Observation of Air Laser at Low Pressure

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Abstract

The stimulated emission of radiation of atmospheric air gas was observed to be 337 nm at room temperature and it is the same wave-length as the nitrogen laser oscillation. The threshold voltage is about 9.5 kV, for 41 Torr at 1 Hz repetition. The optimum air pressure is 37 Torr at 13.8 kV, 36 Torr at 15.0 kV, 30 Torr at 12.0 kV, and 32 Torr at 15.6 kV. The output power ratio of the air laser to the nitrogen laser is about 1/300 – 1/400. The optimum air pressure for lasing shifts to the higher part as the applied voltage increases, and also the lasing area is drastically broadened. The pressure range of the lasing action is narrow compared with that of the nitrogen laser.

1. Introduction

Since the discovery of the stimulated emission on the second positive band of the nitrogen molecule at 337 nm wave-length[1)], there has been a considerable amount of research performed on this molecule in an attempt to increase the output energy and the efficiency. The nitrogen laser has as well become one of the most popular lasers for a dye laser pumping light source in ultra-violet region. The laser action at near 337 nm wave-length can be obtained besides pure nitrogen gas. For example, it is possible to operate laser oscillation by using the atmospheric air gas as a laser medium, and Basting *et al.*[2)] and Herden[3)] reported the laser action in briefly.

At the present developmental stage of the air laser, little is known about the operation characteristics. Basting *et al.*[2)] observed a peak power given off by a 300 kW air laser in which atmospheric air gas was used as an active medium. In their results, they show the output of the 30 cm laser as a function of air pressure, and output power versus voltage at 76 Torr. They assert that the high power obtained is probably due to the fast risetime of the exciting current pulse, which is short compared to the collision time. They also suggested the possibility to use atmospheric pressure for operation with He-N_2 mixture gas. In 1975, Herden[3)] described that a simple nitrogen laser yielded a peak power operated at a pressure of 760 Torr, and that it worked in open air as a laser gas. Pulse lengths of approximately 0.3 nsec were described. With this laser device (27 cm) the gain in the channel was high enough to cause lasing action without a laser gas, namely in the open air (760 Torr). Thereby the electrode spacing is slightly decreased to 2–3 mm. The peak value of the output was reported to be 30 kW.

The purpose of this paper is to observe the laser action in the atmospheric air gas of low pressure at room temperature. To perform this, four measurements were made: 1) threshold voltage, 2) air

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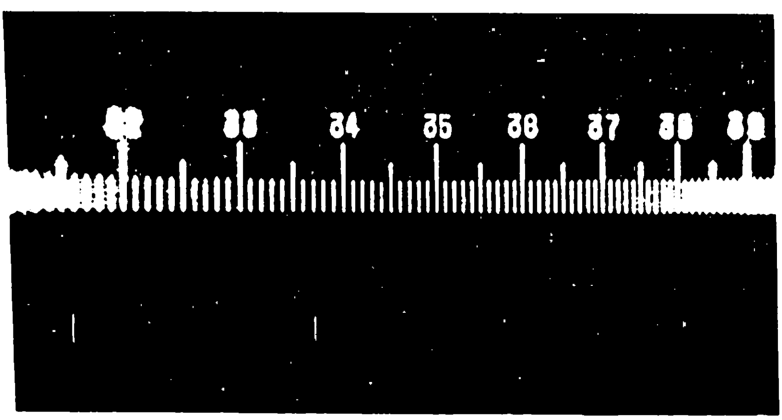
pressure dependence, 3) pulse repetition dependence, and 4) spectrograms of stimulated and spontaneous emission lines. Judging from the results of these measurements, the air laser line spectrum was identified and assigned to be the transition from the second positive band($C^3\Pi_u - B^3\Pi_g$)of the nitrogen molecule[4]. Finally it is strongly suggested that the main contribution to laser action in atmospheric air gas is made by nitrogen gas, which constitutes 78 percent of air gases.

