Optica Applicata, Vol. XVIII, No. 2. 1988

Transversely RF-excited parallel-spaced CO_2 waveguide lasers*

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A double structure of CO_2 waveguide lasers commonly excited by a transverse radiofrequency discharge and operating on common flat mirrors in sealed-off regime is described. Basic parameters and results of double spaced low power lasers are given. Particular attention is payed to the double waveguide structure as a prospective and attractive heterodyne system characterized by good short-term stability of the beat frequency.

1. Introduction

Increasing efforts have been made recently in the investigation of transversely RF-excited waveguide CO_2 lasers because of their promising advantages in comparison with conventional DC-excited CO_2 lasers [1]–[4]. These advantages can be itemized as follows: "cathodeless" operation, considerably lower voltage of excitation, temporal stability and spatial uniformity of plasma discharge, low level breakdown, facility in modulation and regulation of output power. Quite high power per unity discharge length, more than 0.8 W/cm in sealed operation [3], more than 10% efficiency and small dimensions make this kind of laser prospective for technological processing. However, the length of an RF-excited waveguide laser can not be optionally increased because of nonuniformity of the voltage distribution along the discharge even when "inductive termination" [5] "discrete inductors" [6] techniques are applied. So, it is quite natural to use two or more closely composed waveguide structures excited by a common RF transmitter and closed by common flat mirrors as was suggested by Chenausky et al. [7].

The RF excitation is particularly useful for multiwaveguide operation. Such multiwaveguide structures can operate in two general regimes, as independent laser oscillators or in the so-called phase-locked regime [8]. When parts of coherent energy leak mutually to waveguides, the neighbouring lasers can be forced into single-frequency operation. It can be explained by specific strong mode pulling effect between basic mode of one guide channel and leaking mode from the next channel if a coupling between waveguides is high enough and the frequency difference between resonances of the waveguide cavities is not too big. Quite recently, the excellent high-power coupled laser array was reported by Newman et al. [9].

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* This work was accomplished at the Technical University of Wrocław as an internally founded programme.

2. Parallel-spaced waveguide lasers

Here, we report our investigation on a parallel-speced double structure which is formed by two independent waveguide lasers excited by a common transmitter. Figure 1 presents the cross-section of waveguide geometry used in the investigations. The alumina-aluminium sandwich with the well polished walls forms the 2 mm^2 cross-section of both waveguide channels. The channels 15 cm long are separated by a 1 mm thick alumina plate. This internal plate has a 2 mm slit in the middle of its length in order to obtain similar uniformity and better coupling of plasma discharge for both channels. The hole drilled into a waveguide in the alumina plate ensures the filling of the mixture for the sealed-off condition. Both lasers are closed by flat common mirrors from both their ends ("case I" configuration). The leakproof connection between mirrors and waveguides has been done by O-rings as is shown in Fig. 2. This connection is useful because it can be easily dismounted, it gives possibility to align and to tune the cavities by means of a piezoceramic driver due to elasticity of the rubber O-rings. The outcoupling mirror was dielectric coated germanium with the nominal reflectivity $R = 0.95$ but its optical quality was not too good. The reflector was the polished aluminium mirror.

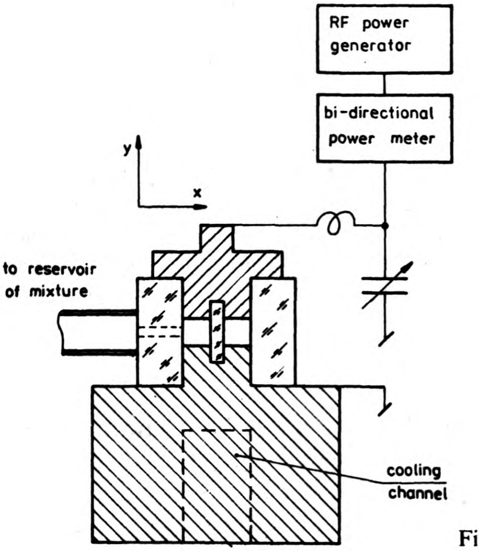

Fig. 1. Cross-section of the double waveguide structure

A conventional π-circuit network has been applied for matching the resistance of the plasma to 50 ohm coaxial line from the transmitter. The capacity of the presented double laser structure is 30 pF and it does not differ very much from the similar single waveguide channel (26 pF). No inductive corrections of the voltage variation along the laser cavity have been used. A typical 3:1:1 mixture of He:CO_2:N_2 has been used in the pressure range 25–60 Torr. The drive frequency was 105 MHz.

