INFLUENCE OF LONGITUDINAL MAGNETIC FIELD ON THE CW SUBMILLIMETER WAVES OUTPUT FROM HCN GAS LASER

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Abstract

HCN gas laser can produce continuous and high power of submillimeter waves of 337μm in wavelength. This paper presents the experimental results concerning the effect of longitudinal magnetic field upon the submillimeter output power. There is the optimum magnetic flux density to produce maximum power and the effect of magnetic field become more noticeable with the diameter of laser tube.

Introduction

There have been reported many papers[1] concerning HCN gas laser as one of the most powerful and CW submillimeter waves source. However it seems to us that not many reported as to quantitative experimental results concerning the effect of longitudinal magnetic field upon the output power of the HCN gas laser.[2,3] So we like to present here those results of experiments which were undertaken as one of the means for improving the efficiency of the HCN gas laser.

Experimental Set-up

Experimental set-up is shown in Figure 1. The laser tube was 75 cm in length of discharge, and its length was fixed during all these experiments. Three kinds of tubes of 70, 60 and 40 mm in diameter were prepared. The wall of each laser tube is cooled by water flowing through coaxial water pipe. The gases, CH_4 and N_2, are mixed and introduced in each laser tube. One concave mirror of 7 m in the radius of curvature and another flat mirror are placed at each tube end, forming a Fabry-Perot resonator of non-confocal type. Coupling hole was made at the center of the flat mirror and various mirrors of coupling hole of 2, 4, 6, 8 mm in diameters were prepared. Output power can be extracted from the hole to a Golay cell detector and appropriate amplifier through proper attenuators and filters. In order to investigate especially the effect of the longitudinal magnetic field upon the submillimeter waves output power several electromagnets are placed such that the longitudinal magnetic field is applied along the axis of the laser tube. The cathode material is tantalum[4], formed in hollow type cylinder and cooled by water. The wavelength of the submillimeter waves was measured by moving a micrometer attached to the concave mirror. The output power was measured by some absolute power measurement technique using Golay detector.

Experimental Results without Magnetic Field

Figure 2 shows the output power as a function of the discharge current in case of the gas mixture ratio of $CH_4 : N_2 = 1 : 2$, $1 : 1$ and $2 : 1$. This describes the fact that as the volume quantity of CH_4 increases compared with that of N_2, the maximum output power of the submillimeter waves increases and the optimum discharge current which gives maximum power tends move towards large current region. Conditions under which this experiment was undertaken are such as written in the figure. The same rule applies to the following experimental results. This experiment shows that the gas mixture ratio which gives the maximum output power depends upon the discharge current. The relation between the output power and the diameter of coupling hole with parameter of the discharge current is shown in Figure 3. In this experiment, 6 mm was optimum as a diameter of coupling hole under the conditions written in the figure. Figure 4 reprents the output power as a function of the discharge current with parameter of diameter of laser tube. The output power increases with the diameter of laser tube due to the fact that the total quantity of HCN molecules increases with the diameter of laser tube and also the fact that the diffraction loss of laser tube increases as the diameter decreases. Further the discharge current which gives the maximum output power tends to increase, because the density of electrons which gives saturated output power remains unchanged.