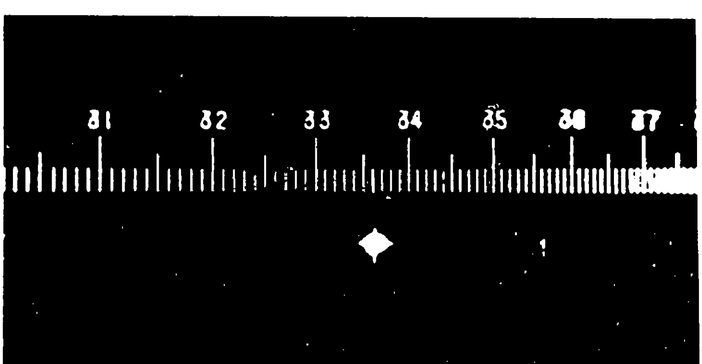
2. Experimental Results and Discussion

A laser cavity used for this experiment is exactly the same as the previous paper[5], except for the use of nitrogen gas. The optical cavity has an active length of 93 cm, electrode separation of 2.5 cm, and 44 capacitors amount (each 1000 pF, 22 on each side). The maximum output power was estimated to be 1 MW. When one obtains laser action in air gas, he must only replace the nitrogen gas by the atmospheric air gas of low pressure, there are no changes to made in the other parts. Exeriments have been carried out on spectrograms and output powers as a function of applied voltage, air pressure and pulse repetition rate, respectively. The results obtained are as follows:

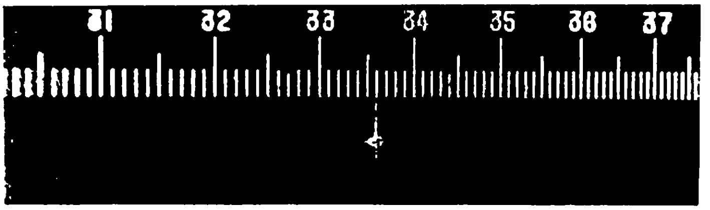
To confirm that the air laser is oscillating at 337 nm, spectrograms are taken, and these photographs of spontaneous emission of air, stimulated emission of air, and stimulated emission of nitrogen are shown in figure (1).



(a)



(b)



(c)

Figure 1. Spectral Photographs.
(a) Spontaneous and (b) stimulated emission of air gas.
(c) Stimulated emission of nitrogen gas. It is seen that the wave-lengths of (b) and (c) are the same.

It is obvious that there are many spectral lines besides the 337 nm line in the case of spontaneous emission of air, and the output power intensity of 337 nm line is also not so strong compared with other lines. But in the case of stimulated emission of air, the spectrum is almost all made of 337 nm line, and the intensity is strong in contrast with figure (1)−(a). It is clear that the wave-length of stimulated emission of air can be assigned to be the same as stimulated emission of nitrogen, 337 nm the wave-length. A laser action, except for at 337 nm line, was not observed in this experiment. From spectrograms, it is suggested that the contribution to the laser action in air gas is mainly made by nitrogen gas.

