26C3 A COMPACT SEALED-TEA CO_2 LASER FOR LIDAR APPLICATIONS

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ABSTRACT

A compact repetitively pulsed TEA CO_2 laser for lidar source has been developed. The laser is designed to produce high peak power output without the use of external devices. In addition, it is line-tunable and operates in sealed-off with the life time of more than 1 million shots. The output characteristics of this laser would be also desirable for a pump source of frequency conversion, giving rise to attainment of a lidar source in 3-5μm region.

INTRODUCTION

TEA CO_2 lasers are widely used for lidar applications such as remote sensing, ranging, DIAL, etc. On the other hand, the second harmonic of CO_2 laser radiation has emerged as a promising candidate for the same purposes, since its wavelength coincides with the 3-5μm transmission window. The one of major advantages of TEA CO_2 lasers is their capability to generate high peak power pulses from rather simplified construction (i.e. gain switching). In general, however, they also produce long pulse tail which is undesirable for the applications mentioned above. Namely tail outputs can interfere with return signals or just heat the optical components resulting in damages. Several methods for reducing tail output have been reported; intracavity switchout employing electro-optic crystal[1], plasma shutter[2], and high pressure operation with He free mixture[3]. However the systems utilizing any of these methods are rather complex or suffer low energetic efficiency. Moreover, the lasers for lidar also have to meet the following requirements:

(a) compact
(b) sealed operation
(c) good beam quality(low divergence)
(d) minimum pointing fluctuations

With these facts in mind we have designed a repetitively pulsed TEA CO_2 laser utilizing corona-preionized self-sustained discharge. The optimization of gas ratio and optical resonator eliminated the need for any additional devices to ensure the high peak power spike pulses in excess of 1MW, while maintaining sealed operation at the RPF of up to 60Hz. Furthermore the simplicity of this device in terms of its construction makes it possible to operate in a wide range of working conditions.

LASER DESIGN

The laser configuration is shown schematically in Fig.1. The laser head consists of a stainless steel tube of 160mm OD and 400mm in length. The electrodes which are made from copper have an approximately uniform profile, and glass insulated preionizer rods are located on the cathode surface. The dimensions of the discharge channel are 1x1x30cm. We selected corona-discharge preionization scheme, since it reduces the size and cost associated with simple structure, and it's also suitable for sealed and high PRF operation. The gas flow is provided by means of a single tangential fan which enables the gas velocity of about 7 m/s. The heat exchanger for removing waste heat from the gas is also attached. The main elements of laser discharge circuitry are a low-inductance storage capacitor Cs(=30nF) charged up to 20 kV, peaking capacitors Cp(=6nF), and a thyratron.

The optical design for laser oscillation is that of a stable resonator for a

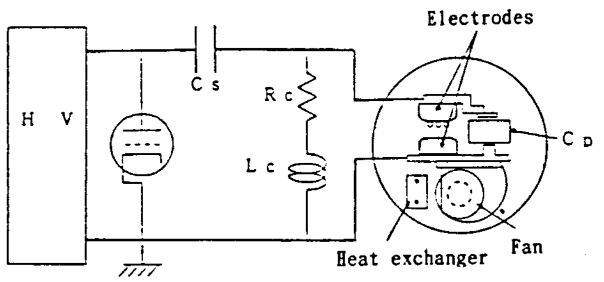

Fig.1 Laser configuration

Gaussian beam with tunable line selection. The resonator consists of a grating in a Littrow configuration and a ZnSe output coupler having 15 m radius of curvature. The cavity length is kept as short as possible to obtain short pulses and also to maximize longitudinal mode separation. The effective aperture is limited by the gain region itself which allows the lowest order transverse mode oscillation.

OPTIMIZATION

A series of optimization with respect to the gas mixture and resonator parameters was performed to obtain the high peak power spike together with a minimum low-intensity tail output. The conventional TEA CO_2 lasers employ a high helium and low CO_2 mixture (typically CO_2:N_2:He = 1:1:8) in terms of both extracting high pulse energy and sustaining stable grow discharge. As is well known, however, a low He and high CO_2 mixture is favorable for obtaining the output at which we aim. So we experimentally confirmed that stable operation with low He (~50%) and high CO_2 (~50%) mixture was achieved in our device, which we attribute to our excellent corona-preionization scheme. However too much decrease of He and N_2 content leads to low overall efficiency, and the optimum ratio should be found.

In order to determine the ideal gas mixture quantitatively, the numerical analyses by a rate equation model were performed. Fig. 2 illustrates the variations of pulse shapes with gas ratio having actual parameters : a gain length of 30cm, a cavity length of 60cm and 65% reflectivity of output mirror. From these figure, the peak power, energy and FWHM of the spike are also deduced.

