Tunable RF-Excited Z –Fold Waveguide CO_2 Laser With Common Electrodes

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Abstract

The design and performance of radio frequency (RF) excited partial Z-fold waveguide CO_2 laser with two channels are exposed. The electrodes for the two channels are common and excited by a same RF source .According to our analysis, this kind of structure can greatly improve the laser offset frequency stability. In the experiments, we studied the offset signal of laser form with two channels and the deviation of offset frequency in long term.

Keywords: Waveguide CO_2 laser, Offset frequency, RF discharge, Common electrodes.

ليزر ثاني أوكسيد الكاربون ذو الموجه الموجهه المتناغم المطوي جزئيا على شكل حرف Z بألكترودات مشتركه ومتهيج بالتردد الراديوي

الخلاصه

عرض تصميم وعمل ليزر ثاني أوكسيد الكاربون ذو الموجه الموجهه المتناغم المطوي جزئيا على شكل حرف Z المحتوي على قناتين و المتهيج بالتردد الراديوي. الاقطاب الكهربائيه للقناتين تكون مشتركه وتتهيج بنفس المصدر . طبقا للتحليل الرياضي فأن هذا التركيب يحسن كثيرآ أستقرارية تردد الليزر و عمليا قمنا بدراسة أشارة تحسين استقرارية تردد الليزر وكذلك انحراف التردد لفتره طويله .

Introduction

CO_2 waveguide laser has been found widespread applications as a compact infrared source in portable systems. At present, high-power CO_2 laser is used widely in industry, military, and metrology [Pearson 1992, Tian 2002, Ma 1994, Xin 1996].Up to now, most of CO_2 coherent laser radars utilize two lasers with different wavelengths. But this may suffer from possibly unacceptable penalties of increased size, weight, complexity, and cost [Fox et al 1989]. However, a single radio frequency (RF) source may be used to excite two laser channels.

The technology of pulse laser heterodyne has been widely applied in the field of laser radar. 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 [Abramski et al 1990] 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.

The offset frequency between channels may originate from several sources, for example, engineering tolerances in the guide dimensions, temperature imbalance due to less efficient cooling of the middle guide, and the difference in cavity lengths for each channel as a consequence of either tilt or curvature of the mirror surfaces

This paper describes experimentally and new theoretically model for the heterodyne offset frequency stabilization in tunable electro-optically Q-switched RF-excited partial Z-fold waveguide CO_2 laser with two channels and common electrodes.

Tunable laser design

The laser is designed around a metal ceramic sandwich waveguide (designed and manufactured in Chinese National Key Laboratory of Tunable laser) [H. A. Badran 2004], which has a 2.25x2.25 mm^2 cross-section, as illustrated in figure (1). The laser structure has two channels, a partial Z-fold channel and a single channel. The two channels are excited by a same RF source and placed within a water-cooled stainless vacuum housing, incorporating a RF feed through to enable the power to be transmitted into the waveguide. The distance between the two channels is 20 mm .The partial Z-fold channel is 3x 460 mm in length and the single channel is 460 mm. A case I waveguide resonator with a flat total reflector and a flat output mirror is used for the single channel. For reducing coupling losses for the EH_{11} mode and to easily insert a modulator crystal and other optical elements into the resonator, we designed an equivalent Case III waveguide resonator for partial Z-fold channel. Two total reflector laser mirrors are placed 5 mm away from the ends of the two waveguides, the other two total reflectors are at the elbow parts of the Z-fold. A flat ZnSe window is placed 5 mm away from the front of the partial Z-fold waveguide. A ZnSe lens and an output mirror, which are placed close to each other, are equivalent to concave mirrors as Case III waveguide resonator for partial Z-fold channel. The four total reflectors, ZnSe window, and flat output mirror are attached to the vacuum housing with mounts sealed by “O” rings, which permit angular adjustments along the two orthogonal axes. The laser output directions from the two channels are opposite.