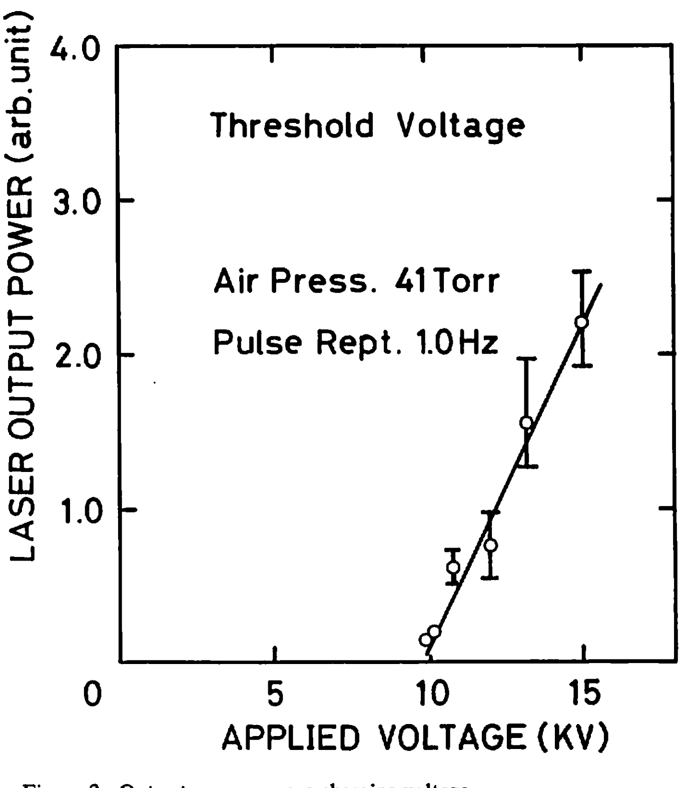
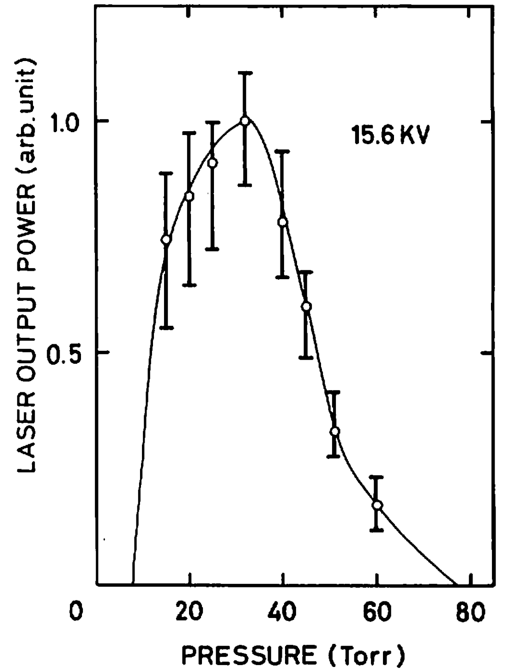
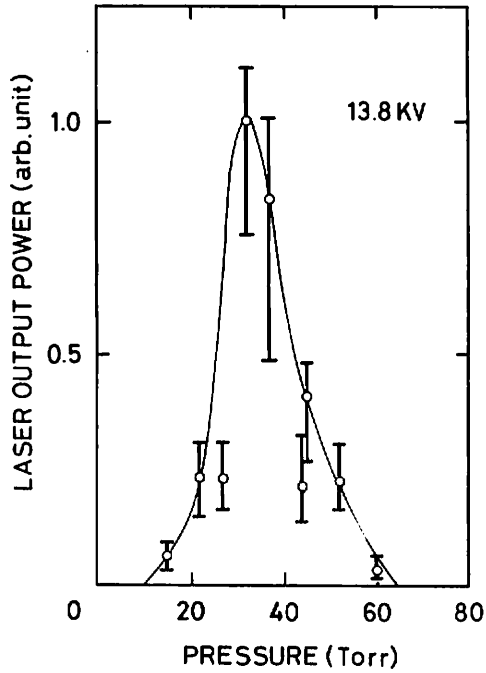


Figure 2. Output power versus charging voltage.
The threshold of air laser is about 9.5 kV and larger than that of nitrogen laser, 8.0 kV.

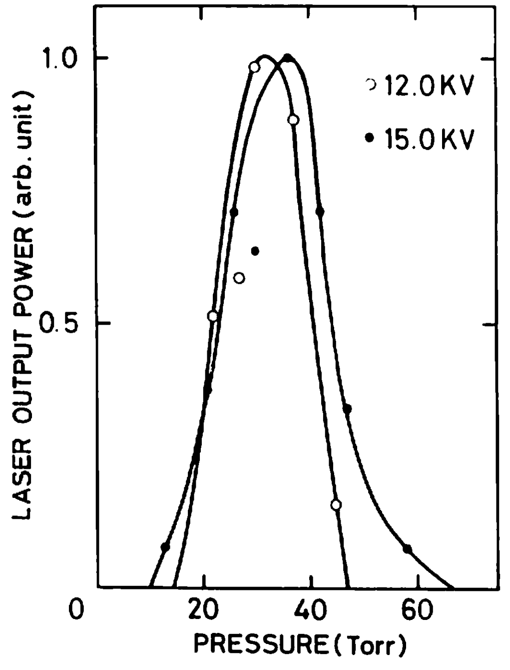
Figure (2) shows the air laser output as a function of applied voltage for 41 Torr. It is indicated that the output is proportional to the applied voltage, and that the threshold voltage is about 9.5 kV, which is high compared with that in the case of nitrogen laser. At higher voltage, the variation of output peak power from shot to shot is greater than in the case of lower voltage.



