NH_3 laser pumped by two CO_2 lasers

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A new method is proposed for exciting the second vibrational level of the ν_2 mode of NH_3 molecule. A number of new laser lines is obtained from an optically pumped NH_3 laser.

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1. Coincidence of certain absorption lines of the ν_2 mode of a NH_3 molecule and emission lines of a CO_2 laser has made possible an optically-pumped NH_3 laser. Moreover, this has resulted in emission at many wavelengths in the far[1,2] and intermediate[2–4] IR ranges. In this work we report on a new method of pumping the NH_3

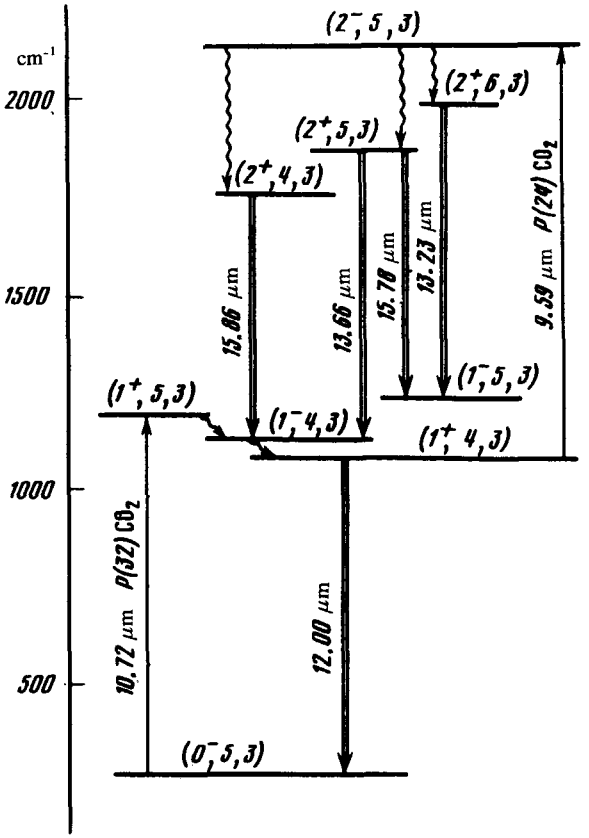

FIG. 1. Energy level diagram of the ν_2 mode of NH_3 molecule.

molecule by means of two CO_2 lasers, and observation of new oscillation lines at the following wavelengths: 12.00, 13.23, 13.66, 15.78 and 15.86 μm. Identification of these lines has been made.

2. Figure 1 shows a partial level diagram of a NH_3 molecule. We shall use the following designation of vibrational-rotational energy levels of the ν_2 mode of NH_3: $(v^{\pm}, J, K)$, where v is vibrational quantum number, J is rotational quantum number, K is a quantum number corresponding to projection of J, " $\pm$ " corresponds to the symmetrical and antisymmetrical states. A number of CO_2 laser lines coincide with NH_3 absorption lines between the zeroth and first $(0^{\pm}, J, K) \rightarrow (1^{\mp}, J', K)$ and the first and second $(1^{\pm}, J, K) \rightarrow (2^{\mp}, J', K)$ vibrational levels of the ν_2 mode. However, none of these coincidences result in a situation where the upper level of the resonant transition $(0^{\pm}, J, K) \rightarrow (1^{\mp}, J', K)$ constitutes the lower level of the $(1^{\mp}, J', K) \rightarrow (2^{\pm}, J'', K)$ transition. We devised the following method of exciting the second vibrational level of the ν_2 mode (see Fig. 1). The $P(32)$ line in the 10.4-μm band of CO_2 laser (10.72 μm) pumps the resonant transition $(0^-, 5,3) \rightarrow (1^+,5,3)$ of the NH_3 molecule in a volume placed in a resonator with respect to far-IR. Subsequently, cascade generation of far-IR radiation takes place due to the $(1^+, 5, e) \rightarrow (1^-,4,3)$ and $(1^-,4,3) \rightarrow (1^+,4,3)$

