CONF-801202--1

LA-UR-80-2216

MASTER

TITLE: INTERACTION OF FAR-INFRARED AND MID-INFRARED LASER TRANSITIONS IN THE AMMONIA LASER

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SUBMITTED TO: TOPICAL MEETING ON INFRARED LASERS

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Form No. 836 R3

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ABSTRACT

Mid-infrared laser emission in ammonia is usually observed on a P(J + 2) transition when a CO_2 laser is used to optically pump a near resonant R(J) absorption feature. However, by generating simultaneous FIR ammonia laser emission in the same optical cavity, mid-infrared emission is obtained exclusively on the P(J) transition.

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A new pattern of mid-infrared laser emission has been observed in the optically pumped NH_3 laser. Laser emission on the conventional 12.8 µm NH_3 laser transition,[1] optically pumped by the 9R16 CO_2 line, has been completely quenched and replaced by emission at 12.2 µm.

Figure 1 presents an energy level diagram for NH_3 and the relevant rotational states for optically pumping the aR(6,0) NH_3 transition with the 9R16 CO_2 laser line. Recently there have been reports in the literature[2,3] of additional NH_3 laser transitions observed at 12.08 µm (sP(7,0)) and 12.2 µm (aP(6,0)).

We have demonstrated the necessity of simultaneous FIR laser oscillation to produce laser action on the 12.2 µm transition. Several optical cavity configurations were used to study the laser process. In the simplest arrangement the CO_2 laser pump is injected into the ammonia cavity through a small hole in the entrance mirror. Ammonia emission is coupled out through this same opening or through a hole in the rear mirror. Both mirrors are mounted internally at the ends of a copper or stainless steel tube.

Figure 2 illustrates the pressure and threshold-time behavior of the 12.2 µm and 12.8 µm NH_3 laser transitions. For these measurements a Lumonics (Model 103) TEA laser with an output energy of 250 mJ on 9R16 was used. Figure 2a shows the CO_2 laser pulse shape (200 nsec/div). As shown in Figure 2b, at low pressures (0.3 torr), both the 12.2 µm and 12.8 µm ammonia laser transitions were present. The intensity ratio (12.2/12.8), of the lines was 0.01. At low pressures, the total pulse duration for the 12.2 µm line was 2 µsec and 1 µsec for relative intensity of the two lines changed to 0.5, and the duration of the 12.8 µm line was reduced to 200nsec, while the 12.2 µm pulse duration remained about 2 µsec. For pressures greater than 1 torr, up to the highest NH_3 pressure (30 torr) where laser emission was observed, only the 12.2 µm line was observed. Figure 2d shows the 12.2 µm pulse shape at 1.3 and 10 torr.

A 12.5 mm thick KCl Brewster angle window was inserted between one of the cavity mirrors and the NH_3 laser cavity. It was now found that only the 12.8 µm NH_3 transition appeared regardless of pressure or buffer gas (He or N_2) used. KCl does not transmit infrared radiation at wavelengths longer than 30 µm. NH_3 FIR laser emission wavelengths are in the range of 70 - 150 µm for optical pumping with the 9R16 CO_2 line[3,4]. Hence, blocking the intracavity FIR laser emission has led to the elimination of the 12.2 µm

