ACCURATE CO_2 LASER FREQUENCIES AND MOLECULAR CONSTANTS OF REGULAR AND NEW HOT-BAND LINES*

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Abstract

A new, high-resolution, highly efficient, cw, CO_2 laser oscillating on more than 250 lines including over 40 lines in the new 9 μm hot band has been built at NIST, Boulder. The frequencies of the 9 and 10 μm hot band lines and high J (to J=66) regular band lines of $^{12}C^{16}O_2$, which now fill the gap between the 9 and 10 μm regions, have been locked to saturated fluorescence signals in CO_2, and measured. New molecular constants and more accurate frequencies of the four common isotopes of CO_2 have been obtained.

A CO_2 laser oscillating on more than 3 times as many lines as the standard CO_2 laser has been built. A regular CO_2 laser oscillates on 75 to 80 lines; this laser oscillates on more than 250 lines. It exhibits such high resolution and efficiency that a whole new band system which had not previously been observed has been discovered. The new system is the 9 μm hot band (01^11-$[11^10,03^10]_{II}$) a partner to the well known 10 μm hot band (01^11-$[11^10,03^10]_I$). More than 40 lines have been observed in this band, the strongest emitting more than 8 W cw. The laser has higher resolution and more efficiency than other CO_2 lasers; this has been brought about by the use of a multi-ribbed discharge tube and zero-order coupling from a high reflectance, ruled-in-gold grating. The grating end of the laser, 1.5 m long and 13.5 mm id, is shown in Fig.1. The ribs are spaced about 10mm apart and are

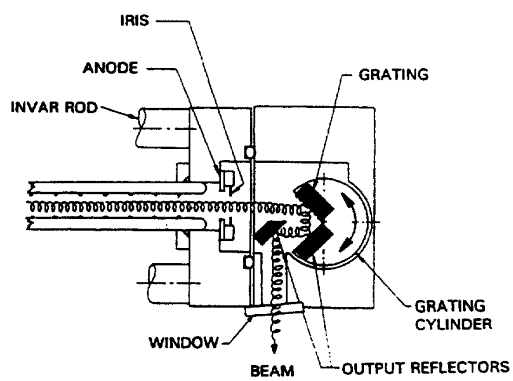

Figure 1. Grating end of zero-order multi-ribbed CO_2 laser.

1.5 mm high (they are simply molded into the 16 mm id Pyrex tube). Their main function is to block the waveguide (wall-bounce) modes from oscillating; this increases the resolution about a factor of three compared with a non-ribbed tube, and permits the weaker lines, such as the sequence and hot band lines, to oscillate. A portion of the scan of laser output versus grating angle is shown in Fig. 2.

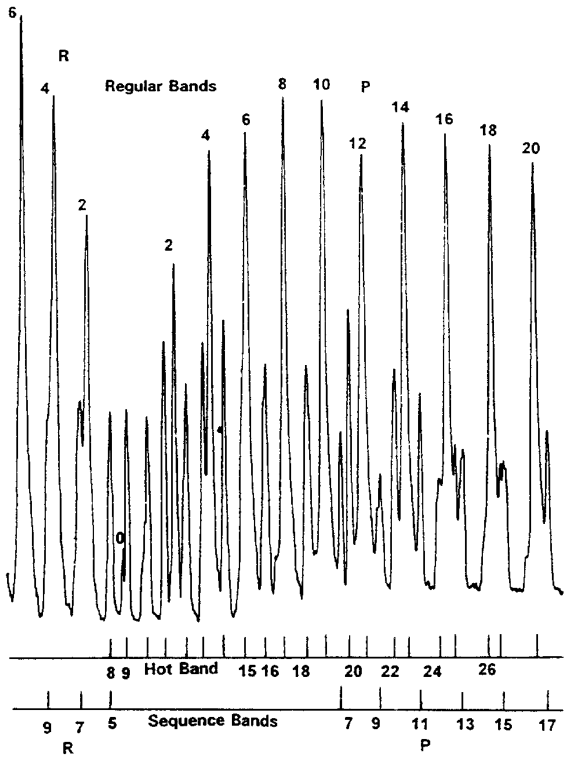

Figure 2. Laser output using a 171 lines/mm grating in 9 μm region with regular, hot band, and sequence band lines identified.

The laser oscillates on higher-J lines, permitting accurate frequency measurements of these lines for the first time. An analysis of these frequencies produces more accurate molecular constants on the transitions in the regular bands of this laser and these lines serve as both frequency and wavelength standards from 27 to 33 THz (11.1 to 9.1 μm).

Both high J (to J=66) regular lines and 9 and 10 μm hot-band lines were stabilized on the saturated fluorescence in CO_2 and frequency measured with respect to $^{13}CO_2$ and $^{12}CO_2$. A least-squares analysis of the frequencies that includes the present measurements, recent new absolute frequency measurements (1), and earlier relative and absolute frequency measurements (2) of the laser transitions has been made. This analysis has resulted in an improved set of rovibrational constants and new values for the laser transition frequencies and their uncertainties for the regular bands of $^{12}C^{16}O_2$, $^{13}C^{16}O_2$, $^{12}C^{18}O_2$, and $^{13}C^{18}O_2$; and for the 9 and 10 μm hot-band transitions of $^{12}C^{16}O_2$.

[1] Ch. Chardonnet, A. Van Lerberghe, and Ch. J. Bordé, "Absolute Frequency Determination of Super-Narrow CO_2 Saturation Peaks Observed in an External Absorption Cell", Optics Comm. Vol. 58, pp.333-337 (1986).

[2] F.R. Petersen, E.C. Beaty, C.R. Pollack, "Improved Rovibrational Constants and Frequency Tables for the Normal Laser Bands of $^{12}C^{16}O_2$", J. Mol. Spec., Vol. 102, pp.112-122 (1983).