Experimental Results with Magnetic Field

Figure 5 indicates the output power as a function of the longitudinal magnetic flux density with parameter of the discharge current. The results show that there exists the optimum magnetic flux density so as to give the maximum output power and that the flux density is dependent upon the magnitude of the discharge current and has tendency of smaller value with the discharge current. The existence of the optimum magnetic flux density is due to the fact that the larger the magnetic flux density the smaller the diffusion coefficient of electrons and irons towards tube wall so that the recombination and the dissociation takes place more actively during charged-particles motion, leading to the larger production of HCN molecules. The output power decreases as the magnetic field exceeds the optimum value, because the pumping rate of the HCN molecules will increase with the magnetic field and the life time of the excited molecules will become shorter with the magnetic field. The output power as a function of magnetic flux density with parameter of flow-rate is shown in Figure 6. This diagram indicates that the ratio of the output power when the optimum magnetic flux density is applied to the output power in case of no magnetic flux density increases with the rate of gas flow. Figure 7 describes the output power as a function of discharge current when certain magnetic flux density is partially applied. Mg 1, ..., Mg 5 refer to each magnet from anode side and the magnetic flux density was fixed 170 gauss each case. In this experiment we found that the output power increases the most noticeably when the magnetic flux density applied to the anode side and the output power increases lesser noticeably in order that when the magnetic flux density is applied to anode-side, cathode-side and central part. Figure 8 represents the output power versus the magnetic flux density with parameter of the position of application of magnetic field. When the magnetic flux density is applied to the region near anode side, the output power increases gradually with the flux density and tends to saturate. On the contrary, when the magnetic flux density is applied to the region near cathode side, the output power goes up first in the low magnetic flux density and takes the maximum power output and then gradually goes down with the magnetic flux density. Figure 9 represents the output power as a function of the magnetic flux density with parameter of diameter of laser tube. This experiment describes that the larger the tube diameter the effect of the magnetic flux density upon the output power the more noticeable. This will be due to partly the fact that since the larger the diameter of laser tube the magnitude of magnetic flux density near the surface of tube wall the larger, the diffusion of the charged particles towards tube wall tends to decrease by the magnetic compression—promoting the impact of charged particles with neutral molecules and also the formation of HCN molecules. Furthermore, since with the diameter of laser tube the time of electron to diffuse from central part to laser tube wall becomes longer the charged particles are affected by the magnetic field during longer time, so that the effect of the magnetic field upon the output power will become noticeable with the diameter of laser tube.

Conclusions

We will be able to derive the following conclusions from the experimental results mentioned above.

(1) The gas mixture ratio and total gas flow which gives the maximum output power depend upon the discharge current. There is optimum coupling hole diameter by which the maximum power output can be extracted. Submillimeter output power is increased with the diameter of laser tube.

(2) There exists some optimum longitudinal magnetic flux density which gives the maximum output power in the region of low discharge current. As far as the increasing ratio of output power, the magnetic flux density applied near anode side gives the most noticeable results. Further both the output power and the increasing rate grows with the diameter of laser tube under the condition that the length of laser tube is kept constant.

Acknowledgment

Authors like to express great thanks to Prof. T. Tako for his valuable suggestions.

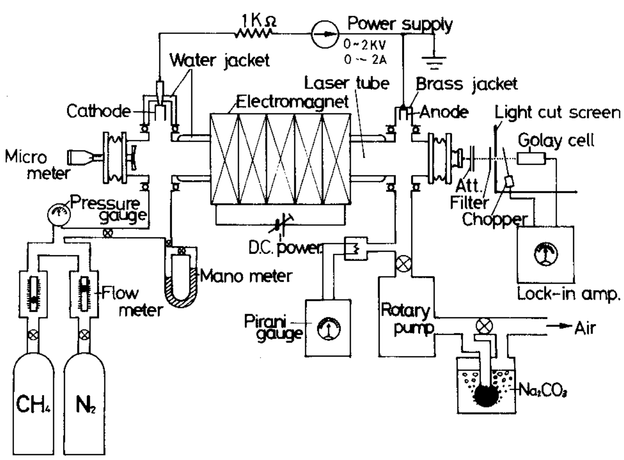

Figure 1. Experimental set-up.

References

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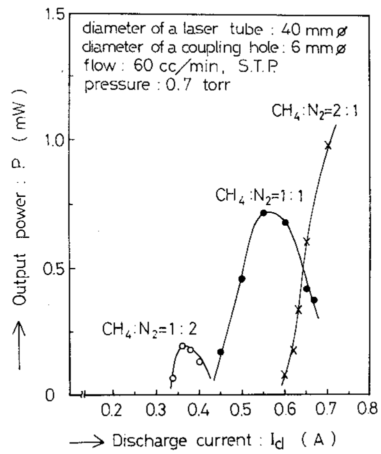

Figure 2. Output power as a function of discharge current with gas mixture ratio as a parameter.

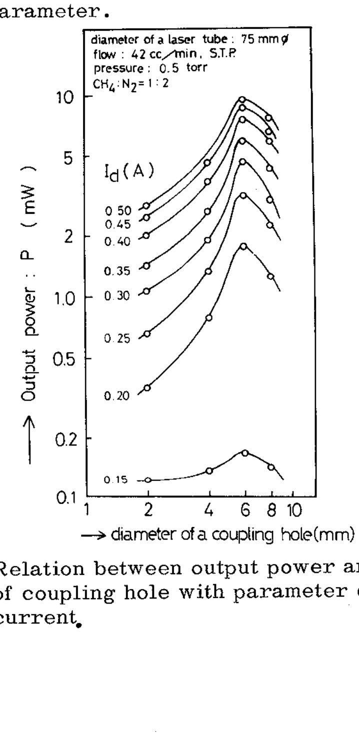

Figure 3. Relation between output power and diameter of coupling hole with parameter of discharge current.