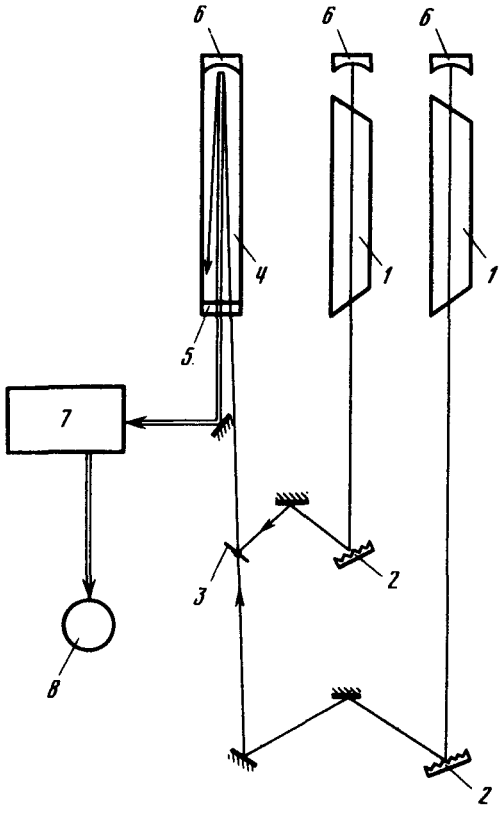

FIG. 2. Experimental setup: 1—TEA CO_2 laser compartment; 2—diffraction grating; 3—Ge-plate; 4—cell with NH_3; 5—KBr-plate; 6—metallic mirror; 7—monochromator; 8—emission receiver.

transitions. Moreover, emission occurs at 151.8 and 291.3 μm, respectively. And, finally, the $P(24)$ line in the 9.4 μm band of CO_2 laser (9.59 μm)—which is resonant with the $(1^+,4,3)\rightarrow(2^-,5,3)$ transition—excites the $(2^-,5,3)$ level.

3. Figure 2 shows the experimental setup. The output of two synchronized CO_2 lasers (1) tuned by means of 100-line/mm diffraction gratings (2) to the $P(32)$ line in the 10.4-μm band and the $P(24)$ line in the 9.4-μm band with respective power output of 0.5×10^6 and 1×10^6 W was spatially integrated by means of a parallel-plane Ge plate (3) and coupled to a cell containing NH_3 (4). The cell input window was a KBr plate (5) which also served as one of the resonator mirrors with respect to far-IR (reflectivity $R\sim20\%$) and mid-IR ($R\sim8\%$). On the opposite side of the cell a metallic mirror with 6-m radius (6) was placed; the resonator length was 1.4 m. Emission from the cell was coupled to a grating monochromator (7) and recorded by Ge:Ga detector (8) which was designed in the shape of a lightpipe into a portable liquid helium dewar to record far-IR radiation due the $(1^+,5,3)\rightarrow(1^-,4,3)$ and $(1^-,4,3)\rightarrow(1^+,4,3)$ transitions; the metallic mirror (6) was replaced with a Ge mirror with identical radius. The emission was recorded by means of an InSb detector.

4. We have established the absorption of the 9.59-μm CO_2 laser emission increases sharply in the presence of high-power laser emission at 10.72-μm. This confirms the fact that the foregoing pumping system excites the $(1^+,4,3)$ level. We measured cell

TABLE I

wavelength, μm	Transition
12.00	$(1^+, 4, 3) \Rightarrow (0^-, 5, 3)$
13.23	$(2^+, 6, 3) \Rightarrow (1^-, 5, 3)$
13.66	$(2^+, 5, 3) \Rightarrow (1^-, 4, 3)$
15.78	$(2^+, 5, 3) \Rightarrow (1^-, 5, 3)$
15.86	$(2^+, 4, 3) \Rightarrow (1^-, 4, 3)$

output wavelengths in the 12–16-μm range. Moreover, we identified five spectral lines at wavelengths indicated in the table below. Line identification was made using data from Ref. 5. Generation of emission at 12.00 μm was observed for excitation by a single line in the 10.4-μm band of a CO_2 laser.

Generation was observed at NH_3 cell pressure of 1–8 mm Hg and it attained a maximum at 4 mm Hg. Generation at the 15.86-, 13.66- and 12.00-μm lines occurs practically concurrently with the pumping pulses, while at the 15.78- and 13.23-μm lines a delay of approximately 5×10^{-7} sec occurs with respect to the onset of generation of the CO_2 lasers.

5. The described method of pumping the $(2^-,5,3)$ level of the ν_2 mode of NH_3 molecule has resulted in a number of new laser lines. This method may also be used for pumping other levels of the ν_2 mode. For example, having tuned a CO_2 laser to the $R(14)$ and $P(14)$ lines of the 10.4-μm band, it becomes possible to excite the $(2^-,1,1)$ level of NH_3 molecule as follows:

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