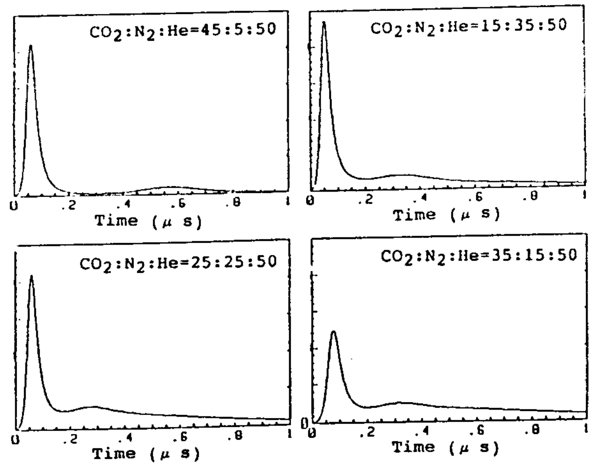

Fig.2 Calculated laser intensity

Fig. 3 shows the results of the variation of those values plotted as a function of CO_2 content while maintaining the ratio of He gas of 50%. It is seen that the percentage of CO_2 corresponding to the maximum energy falls around 20%, while that to the maximum peak power around 40% indicating that the tail output is considerably reduced. In this way the optimum gas ratio for our device was found to be around CO_2:N_2:He=4:1:5.

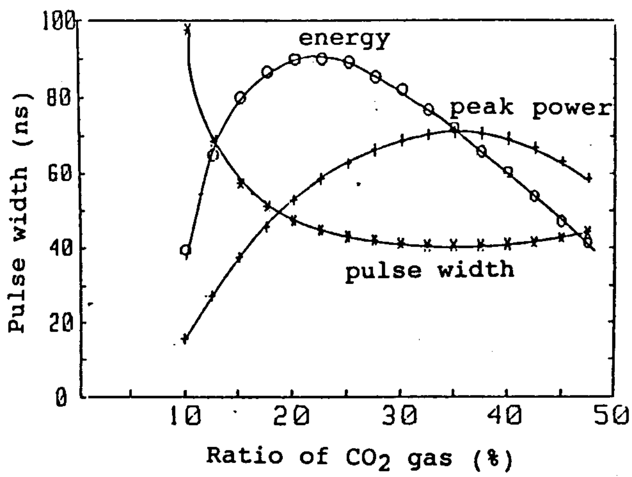

Fig.3 Calculated output characteristics as a function of gas ratio

Fig.4 shows the output characteristics as a function of output mirror reflectivity. We can see that the optimum output reflectivity for peak power extraction is about 65% which is 10% lower than that for energy power extraction.

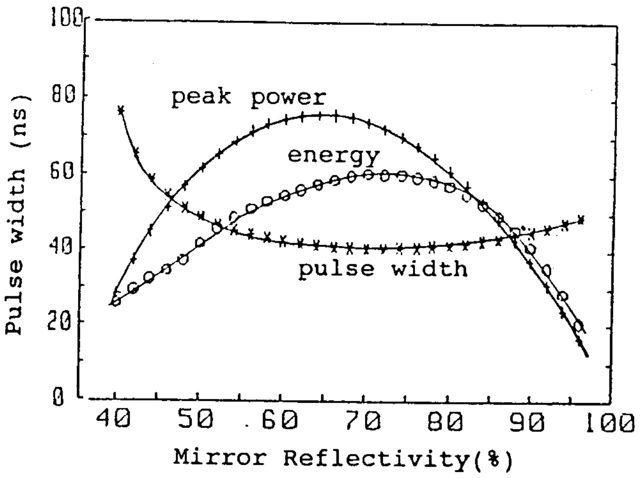

Fig.4 Calculated output characteristics as a function of output mirror reflectivity

LASER PERFORMANCE

We performed lifetests with several different gas mixtures and found replacing 20% of He with CO yielded the long sealed-off lifetime of more than 1 million shots almost without changing the output characteristics. The output pulse shape monitored on a HgCdTe detector with response time of 1 ns is shown in Fig.5.

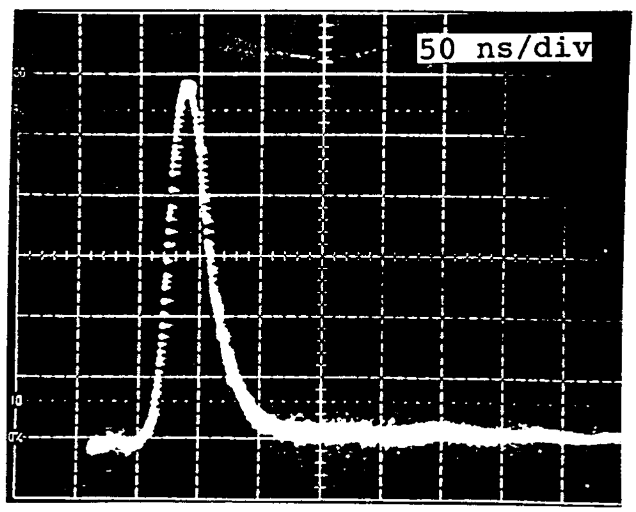

Fig.5 Measured laser pulse shape

As can be seen from this figure, the tail output is reduced and most of energy is contained in the spike. The measured total energy, peak power and FWHM of spike are 50mJ, 1.1MW, 36ns respectively. These results are in good agreement with calculated values. In addition, the pulse shape exhibited a low degree of modulation, which indicated that one axial mode was oscillating dominantly. Besides, the spatial profiles measured with a pyroelectric detector array exhibited a smooth Gaussian like intensity distribution and the divergence angle was less than 2.5 mrad.

SUMMARY

We have developed an inexpensive, compact TEA CO_2 laser with design emphasized on obtaining pulse shape desirable for lidar source. The device is capable of short and high peak pulse output in 9-11μm region. This laser is also expected to be applied to a lidar source in 3-5μm region by frequency doubling[4].

References

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