Theoretical analysis of frequency stabilized

According to laser theory, the frequency excursion of laser is influenced by the variations of cavity length and refractive index of gain media [Nei et al 2000],

$$\Delta v = -v_0 (\frac{\Delta n}{n_0} + \frac{\Delta L}{L}) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where n_0 is the average value of refractive index, Δn represents the variation of the refractive index, L_0 is the initial cavity length, ΔL represents the variation of the cavity length, and v_0 is the oscillation frequency corresponding to the cavity of length L_0 and an intracavity refractive index n_0 .From Equation(1) we can see that two factors are contribut to the frequency stability, i.e the cavity length and the refractive index. The laser we designed, is a Z-fold laser, in which

$$L_Z \approx 3 L_S \quad \text{and} \quad \Delta L_Z \approx 3 \Delta L_S , \qquad \ldots\ldots\ldots\ldots(2)$$

where L_Z is the cavity length of the partial Z-fold channel and L_S is the cavity length of the single channel .The instantaneous oscillation frequency of the partial Z-fold laser and single laser are respectively given by:

$$\Delta v_Z = -v_0 \left(\frac{\Delta n}{n_0} + \frac{\Delta L_Z}{L_Z} \right) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$\Delta v_S = -v_0 \left(\frac{\Delta n}{n_0} + \frac{\Delta L_S}{L_S} \right) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The variation of offset frequency from two channels can be expressed by

$$\Delta v_C = \Delta v_Z - \Delta v_S \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Substituting Equation (3) and Equation (4) into Equation (5),one can get

$$\Delta v_C = -v_0 \left(\frac{\Delta L_Z}{L_Z} + \frac{\Delta L_S}{L_S} \right) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

With the substitutions

$$L_Z \approx 3 L_S \quad \text{and} \quad \Delta L_Z \approx 3 \Delta L_S , \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

one can write the variation of offset frequency from two channels as

$$\Delta v_C = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Experimental Arrangement

In order to improve the heterodyne frequency stability, we design an electro-optically Q-switched RF excited partial Z-fold CO_2 waveguide laser with two channels excited by the same RF power supply. The partial Z-fold channel is used as transmitter laser and a single channel is used as local oscillator laser. By using two different channels, most of the RF power is transmitted to the partial Z-fold channel. Because of the structure of common electrodes and the close distance between the two channels, the voltages on the two channels are nearly equal. When the RF input power is varied, the variations of gas refractive index and cavity length of the two channels are nearly in the same direction. So the relative frequency stability of the laser from the two channels is less disturbed by the variation of RF power and circumstance influences. It can be predicted that the relative frequency stability between two lasers excited by the same RF generator is much better than that for both independent and separate lasers [Colley 1991,Tian 2001,Wang 2000] .

In this structure we insert Q-switched system into the cavity. The schematic diagram of the Q-switched laser is shown in figure (2). The Q-switched system includes CdTe crystal, Brewster window and $\lambda/4$ phase plate. The $\lambda/4$ voltage of the CdTe crystal at 10.5710 μm is 2.3 kV. The pulse repetition rate can be tuned from 1Hz to 10 KHz. At a pulse repetition rate of 10 KHz, the Q-switched laser pulse is detected by a photovoltaic of a HgCdTe detector and the laser waveform is monitored on TDS3032 digital storage oscilloscope.

Results and discussion

In this paper, we have described a new simple and reliable theoretical analysis model of the tunable heterodyne frequency stability for partial Z-fold waveguide CO_2 laser. According to the analytical result, the laser we designed can improve the offset frequency stability ($\Delta v_C = 0$) by compensating the variables of the cavity length imposed by circumstance temperature, voltage of RF input and random vibration..

