions identified.

resulting from a variation in the perturbations between these levels and the perturbed sigma levels. Linewidths were approximately the same as those observed in the previous experiments (8 MHz at pressures of 1 torr).

The observed signals were stimulated emission rather than absorption because the application of microwave power to the cavity produced an increase in the 4000-Å optical emission from the glowing gas mixture. The normally forbidden $A \rightarrow X$ transitions become possible for the $\pi(p)$ state due to its mixing with the $\Sigma(p)$ state. Thus, the increased optical activity corresponds to an increase in the population of the lower lying $\pi(p)$ state, and hence, the observed phenomenon is stimulated emission.

The same double-resonance technique was used to investigate mechanisms of the "so-called" CN laser at 337 μm. To discover if any of the proposed CN levels[5] might indeed be responsible for the lasing action, a CW 337-μm laser radiation was mechanically chopped at 8 cps within the laser cavity, while a scanning monochrometer, viewing perpendicular to the laser, monitored the emission spectrum from 2000 to 6000 Å. The IP28 photomultiplier output in the monochrometer was fed to an 8-cps narrow-band detector phased to the chopper wheel frequency. No signals were obtained. Mathematical considerations utilizing monochrometer sensitivity (including geometrical and photomultiplier sensitivity), efficiency, and laser power output, predicted a signal approximately three hundred times greater than the observed noise level. The absence of a signal agrees well with the recent work of Lide and Maki[6] who have shown that HCN is likely to be responsible for the lasing action in the "so-called" CN laser, and with Hocker and Javan[7] who have completely verified Lide and Maki's identification.

The observation of weak stimulated emission in these high-lying excited electronic levels of CN not only provides information about the fine and hyperfine levels of this state of CN but also indicates the power of this technique for discovering active energy levels in various lasers.

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