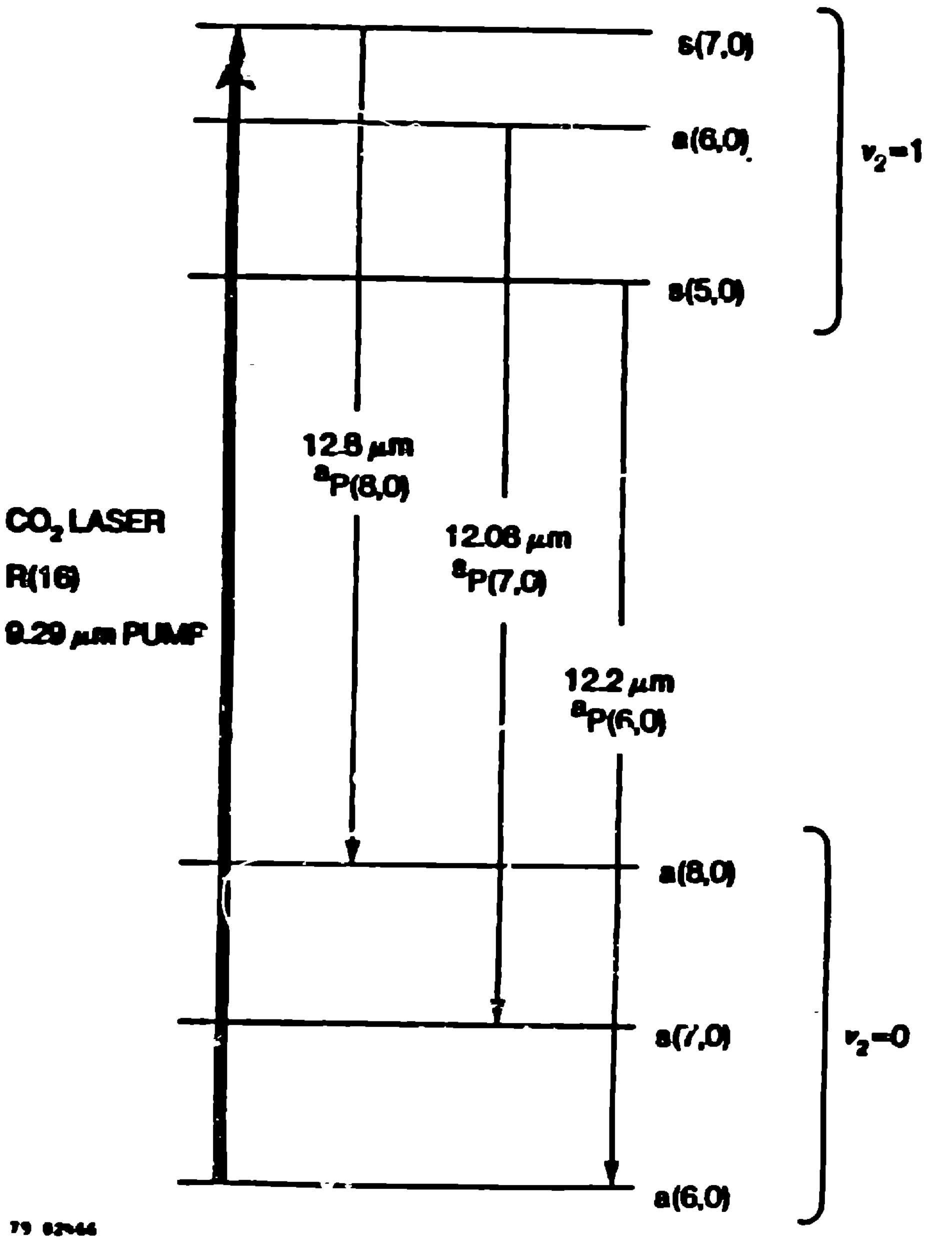


Figure 1. Relevant energy levels of NH_3 and summary of observed optically pumped mid-infrared laser transitions found in this work and in References 1, 2 and 3.

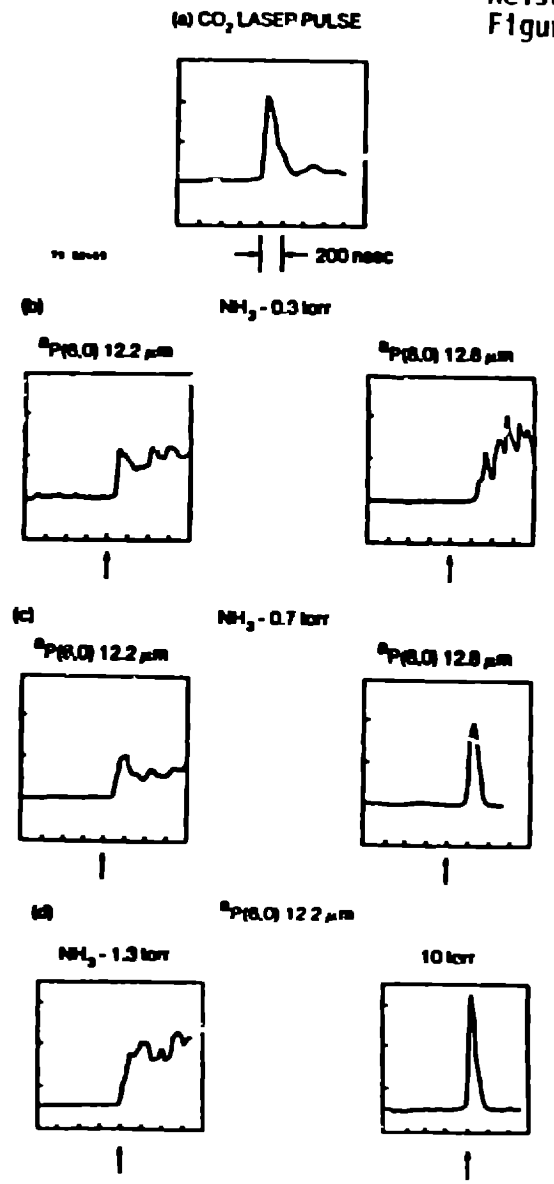
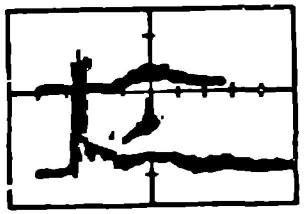
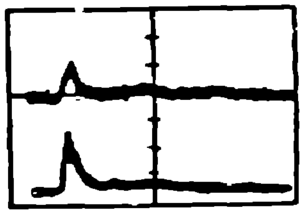