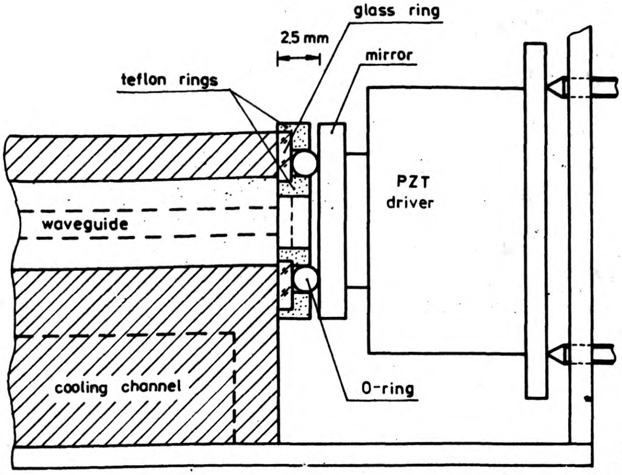

Fig. 2. Sectional view of the waveguide structure

3. Experimental results

No difficulties in simultaneous excitation of both waveguide channels (Fig. 3**a**) have been observed [10]. Characteristic nonuniformities of visible emission have been observed in the transverse direction to the optical axis of the waveguides. These so-called "discharge striations" [3], [4], specific for RF discharge, are presented in the photograph (Fig. 3**b**) taken at a small angle to the waveguide axis in order to make them more visible. Both lasers operated all the time in the linearly polarized EH_{11} modes (Fig. 3**c**) with polarization parallel to the aluminium walls.

We had no possibilities to maximize the output powers of the lasers because of limitations in the optical and electronic equipment. The maximal output powers from both waveguides were comparable to each other and they reached more than 1 W in each channel at the pressure 60 Torr and input RF power 55 W (Fig. 4). The efficiency for one channel was more than 4%. The average output power decreased to about 30% of the initial output power after about three minutes of operation. This dropping of the output power in time was caused probably by a not too efficient cooling of the internal common alumina plate which was not in good mechanical contact with the bottom cooled aluminium electrode, which can be seen in Fig. 3**a**.

The output powers fluctuated in time and their temporary values and transitions differed due to thermal drifts. However, their temporary outputs were correlated as is shown in Fig. 5, where the simultaneous signatures of both laser outputs were registered by a pair of home-made pyroelectric photodetectors during the tuning of the cavity length by a PZT driver. A certain shift of the signatures has been observed as a result of a difference in the optical length of the lasers. This shift could be regulated manually by a slight tilt of one of the mirrors, but the range of the shift was

