COMPUTER-AIDED CO_2-LASER CAVITY-LENGTH SELECTION FOR REDUCED LINE COMPETITION*

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Carbon-dioxide lasers are attractive for space communications systems because they have many advantages (high efficiency, wavelength near 10 μm where the atmosphere has a window, and good frequency stability). These properties allow the building of heterodyne receivers as part of communications systems which come close to the theoretical sensitivity limit.

Figure 1 shows the absorption spectrum of CO_2 gas in the 10-μm and 9-μm regions. In the case of a CO_2 laser, the gain shows a similar behavior. The strongest laser line is P(20) of the 10-μm band. Because so many lines can oscillate, competition effects occur, and it is often difficult to obtain oscillation at the desired lines. For example, in heterodyne communications systems, the transmitter and the L.O. must operate at the same line, and the L.O. must have a sufficiently large tuning range. This paper shows how competition effects can be reduced by selection of an appropriate cavity length.

The upper portion of Figure 2 shows a laser consisting of a laser tube which contains the active medium and an optical resonator made of two spherical mirrors. One mirror can be moved by a piezoelectric transducer (PZT) element to tune the resonator. The resonator has many resonances (middle portion of Figure 2) with a frequency interval of $c/2d$ (d is the mirror separation distance). If one resonance coincides with one line of the active medium (three lines are plotted), then oscillations start. When the resonator is tuned, the cavity resonances are shifted, and another line starts to oscillate. In the lower section of Figure 2, a typical output power profile of a CO_2 laser is shown as a function of the cavity length (or PZT voltage).

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Several complete and incomplete line tops can be seen. The lines can be identified by means of a monochromator. The sequence and distribution of line centers over a half-wavelength tuning interval repeats nearly unchanged within the next half-wavelength tuning interval. However, a change of the cavity length on the order of 0.1 mm or more may completely alter the sequence and distribution of line centers. This property is more or less unique for each laser and is called its "signature".

During this study we first attempted to predict the signature of CO_2 lasers. It was found that this requires very accurate data on the laser wavelengths (accuracy on the order of 10 MHz). The results of recent absolute frequency measurements of CO_2 lines were utilized, and a list of accurate frequencies was calculated that fulfilled the requirements.

A computer program which can be used to predict the signature was written. Several comparisons were made, and in each case close agreement was found. Figure 3 shows signatures taken with decreasing (top) and increasing (bottom) PZT voltage. Unfortunately, the PZT elements are not perfectly linear and show hysteresis effects. The portion between the two P(26) lines seems to be fairly linear. Figure 3 also contains for this portion the predicted positions of the line centers, which fit quite well.

Another computer program was written which searches through large ranges of cavity length and prints lists of regions where a particular line is well separated from adjacent lines in the signature. Lasers designed according to this list will have an undisturbed tuning profile for one or more lines. These results make it possible to design L.O.'s for heterodyne systems without a grating within the resonator. (Until now, gratings had to be used in order to achieve a satisfactory tuning range.) This results in an increased efficiency for the L.O. and a power saving of several watts.

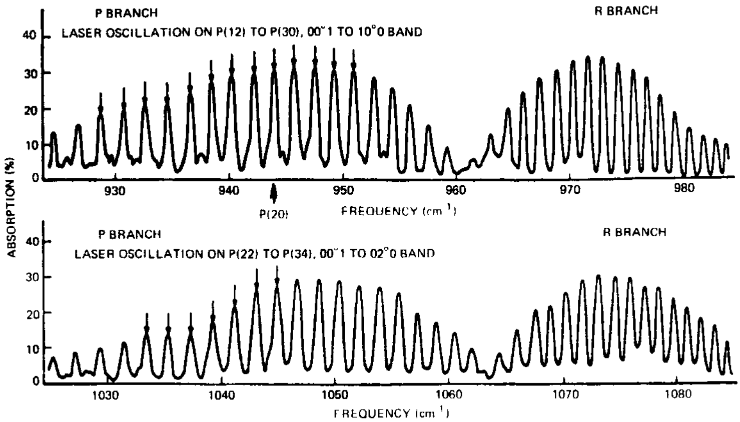

Figure 1—Carbon-dioxide absorption spectrum for the 10-μm or 28.8-THz band (top) and for the 9-μm or 31.9-THz band (bottom). (After Barker and Adel, *Phys. Rev.* 44:185, 1933, and Patel, *Phys. Rev.* 136A:1187, 1964.)