Figure 2. Pulse shapes and relative time histories of the CO_2 pump and NH_3 laser transitions. Onset time of CO_2 laser pulse is indicated by an arrow for each trace. Time scale is 200 nsec/division.



(a) TOP = NH_3 - 12.2 μm
BOTTOM - CO_2 - 9.29 μm
200 nsec/div
1.8 torr NH_3



(b) TOP - TOTAL FIR
BOTTOM - CO_2
200 nsec/div

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Figure 3. Pulse shapes and time histories for the 12.2 m NH_3 laser transition, FIR laser emission and CO_2 pump pulse.

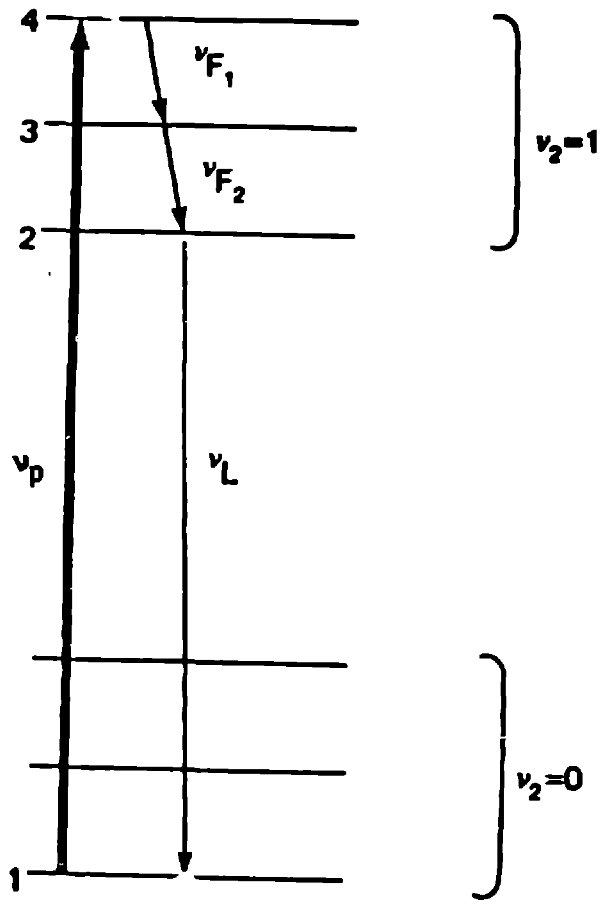

Figure 4. Optically pumped ammonia laser mechanism suggested by present experiments.

mid-infrared laser transition.

In an ammonia laser cavity which used a Littrow grating as a dichroic beamsplitter for the CO_2 and ammonia lasers, we have obtained several millijoules of 12.2 μm emission. In these studies the 12.2 μm emission was not coincident with the gain switched 9R16 CO_2 laser pulse. Instead it overlapped the N_2-tail portion of the CO_2 laser pulse (Figure 3a). FIR emission (Figure 3b), however, followed both the gain switched peak and N_2-tail portions of the CO_2 laser. This temporal behavior of the 12.2 μm emission is not understood at this time and may be related to excessive pump power broadening of the gain[5].

Figure 4 presents a schematic set of energy levels relevant to the proposed laser mechanism. ν_p corresponds to the CO_2 pump laser frequency, ν_L is the mid-infrared NH_3 emission frequency, and the intermediate FIR steps are denoted as ν_{F_1} and ν_{F_2}. The Brewster angle window experiment demonstrates that at least one of the FIR transitions is radiative. Collisional processes may contribute to population transfer into level 2 in Figure 5. A density matrix calculation[6] for the four wave, four level ammonia system indicates that emission at ν_L will take place near line center and in the absence of a population inversion for levels 1 and 2.

Research support from the U.S. Department of Energy is gratefully acknowledged.

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