In experiment, at the condition of RF input power 300 W, gas pressure 8 KPa. The two laser beams in the same branch (P18 and 4W out put power) are mixed on the detector, The offset signal of laser from the two channels is shown in figure (3). We also measured variation of offset frequency in long term for Q-switched laser output during 60s at pulse repetition rate of 10 KHz figure 4.It can be seen that the variation in one second is less than (2 MHz), we can say, that the long term heterodyne frequency stability can be up to 10^{-8}. 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 partly 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.

In conclusion, the objective of this study was to explore method of obtaining offset frequency stability from an electro-optical Q-switching partial Z-fold laser. The main advantages of the laser are a compact structure, small size, easy manufacturing, and lower cost. At present, laser output has been obtained from the two channels simultaneously. These advantages can well satisfy the requirements of laser radar and other scientific study.

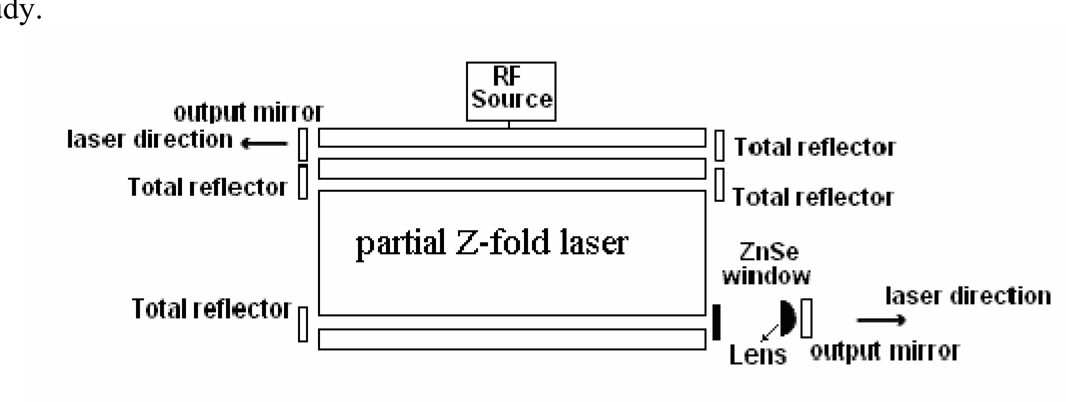

Figure (1): Structure of partial Z-fold waveguide Q-switching CO_2 laser with common electrodes