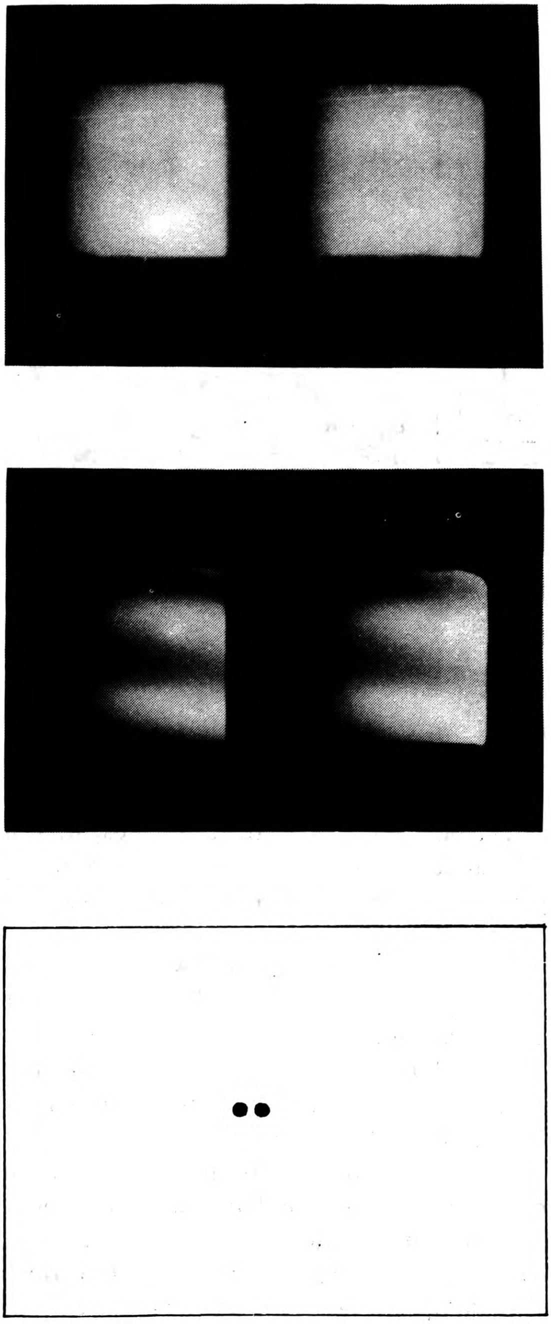

Fig. 3. Photographs of spontaneous emission from both channels taken (**a**) perpendicularly to waveguide axis, (**b**) at a small angle to the optical axis, for better appearing "discharge striation". Spots burned by laser beams (EH_{11} modes) 20 cm from output mirror (**c**)

not too big. Because of the lack of a high-bandwidth photodetector we did not measure the heterodyne signal between both waveguide lasers. A spectral analysis of the heterodyne signal seems to be very attractive for lasers operating on the same transitions.

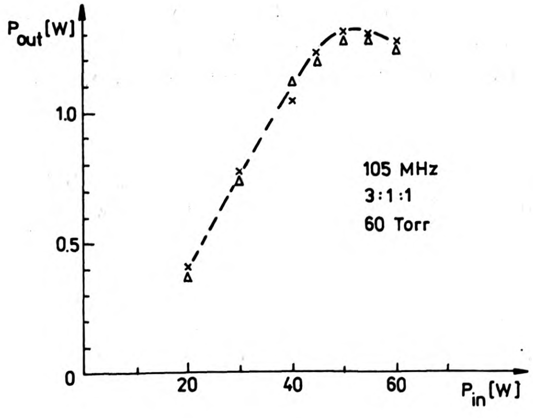

Fig. 4. Dependence of output power of each waveguide laser on input RF power

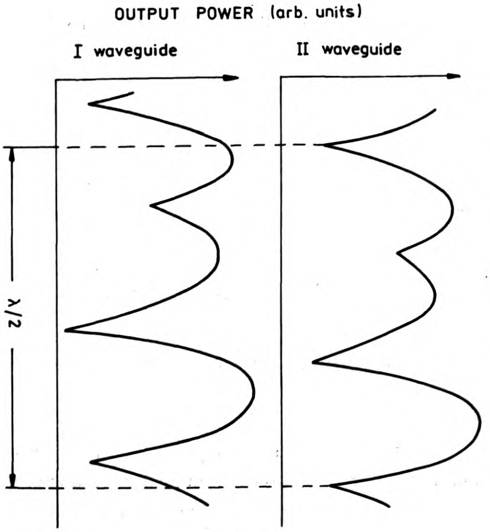

Fig. 5. Signatures of both waveguide lasers as a result of the cavity tuning by PZT driver

4. Conclusions

Concluding, we want to emphasize here the potential usefulness of such a laser tandem from a metrological point of view. Because of common mirrors and common supply system, short-term frequency fluctuations of both lasers should be strongly correlated. So, the short-term stability of the frequency difference between two parallel-spaced waveguide lasers should be much better than in separate heterodyne laser systems connected by means of electronic frequency-offset lock sets [11], [12], characterized by a limited bandwidth of the frequency stabilization. Much worse long-term stability of the beat frequency in free running double waveguide lasers can be suspected because of thermal drifts and mode pulling effects. An improvement in the long-term stability of the beat frequency would require an additional frequency control such a frequency stabilization in the center of one of the emission laser lines. Having improved short-term stability of the beat frequency, double waveguide lasers seem to be a prospective tool for many metrological and telecommunication applications.

Acknowledgements – The authors would like to thank Prof. W. J. Witteman, Dr G. J. Ernst and Mr A. B. M. Nieuwenhuis for their helpful discussions during K. M. Abramski's fellowship at the Twente University of Technology, the Netherlands.

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Received July 13, 1987

Параллельные волноводные лазеры CO_2 с радиоволновым поперечным возбуждением

В работе представлена конструкция двойной структуры волноводных лазеров CO_2 с радиоволновым возбуждением, работающих на общих плоских зеркалах. Даны основные параметры и результаты. Особенное внимание направлено на возможность получения лазерного гетеродина с хорошей кратковременной стабильностью частоты гетеродинного сигнала.