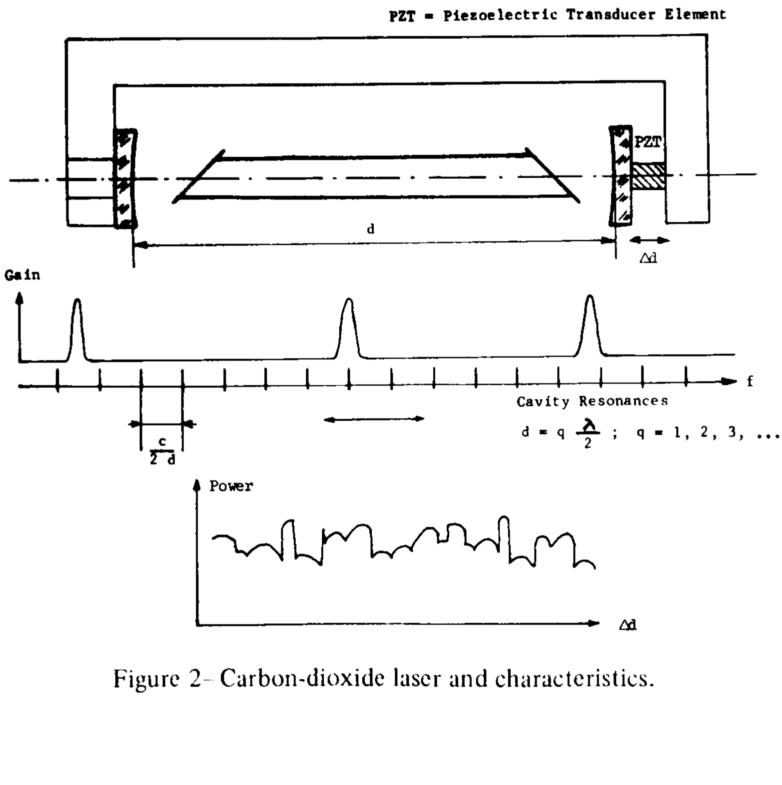

Figure 2–Carbon-dioxide laser and characteristics.

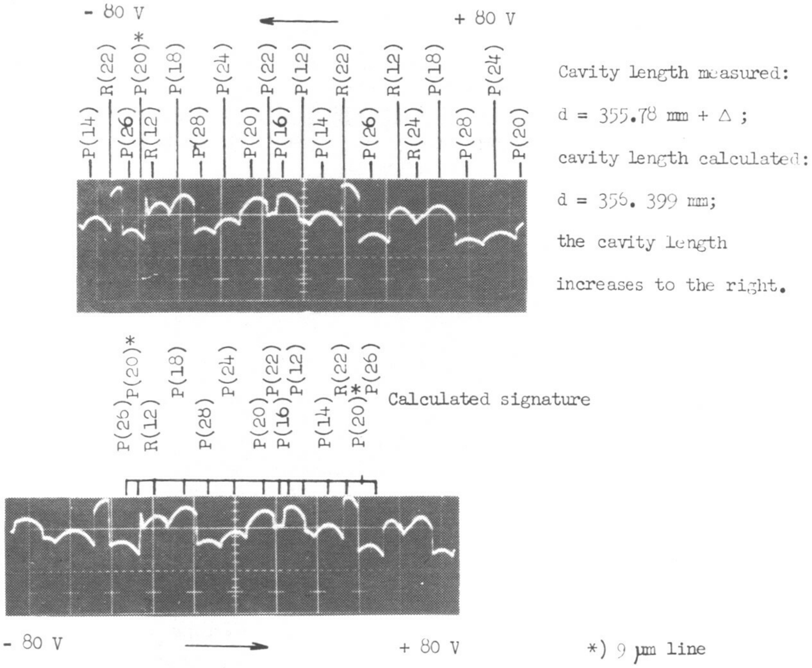

Figure 3–Comparison of measured and predicted signature.