A Study of pulse heterodyne of Z-Fold waveguide CO_2 laser

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Abstract:

Pulse heterodyne of electrooptically Q-switched RF excited Z-fold waveguide CO_2 laser with two channels (partial Z-fold channel and single channel) and common electrodes are presented. The Heterodyne waveform of the pulsed laser and the CW laser are compared to pulse waveform of Q-switched laser. CW laser output has been obtained from the single channel. Pulse width is 140 ns, the delay 300 ns and the peak power 300W. The largest tunable range of heterodyne frequency is 150 MHz and the width of the voltage pulse on the crystal is about 1.2µs.

Keywords: Waveguide CO_2 laser, Q-switched , Pulse heterodyne, RF excited

Introduction

The CO_2 waveguide laser is one of the ideal devices for heterodyne detection .It has many applications, such as speed measurement, laser imaging, and laser radar. Generally, heterodyne detection needs two lasers a local laser and a transmitter laser [1-5] .Both lasers need high frequency stability to ensure high heterodyne frequency stability so as to improve the heterodyne detection efficiency .Besides, the pulsed transmitter laser should have higher output power for far target detection .At present, two independent lasers with complex structure of frequency stabilization are often needed in order to obtain stabilized heterodyne signals. However, the lasers may suffer from possibly unacceptable penalties of increased size, weight, complexity and cost. Abramski [6] reported a method to use an RF excited waveguide CO_2 laser array to obtain stabilized heterodyne signal, but it is not easy to insure which branch the laser works on due to the plane resonator. In addition, it is difficult to insert a modulator crystal and other optical elements into the resonator due to the close distance between the two channels and the same direction of laser output.

With those aims, a radio frequency (RF) excited tunable Q-switched partial Z-fold CO_2 waveguide laser with two channels and common electrodes has been designed and manufactured (Chinese Patent Number: ZL02 1 23786.7)[7-9]. The laser output directions from the two channels are opposite. The two channels are excited by the same RF source. CW laser output can be obtained from one of the channels with grating tuning and the laser frequency can be tuned by a piezoelectric transducer (PZT). Elecrooptically Q-switched pulsed laser output is achieved from the partial Z-fold channel also with grating tuning. The experimental measurement and result for laser output power of partial Z-fold channel and single channel are presented .Two lasers are combined onto a HgCdTe detector, and stable pulse heterodyne waveform and its Fourier transform frequency spectrum were also observed.

Experimental results

The schematic of the experimental arrangement is shown in Fig.(1) . The laser designed by us is a Q-switched Z-fold CO_2 laser with two channels [7-10]. The two waveguide channels consist of two alumina side walls with aluminium top and bottom electrodes . The partial Z-fold channel is 3x460 mm in length and the single one is 460 mm with a cross-section of all the waveguides is 2.25x2.25 mm^2 are put into a stainless steel vacuum envelop .In order to insure the RF voltage distribution along the electrodes uniformly and each channel can discharge at the same time, a distance between the two channels is 20 mm. The whole two-channel waveguide electrodes are placed in a stainless steel vacuum volume with water-cooled , and the laser works in sealed operational mode. .The laser utilized a parallel-resonant distributed inductance technique to uniformly distribute voltage along the electrodes and hence to uniformly excite the gain medium .These inductors provide a negative admittance[11],which compensates for the variation in the phase angle of the transmission line .They also serve as part of the impedance matching network ,and theirs values can be adjusted until a resonance at RF oscillating frequency is realized[12].With this method, a number of equal-value parallel inductors are uniformly spaced from the center of the laser channels to an approximately distributed inductance [13].In order to efficiently couple the RF power into the active medium, a LC matching circuit is used between the generator and the laser head[14] .The value of the inductance is chosen such that it resonates with the capacitance (C =9pF) of the waveguide structure at the RF frequency. With the discharge resistance for C = 9pF and f =120 MHz where the total inductance have been chosen for the case of R = 400 Ω.In the opposite direction of the resonant of the two channels ,a 95% reflecting 150-line/mm diffraction gratings is placed 10mm away from the respective waveguide ends .Two ZnSe windows are placed on either sides of the two channels at a distance of 5mm away from the channels.A CdTe electrooptical crystal is inserted between the window and the output mirror of the other channel.The CdTe crystal is 3x3x40 mm^3 in size, manufactyred by II-VI, Inc.The 3x3 mm^2 ends are (110) planes, the top and the bottom electrodes are ($\bar{1}11$)planes ,and the sides are ($\bar{1}1\bar{2}$)planes. The polarization direction of the input laser beam is at 45^0 from ($\bar{1}1\bar{2}$) planes, the phase difference of the two perpendicular output laser beams is expressed as

$$\Gamma = \frac{\sqrt{3}\pi}{\lambda} n^3 r_{41} \frac{\ell}{d} v \qquad .... (1)$$

Where **v** is the voltage applied to the crystal, **n** is refractive index, r_{14} electrooptic coefficient, ℓ and **d** are the length and height of CdTe crystal. From Eq. (1), the λ/4 voltage of crystal is given by

$$V_{\frac{\lambda}{4}} = \frac{\lambda}{2\sqrt{3}n^3 r_{41}} \frac{d}{\ell} \qquad .... (2)$$

The two end of the crystal are given **AR** coating centered at 10.6μm with a transmissivity of 98.9%.