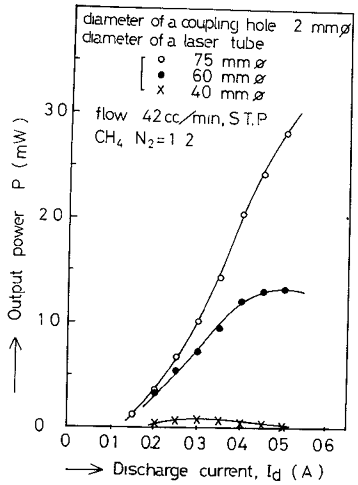

Figure 4. Output power vs discharge current with laser tube diameter as a parameter.

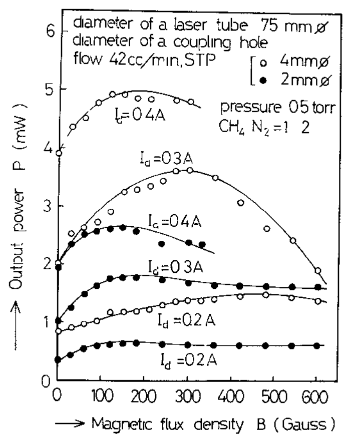

Figure 5. Output power vs longitudinal magnetic flux density with discharge current as a parameter.

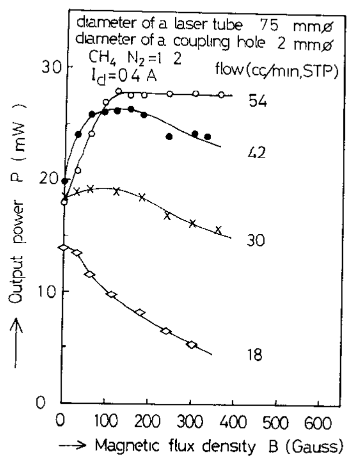

Figure 6. Output power as a function of magnetic flux density with gas flow-rate as a parameter.

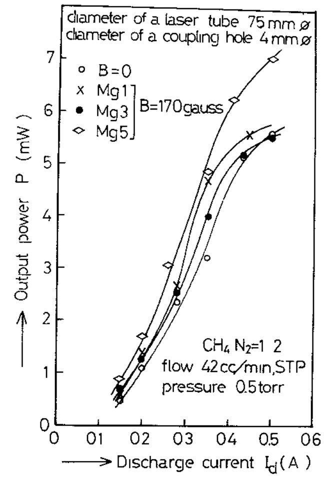

Figure 7. Variation of output power with discharge current when a magnetic flux density is partially applied.

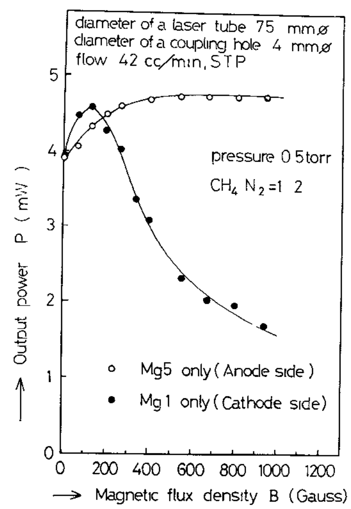

Figure 8. Output power vs magnetic flux density with position of its application as a parameter.

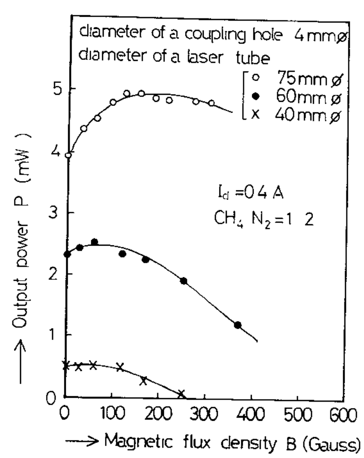

Figure 9. Output power as a function of magnetic flux density with laser tube diameter as a parameter.