A COMPACT, DIFFRACTION LIMITED, He FREE, HIGH REPETITION FREQUENCY NANOSECOND CO2 LASER

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A COMPACT, DIFFRACTION LIMITED, He FREE, HIGH REPETITION FREQUENCY NANOSECOND CO₂ LASER

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Abstract: A compact He free CO₂ laser is briefly described. This laser can operate at 10Hz with 150mJ (12 ns) , without tail at its diffraction limit (1.5mrad) and it can be used in LIDAR experiments with few meter spatial resolution.

1:INTRODUCTION

The LIDAR experiments need a typical laser source with 0.1-1J fluence, more than 10 Hz repetition frequency ,10ns laser pulse, at 1mrad diffraction or less. By using a similar source it is possible to detect an echo signal 10Km away with meter resolution.. Normally a CO₂ laser has 1J ,1 Hz ,100ns emission so that a particular work is necessary to obtain the ideal characteristics. In particular a tail free short pulse can be obtained only in He free mixtures at few bar pressure in a short, high gain device, so that a particular discharge design must be used to stabilize a multiatmosphere CO₂ dominated high energy density discharge. Besides these problems limit the electrode distance, so that a suitable optical design is necessary to obtain a short pulse diffraction limited emission without optical damage.

2: EXPERIMENT AND RESULTS

To obtain a laser discharge with elevate pressure and energy density ,and with moderate specific electric field E , we have used a double tension symmetrical Blumlein LC inverter (1-2) . In this case a fast low inductive discharge is produced. The discharge design is reported in fig 1. 8 C₁ banks are discharged in four preionization spark lines (the design shows only four C₁ banks and two P preionizations for clarity) in the time (100ns) of the LC inversion polarity relatively to four C^{*} banks (C^{*}=C) by means of a single sparg gap SG. This inversion and the use of opposite polarity for one half of banks allow to apply a 4V peak voltage to the electrodes E allowing a fast energetic discharge in a strongly preionized mixture . Typical 1000J/l energy deposition can be obtained with V=20KV. A 2bar discharge with 2d=8mm electrode distance can be obtained with 80KV peak voltage in the standard CO₂:N₂=1:1 He free mixture. Now it has been reported previously (3) that with a suitable cavity design a tail free emission in 10ns time it is possible in a similar device with 30 J/l fluence extraction which is a damage limit for the optical components.

By using a longer device with moderate power density(700J/l) it is possible to obtain the same results without optical damage if a 60-80 % typical outcoupling transmission is used. In this case it is possible to use an unstable configuration to obtain a diffraction limited emission .In our case a 8mm discharge can give a full divergence (FWHM)

$$2 \theta \text{ (FWHM)} = 1.22 \lambda / (2 d) = 1.5 \text{ mrad} \quad (1)$$

but due to the collimation ,which is necessary to avoid the transverse modes ,the divergence with

Fig1 the discharge design (see text)

a stable cavity is two times larger. So we need an unstable cavity very short. The optical design is reported in fig 2. A plane mirror M_1 is 45° rotated respect to the optical axis and it has a $2a = 3.6$ mm hole. The M_2 mirror reflects the transmitted power to the grating G . The amplified and diffracted beam is splitted by M_1 so that a circular ring with 70% of the total power is ejected out of the cavity to M_3 with 4mt curvature radius posed in a suitable distance (1mt from M_1) where the beam is collimated to obtain the theoretical divergence. The cavity lenght L is 70 cm and the L and a values are chosen to fully cover the discharge section with an approximated 70% outcoupling. The emitted power is roughly an overlap of two field distributions with two different confocal parameters $b_0 = \pi d^2/\lambda$ and $b_1 = \pi a^2/\lambda$ where $b_0 \gg b_1$ so that when the distance D from M_1 is $\gg b_1$ we have only the first component inside the laser spot with a power loss $\approx (a/d)^2 \approx 0.25$, and a like gaussian spot for $D \gg b_0$ (far field) where in the near field ($D < b_0$) we have all the power with an interfered spot.

Fig 2 the cavity design(see text)

The spot diameter and the total power inside it vs. the distance D from the M_1 mirror is reported in fig 3. The fluence is directly measured by focusing the power in a large pyroelectric and the spot is detected by a graphite plate in the near field, while in the far field it is relatively

FIG 3 : The fluence F and the diameter vs. the distance D

FIG 4: The laser pulse

measured by means of a small section pyroelectric .M points to the M3 mirror position. The divergence in the far field (linear fit) is near 1.5 mrad while the estimated fluence inside the spot goes down from 160mJ to 110 mJ about (30% reduction) near the expected value. The spot for distances larger than 10 meters is like -gaussian. The time profile for this diffraction limited pulse is measured focusing it in a Photon-drag . The relative pulse is reported in fig 4., where a like gaussian pulse is detected . The shape is Fourier transform limited to the time resolution of our digital oscilloscope, as shown by the side modulation, and a 12 ns pulse width can be estimated. To increase the repetition frequency it is necessary to increase the gas flow . The maximum possible rate is $PPS = F / (V_0 P)$, where F is the flow (liter/sec (TPS)) and V_0 is the discharge volume (liters) and P the operating pressure (atm) . Normally the effective limit is 2 times lower due to occasional arcing. For exemple with $F = 0.3$ lit/sec and $V_0 = .02$ lt. and $P = 2$ bar we have obtained a linear mean power increase up to 7 Hz. The He free mixture is very cheap , so that the laser running cost at this flow is very low .

3: CONCLUSIONS

A tail free, unstable, He free, multiatmospheric CO_2 laser is briefly described. About 110 mJ (12ns) in the diffraction limit (1.5mrad) are observed in a far field gaussian spot. A low cost 10Hz operation is possible without any gas circulation. This laser is ideal for high resolution LIDAR experiments.

4: REFERENCES

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