(a)



(b)



(c)

Figure 3. Output power versus air pressure for (a) 15.6 kV, (b) 13.8 kV, and (c) 12.0 kV and 15.0 kV.
The air pressure range for laser action is smaller than that of nitrogen laser.

The laser output power as a function of air pressure is shown in fig. (3). The air pressure range for laser action is about 10 to 75 Torr and is large at higher applied-voltage. The optimum air pressure is 30 Torr at 12.0 kV, 37 Torr at 13.8 kV, 36 Torr at 15.0 kV, 32 Torr at 15.6 kV, respectively. It is found that the air pressure range for laser action and optimum air pressure are small compared with that of nitrogen laser at the same applied voltage, and as a possible reason for this is that it could not neglect the effects of other gases, such as oxygen, carbon dioxide, water vapour and inert gas.

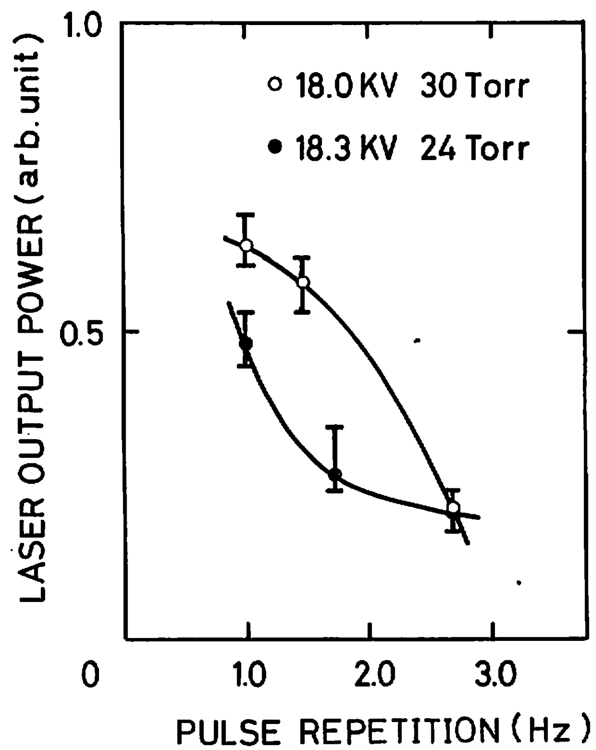


Figure 4. Output power as a function of pulse repetition for 18.0 kV at 30 Torr and for 18.3 kV at 24 Torr.

Figure (4) shows the air laser output as a function of pulse repetition rate. It is clear that the output decreases as pulse repetition increases, and the maximum pulse rate for laser action is about 4 Hz. This value is very low compared with that of nitrogen laser, which is about 30 Hz.

3. Summary

The experimental results obtained in this work are summarised as follows; (1) The oscillation wave-length of air laser is assigned to be 337 nm, which is the same wave-length as the nitrogen laser oscillation. (2) The threshold voltage is about 9.5 kV, for 41 Torr at 1 Hz repetition. (3) The optimum air pressure is 30 Torr at 12.0 kV, 37 Torr at 13.8 kV, 36 Torr at 15.0 kV, and 32 Torr at 15.6 kV, respectively. (4) The output power ratio of air laser to nitrogen laser is about 1/300−1/400. (5) The pressure area for the lasing action is narrow compared with that of nitrogen laser. (6) The properties of air laser are similar to those of nitrogen laser, and it is suggested that the main contribution for laser action in air gases is made by nitrogen gas. (7) Air laser is very much useful for a dye laser excitation source because of low cost, and a equipment for air laser can be homemade. In future, we wish to apply it to a dye laser excitation light-source.

Finally, the authors would like to thank Lord Jesus Christ for grace and safety.

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