The RF input power is 0-300 W, RF frequency 120 MHz and the ratio of unoptimized gas mixture CO_2:N_2:He=1:1:3.At the condition of RF input power 300 W, gas pressure 8 KPa , the two channels can uniformly discharge simultaneously and the 10P(18) laser output is achieved from the partial Z-fold channel and single channel. Adjusting the voltage on the piezoelectric transducer (PZT), pulse heterodyne frequency changes can be observed on the spectrum analyzer. Considering the limitation of the line profile width and free spectral range .There are about 300 MHz of tenability on the strongest line 10p(18) .Due to the limitation of bandwidth of the amplifier of the HgCdTe detector , the largest tunable range of heterodyne frequency is 150 MHz .The heterodyne wave form is shown in Fig.(2) the pulsed laser and the CW laser are compared to the pulse waveform of the Q-switched laser (a) E_S =10E_L , (b) E_S =E_L and (c) 10E_S =E_L .The observed pulse width is 140 ns, the delay 300 ns and the peak power 300W.The width of the voltage pulse on the crystal is about 1.2μs.The spectrum of Fourier transform of heterodyne waveform of the pulsed laser is shown in Fig.(3).It can be seen that the heterodyne waveform is
0~10 MHz and 60 MHz.

Conclusion:

The method of reduced voltage Q-switch is taken in the pulsed channel. The λ/4 voltage of the CdTe crystal at 10.6 μm is 2.3 kV; however, the Q-switched pulse laser can be obtained with only about 1 kV on the crystal. When there is no voltage on the crystal, the CW laser output can be obtained .The two laser beams in the same branch are mixed on the detector, the heterodyne frequency can be observed on a frequency meter. Due to the structure of common electrodes and the close distance between the partial Z-fold channel and single channel, the voltages on the two channels are nearly equal. When the RF input power is varied, the variation of gas refractive indexes of the two channels are nearly equal and the variation of the cavity length for the two lasers is also in the same direction. So the heterodyne frequency of the laser from the two channels is less disturbed by the variation of RF power. In addition, this kind of structure can partially compensate the variation of the laser heterodyne frequency imposed by temperature and vibration. Hence, the heterodyne frequency stability is high even without any additional measure being taken.

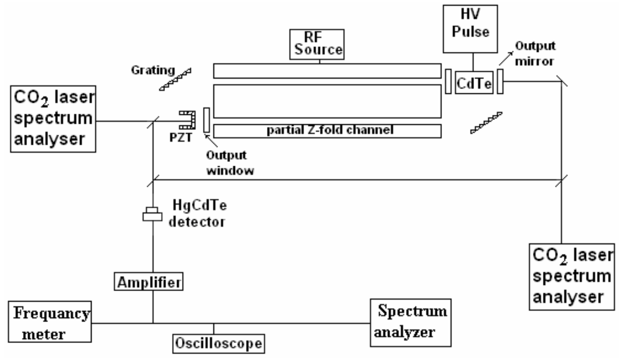

Fig.(1): Schematic of the experimental arrangement

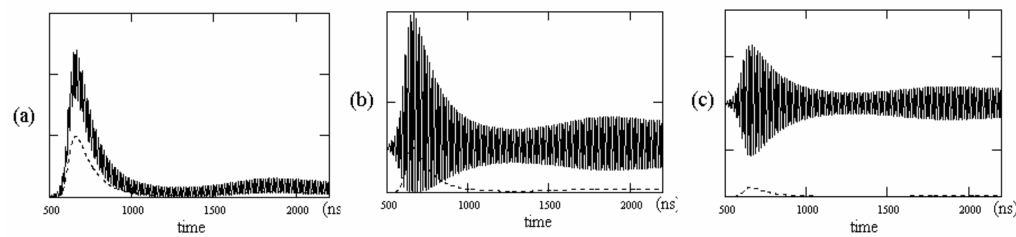

Fig.(2): The heterodyne wave of the pulsed laser and the CW laser comparing to pulse waveform of Q-switched laser (a) $E_S = 10E_L$, (b) $E_S = E_L$, (c) $10E_S = E_L$

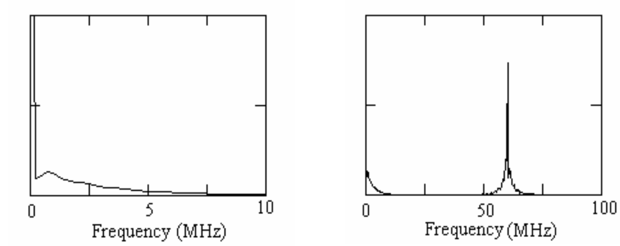

Fig.(3): Spectrum of Fourier transform of heterodyne waveform of the pulsed laser

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دراسة النبضه الثنائيه الموجهه لليزر ثاني اوكسيد الكاربون المطوي على شكل حرف Z

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الخلاصه:

في هذا البحث تم دراسة النبضه الثنائيه المتناغمه الموجهه لليزر ثاني أوكسيد الكاربون المطوي جزئيا على شكل حرفZ المحتوي على قناتين (قناة مطويه وأخرى منفرده طوليه) بألكترودات كهربائيه مشتركه بين الاثنين .حيث تمت مقارنة النبضه الثنائيه الموجهه لليزر المستمر والنبضي بالنبضه العملاقه لليزر وقد تم ايجاد خرج الليزر المستمر من القناة الطوليه المفردة . في هذه التجربه تم الحصول على عرض نبضه مقدارها 140 ns بمقدار تأخر قدره300 ns بقمة مقدار قدرتها 300W فقد أستخدمت في هذه التجربه بلورهCdTe حيث كان أعظم تردد متناغم حوالي 150 MHz بفولتيه نبضيه عرضها حوالي 1.2µs مطبقه على البلوره الكهروضوئيه .