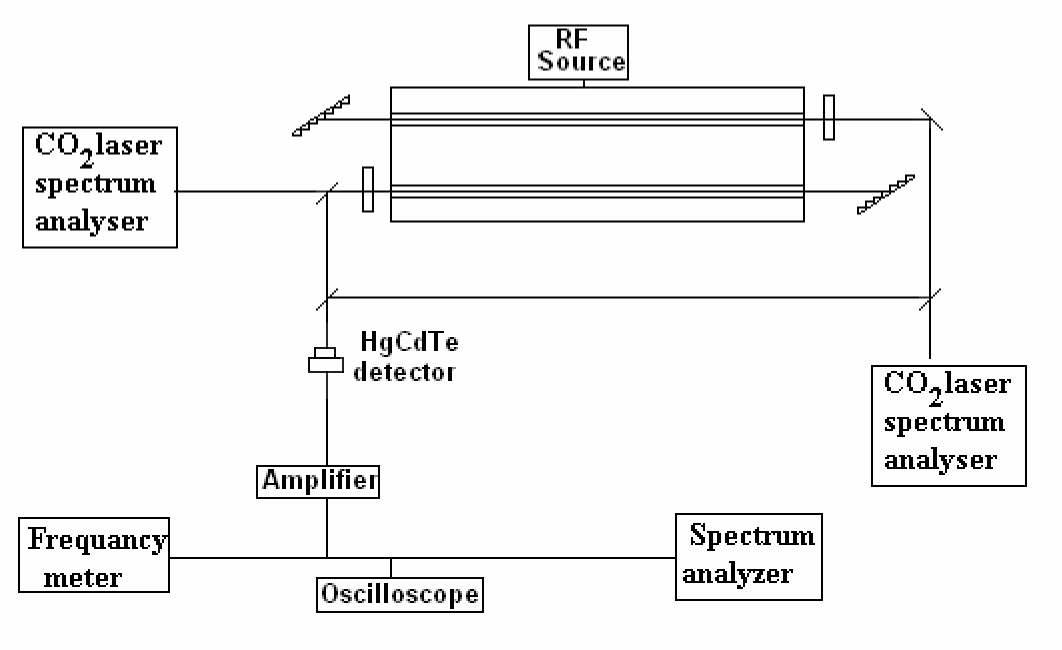

Figure (2): Schematic diagram of the experimental setup

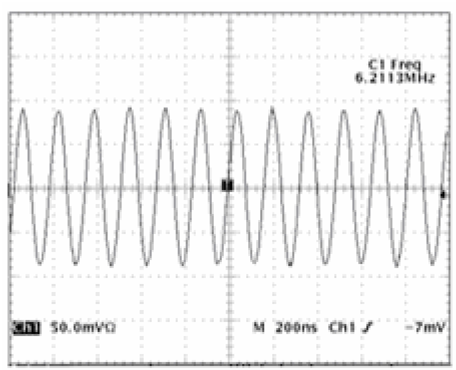

Figure (3): Offset signal of laser from the two channels

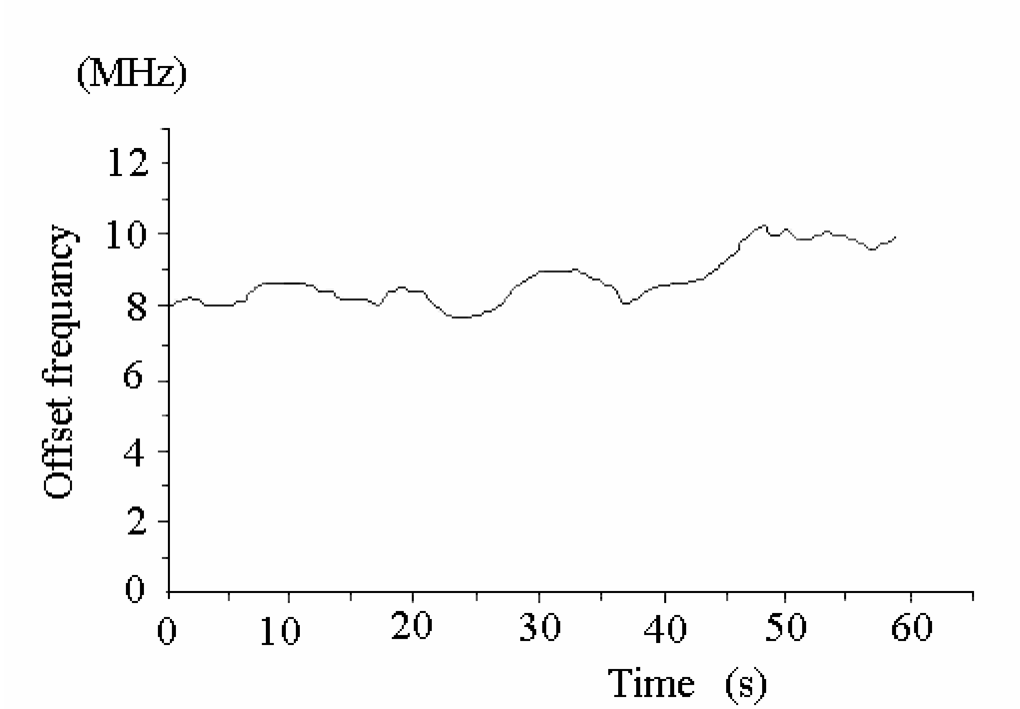

Figure (4): Deviation of offset frequency in long term

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